international advanced coal technologies conference 2010

THE CASE FOR COOPERATION

June 23 - 24, 2010 at the University of Wyoming in Laramie
The University of Wyoming Conference Center at the Hilton Garden Inn
Dear Colleagues,

I am very pleased to welcome each of you to Laramie, Wyoming and the 2010 International Advanced Coal Technologies Conference. The University of Wyoming is honored to host this year’s event in partnership with the University of Queensland.

As you know, state and national economies around the globe depend on our ability to steadfastly move forward with all stakeholders – partner nations, national laboratories, university collaborators, and industry colleagues – to solve the equation of capturing carbon dioxide for energy sustainability and security in the most environmentally sensitive way. Your research into advanced coal technologies and your visions on how to accelerate our united success in CO₂ capture are the foundation of every discussion we will have in the coming days.

I look forward to these conversations, and to strengthening our resolve to work collaboratively with all our partners now and into the future.

Sincerely,

Thomas Buchanan
President
University of Wyoming
Dear Colleagues

Thank you for participating in the second International Advanced Coal Technologies Conference. As hosts of the first International Conference in 2008, The University of Queensland is delighted to be partnering again with the University of Wyoming in bringing together key researchers and industry representatives from around the world who are at the forefront of developing advanced coal technologies. The development of these technologies remains a global priority and requires innovative global approaches, which must include collaboration across universities, research institutes, industry and governments.

Since the 2008 Conference, the University of Wyoming and The University of Queensland have established a good cooperative relationship including the coordination of research capabilities and activities, the exchange of postgraduate students and staff (faculty), and the promotion of joint workshops and conferences, with the organisation of this second International Conference one major outcome.

I have no doubt that the Conference will provide an excellent avenue for learning, exchange and the identification of further collaborative opportunities. I look forward to hearing of the outcomes.

Professor Paul Greenfield AO
Vice-Chancellor and President
The University of Queensland
<table>
<thead>
<tr>
<th><strong>TUESDAY, JUNE 22</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3:00 – 7:00 pm</td>
<td><strong>Registration</strong>, Grand Ballroom Lobby</td>
</tr>
<tr>
<td>5:00 – 7:00 pm</td>
<td><strong>Welcome Reception &amp; Networking</strong>, Grand Ballroom Lobby</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>WEDNESDAY, JUNE 23</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am – 5:00 pm</td>
<td>Registration and Hospitality Desk Open, Grand Ballroom Lobby</td>
</tr>
<tr>
<td>7:30 – 8:30 am</td>
<td><strong>Continental Breakfast</strong>, Salon A</td>
</tr>
<tr>
<td>8:30 – 8:45 am</td>
<td><strong>Opening and Welcome</strong>, Salon C</td>
</tr>
<tr>
<td></td>
<td><strong>Gus Plumb</strong>, Director of Clean Coal Technologies, University of Wyoming</td>
</tr>
<tr>
<td></td>
<td><strong>Tom Buchanan</strong>, University of Wyoming President</td>
</tr>
<tr>
<td>8:45 – 11:00 am</td>
<td><strong>Keynote Session</strong>, Salon C</td>
</tr>
<tr>
<td></td>
<td><strong>Chair</strong>: <strong>Mark Northam</strong>, Director, University of Wyoming School of Energy Resources</td>
</tr>
<tr>
<td></td>
<td><strong>Hon. Dave Freudenthal</strong>, Governor of Wyoming</td>
</tr>
<tr>
<td></td>
<td><strong>Joseph Strakey</strong>, Chief Technology Officer, Department of Energy’s National Energy Technology Laboratory</td>
</tr>
<tr>
<td></td>
<td><strong>Hon. Peter Beattie</strong>, Queensland’s Trade Commissioner to the USA</td>
</tr>
<tr>
<td>11:00 – 11:15 am</td>
<td><strong>Break</strong>, Grand Ballroom Lobby</td>
</tr>
</tbody>
</table>

*Please note: All sessions are open to the public.*
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:15 am–12:20 pm</td>
<td><strong>Industry Perspective</strong>, Salon C&lt;br&gt;&lt;br&gt;<strong>Chair</strong>: Gary Stiegel, Director Major Projects Division, NETL&lt;br&gt;<strong>Monte Atwell</strong>, General Manager – Gasification, GE Energy&lt;br&gt;<strong>Fred Palmer</strong>, Senior Vice President of Government Relations, Peabody Energy</td>
</tr>
<tr>
<td>12:30 – 1:15 pm</td>
<td>Lunch, Salon A</td>
</tr>
<tr>
<td>1:30 – 3:15 pm</td>
<td><strong>Invited Session A</strong> “Processes”, Salon C&lt;br&gt;&lt;br&gt;<strong>Chair</strong>: Jenny Tennant, Technology Manager, Gasification, NETL, US Dept. of Energy&lt;br&gt;<strong>Harry Morehead</strong>, Manager, IGCC and Gasification Sales and Marketing, Siemens Energy, Inc.&lt;br&gt;<strong>Michael Blinderman</strong>, Director, Ergo Exergy Technologies – Canada&lt;br&gt;<strong>David Denton, P.E.</strong>, Director, Energy Policy Development, Eastman Chemical Company&lt;br&gt;<strong>Deborah Murphy</strong>, Vice President, Commercial Development, GreatPoint Energy Inc.</td>
</tr>
<tr>
<td>3:15-3:30 pm</td>
<td>Break, Grand Ballroom Lobby</td>
</tr>
<tr>
<td>3:30 – 5:15 pm</td>
<td><strong>Invited Session C</strong> “Products”, Salon C&lt;br&gt;&lt;br&gt;<strong>Chair</strong>: Rob Ettema, Dean, University of Wyoming College of Engineering and Applied Sciences&lt;br&gt;<strong>Maha Mahasenan</strong>, Senior Policy Advisor, Hydrogen Energy&lt;br&gt;<strong>Bob Kelly</strong>, Executive Chairman, DKRW&lt;br&gt;<strong>Claudia Miller</strong>, Engineering Manager, Dakota Gasification Company</td>
</tr>
<tr>
<td></td>
<td><strong>Invited Session D</strong> “National Labs &amp; Universities”, Salon D&lt;br&gt;&lt;br&gt;<strong>Chairs</strong>: Lifa Zhou, Director of Shaanxi Provincial Institute of Energy Resource and Chemical Engineering and&lt;br&gt;<strong>John Jiao</strong>, Wyoming Geological Survey&lt;br&gt;<strong>Mark Davies</strong>, SEO, National Low Emissions Coal Research &amp; Development Centre, Australia&lt;br&gt;<strong>Dr. Richard Boardman</strong>, Head, Energy Security Initiative, Idaho National Laboratory&lt;br&gt;<strong>Dr. John Carras</strong>, Director, Coal Technology, CSIRO, Australia</td>
</tr>
<tr>
<td>6:30 – 8:30 pm</td>
<td>Dinner, Garden Ballroom</td>
</tr>
</tbody>
</table>
THURSDAY, JUNE 24

7:00 am – 5:00 pm  
Hospitality Desk Open, Grand Ballroom Lobby

7:00 – 8:00 am  
Continental Breakfast, Salon A

8:00 – 9:45 am  
Invited Session E “Coal Research and Policy”, Salon C  
Chair: Dr. Kelly Thambimuthu, FTSE, Director of the Centre for Coal Energy Technology and Professor of Chemical Engineering, The University of Queensland  
Philip Smith, Director, Institute for Clean and Secure Energy (ICSE), University of Utah  
Robert Williams, Senior Research Scientist, Princeton Environmental Institute (PEI), Princeton University  
Mark Finkelstein, Vice-President, Luca Technologies  
Don Schofield, General Manager, New Projects, Linc Energy

Session F “General”, Salon D  
Chair: Ron Surdam, Wyoming State Geologist / Director of Carbon Management University of Wyoming  
Gus Plumb, Director of Clean Coal Technologies, University of Wyoming  
Assessing Opportunities and Challenges of Utilizing Coal in Botswana  
Vijay Sethi, Ph.D., Western Research Institute  
Development of a “Green Coal” for Utilities  
Michael Stoellinger, University of Wyoming  
Modeling of Turbulent Coal Combustion

9:45 – 10:00 am  
Break, Grand Ballroom Lobby

10:00 – 11:45 am  
Session G “Gasification”, Salon C  
Chair: Alex Klimenko, SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland  
Dr. Thomas Barton, Western Research Institute  
Hydrogen Separation: Membranes, Processes and Engineering  
Will Schaffers, University of Wyoming  
Coal Fired IGCC Power Plants in Wyoming  
Dr. Alan Bland, Western Research Institute  
WRITECoal™ Gasification of Low-Rank Coals for Improved Advanced Clean Coal Gaseifier Design  
Philip Smith, University of Utah  
Prediction of Entrained Coal Gasification using Large Eddy Simulation (LES) with the Direct Quadrature Method of Moments (DQMOM)

Session H “Carbon Management”, Salon D  
Chair: Mark Northam, Director, University of Wyoming School of Energy Resources  
Eric Eddings, University of Utah  
Oxy-Coal Combustion Research Activities at the University of Utah
Bo Feng, Senior Lecturer, The University of Queensland
*CO₂ adsorbing material for coal-fuelled zero emission power generation*
Lyman Frost, Ceramatec, Inc
*Renewable Energy Storage by CO₂ Recycling*
Mohammad Piri, Ph.D., University of Wyoming
*Morteza Akbarabadi, Ph.D., Student, University of Wyoming
The effects of hysteresis and wetting on permanent geologic storage of carbon dioxide: An experimental study of capillary trapping and relative permeability*

12:00 – 12:45 pm  **Lunch, Salon A**

Director Zouli Zhu, Director of Shaanxi Provincial Development and Reform Commission, China

1:00 – 2:45 pm  **Session I “Fuels and Chemicals from Coal”, Salon C**

Chair: Maohoung Fan, Associate Professor of Chemical and Petroleum Engineering, University of Wyoming

John Pope, Ph.D., NDCPower
*Advanced Fuel Cell Technology for Co-Production of Electric Power and Carboxylic Acids using Coal-derived Alcohols*

Dr. Gerardine G. Botte and Ana-Maria Valenzuela Muniz, Ohio University
*Hydrogen Production Via Coal Electrolysis*

Rodolfo Monterroso, University of Wyoming
*Development of New Mercury Sorbents*

Session J  “CO₂ Storage and Utilization”, Salon D

Chair: Bo Feng, Senior Lecturer, School of Mechanical and Mining Engineering, UQ

Ron Surdam, Wyoming State Geological Survey
*The key to commercial-scale geological CO₂ sequestration: Displaced fluid management*

Dr. Alan Bland, Western Research Institute
*A Novel Integrated Oxy-Combustion and Flue Gas Purification Technology: A Near-Zero Emissions Pathway*

Hollis Weber, University of Wyoming
*Direct Mineralization of Carbon Dioxide from Coal Combustion Flue Gas*

Ying Li, University of Wyoming
*Effect of Co on promoting RuxCoy/Al₂O₃ based catalytic water gas shift reaction*

2:45 – 3:00 pm  **Break, Grand Ballroom Lobby**

3:00 – 4:45 pm  **Session K “Gasification”, Salon C**

Chair: Bob Ballard, University of Wyoming, Project Manager for High Plains Gasification – Advanced Technology Center

Kevin Whitty, University of Utah
*Initial Experience with a 500 kWth Pressurized Entrained Flow Coal Gasifier*

Alex Klimenko, SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland
*Utilization of Unmined Coal – Centennial of the Invention*
Karl Libsch, P.E., Emery Energy Company
*Emery Energy’s Pilot Gasifier for PRB Coal and Coal/Biomass Blends*

Adel Sarofim, University of Utah
*Chemical Looping With Copper Oxide as Carrier*

**Session L “Carbon Management,” Salon D**

Chair: KJ Reddy, Professor Renewable Resources – UW

Richard Baraki, University of Utah
*Copper Functioning as an Oxygen Carrier in Chemical Looping Combustion*

Maciej Radosz, University of Wyoming
*Carbon Filter Process for Separating CO₂ from Power-Plant Flue Gas*

Dmitry Saulov, The University of Queensland
*Adsorption Thermodynamics in the Framework of Modified Associate Formalism*

Peter Sallans, Liberty Resources Limited
*Choosing the Best Coals in the Best Locations for Underground Coal Gasification*

5:00 – 6:30 pm Reception and Closing Remarks, Salon E
Followed by dinner on own
Gus Plumb, Director of Clean Coal Technologies, University of Wyoming

Tom Buchanan, University of Wyoming President

BIOGRAPHIES:

**Gus Plumb**  
Director of Clean Coal Technologies, University of Wyoming

Dr. Plumb received his BS and MS degrees in mechanical engineering from Colorado State University and Ph.D. from the State University of New York at Buffalo. From 1976 to 1999 he was a member of the mechanical engineering faculty at Washington State University where he served as the Assistant/Associate Dean for Instruction and Administration for the College of Engineering and Architecture and the Chair of the Department of Mechanical and Materials Engineering. Dr. Plumb was appointed Dean of the College of Engineering at the University of Wyoming on July 1 of 1999. Since 2007 he has been a Professor of Mechanical Engineering at the University of Wyoming.

Dr. Plumb is active in the Heat Transfer Division of ASME serving on the K-6 Committee (Heat Transfer and Energy Systems) from 1978 to the present.
and as a member of the Division’s Executive Committee from 1990 to 1998. He was Chair of the Heat Transfer Division during 1996-1997. He was elected to grade of Fellow in ASME in 1995.

Dr. Plumb is the author or co-author of more than 75 technical papers primarily in the areas of heat and mass transfer in porous media and convective heat transfer. The majority of these papers are co-authored with the 8 Ph.D. students and 16 MS students that he supervised at Washington State University. Current research interests include heat transfer during materials processing, heat transfer in energy systems and environmental heat and mass transfer. His research has been supported by the NSF, USDA, NIST, government laboratories and private industry.

Most recently Dr. Plumb was the recipient of a Fulbright Scholar Award to visit the Center for Renewable and Sustainable Energy at the University of Botswana for the spring semester of 2010.

After completing his doctorate, Buchanan returned to Wyoming as an assistant professor in the Department of Geography at the University of Wyoming. Over the next 30 years, he rose through the faculty ranks to full professor, and has held various administrative positions including department head, associate dean of the College of Arts and Sciences, and vice president for academic affairs. On July 1, 2005, he was appointed the 23rd president of the University of Wyoming.

As UW president, Buchanan’s priorities for the University have included excellence in academics, promoting access to higher education in Wyoming, and enhancing economic and workforce development in Wyoming.

Buchanan is the recipient of numerous awards recognizing excellence in teaching and administration, including the Elbogen Meritorious Classroom Teaching award and the Seibold Professorship in the College of Arts and Sciences. He serves on the governing boards of the Mountain West Athletic Conference, the Western Interstate Commission for Higher Education, and the Western Cooperative for Educational Telecommunications. He is Wyoming’s representative to State Higher Education Executive Officers (SHEEO).

Buchanan is married to Jacque, whom he met while a student at UW. They are the proud parents of Eric and grandparents of Bradley.

Tom Buchanan
University of Wyoming
President

Tom Buchanan’s career in higher education has spanned more than 35 years, as a student, teacher, and administrator.

A native of New York, Buchanan attended the State University of New York at Cortland where he graduated with his undergraduate degree in 1973. He earned his master’s of science from the University of Wyoming in 1975 and a Ph.D. from the Institute for Environmental Studies at the University of Illinois at Urbana-Champaign in 1979.
**KEYNOTE SESSION**

**Chair:** Mark Northam, Director, University of Wyoming School of Energy Resources

Hon. Dave Freudenthal, Governor of Wyoming

Joseph Strakey, Chief Technology Officer, Department of Energy’s National Energy Technology Laboratory

Hon. Peter Beattie, Queensland’s Trade Commissioner to the USA

**BIOGRAPHIES:**

**Dr. Mark A. Northam**
Director, University of Wyoming School of Energy Resources

Mark Northam is the Director of the School of Energy Resources at the University of Wyoming. He came to the university after a year and a half with Saudi Aramco in Dhahran, Saudi Arabia where he worked as a Research Science Consultant in the Research and Development Center. Prior to joining Saudi Aramco, Mark worked for over twenty years at Mobil and ExxonMobil. He held a variety of positions during that time, including:
• Technical Coordinator/Business Advisor in Geoscience Research at ExxonMobil
• Technology Consultant in the Office of the Chief Technology Officer for Mobil Oil Corporation
• Technology Manager for Mobil Exploration Norway, Inc.
• Manager of Tectonics and Sedimentology
• Manager of Basin Analysis
• Manager of Organic Geochemistry for Mobil R & D
• Exploration/Operations Geologist for Mobil E&P in New Orleans
• Research Scientist – Organic Geochemistry for Mobil R&D

Mark earned a Ph.D. degree in Organic Geochemistry from the University of Texas at Austin and a Bachelor of Science degree in Chemistry from Wake Forest University. He is originally from Virginia. Mark has been Director of the School of Energy Resources for 3 years.

Governor David D. Freudenthal
31st Governor of the State of Wyoming

Dave Freudenthal took office as Wyoming’s thirty-first Governor on January 6, 2003. Dave was born in Thermopolis in 1950, the seventh of eight children, and grew up on the family farm north of town. To help pay for college, he earned money by working construction during the summer. His jobs included working rigs and building tanks as a member of the National Brotherhood of Boilermakers and Blacksmiths Union.

After graduating from Amherst College in 1973, Dave returned to Wyoming to take a position as an economist for the Wyoming Department of Economic Planning and Development. Governor Ed Herschler appointed him State Planning Coordinator in 1975. While working for the state, Freudenthal simultaneously earned a law degree from the University of Wyoming. After graduating from law school, he opened his own law office in Cheyenne in 1980; this office grew into a general practice firm that represented individuals and businesses. In 1994, he was appointed United States Attorney for Wyoming, a position that he held until May 2001.

Over the years, Dave has actively participated in a wide variety of civic activities. Among other things, he has been Chairman of the Greater Cheyenne Chamber of Commerce; a founding director of the Wyoming Student Loan Corporation; a member of the Education Policy Implementation Council; Board Member, Wyoming Community Foundation; a member of the state Economic Development & Stabilization Board; a member of the Laramie County Community Action Board; and a Layreader and Vestryperson in his church.

Dave and his wife Nancy have four children: Don, Hillary, Bret, and Katie. He enjoys spending time with his family, hunting, fishing, and restoring sheepwagons, airstream trailers, and antique furniture.

Dr. Joseph Strakey
Chief Technology Officer, National Energy Technology Laboratory

Dr. Joseph Strakey is the Chief Technology Officer at the Department of Energy’s National Energy Technology Laboratory. In this capacity, he is responsible for providing strategic direction and oversight for all of NETL’s research, development and demonstration programs including its in-house research efforts.

The laboratory’s RD&D programs encompass a broad range of advanced technology development initiatives in the areas of carbon capture and storage technologies, coal gasification and combustion, hydrogen and fuels production, gas turbines, and fuel cells. The lab’s portfolio also includes major national demonstrations of advanced coal technologies with carbon capture through the Clean Coal Power Initiative and other programs.

During his 39 years of Federal service, Dr. Strakey has held senior management positions leading national fossil energy RD&D programs. He previously headed NETL’s Strategic Center for Coal, and prior to that, the Strategic Center for Natural Gas.

Dr. Strakey has a B.S. degree in Chemical Engineering from Lehigh University, and M.S. and Ph.D. degrees in Engineering and Applied Science from Yale University, where he also performed postdoctoral research. He began his Federal career as a researcher with the U.S. Department of the Interior’s Bureau of Mines. Dr. Strakey has authored or coauthored over 100 publications in technical journals and the proceedings of various energy and environmental conferences.

Hon. Peter Beattie, Queensland’s Trade Commissioner to the USA

Beattie served as Premier (Governor) of the state of Queensland from June 1998 to September 2007. As Premier his key strategy was to turn Queensland into Australia’s Smart State by refocusing...
the education system, skill the workforce, encouraging research and development and creating thousands of long-term, new-age jobs in high tech industries such as biotechnology, information technology and aviation.

After working as a lawyer, Mr. Beattie was elected to State Parliament as the Member for Brisbane Central in 1989. He was immediately appointed as the chairman of the reforming Parliamentary Criminal Justice Committee. From July 1995 he served as Minister for Health before becoming Leader of the Opposition in February 1996.

After forming a minority government in 1998, Mr. Beattie’s Government was re-elected three times, winning 66 of the 89 seats in Parliament in 2001, 63 seats in 2004 and 59 in the September 2006 election.

Peter Beattie was born on November 18, 1952, the youngest of seven children. He is married with three adult children. His qualifications include B.A., LL.B., M.A., while in 2003 he was awarded an Honorary Doctorate of Science from the University of Queensland “in recognition of his leadership and commitment to higher education through Smart State initiatives and his support for research in the fields of biotechnology and nanotechnology”. In 2007 he was awarded an Honorary Doctorate of Laws from the University of South Carolina. Mr. Beattie also has Honorary Doctorates from Griffith University, Queensland University of Technology and Bond University.

Mr. Beattie’s interests include economics and trade development, biotechnology, aerospace, international relations and creative industries such as music, photography and architecture. He is a keen walker and the author of three books: the autobiographical In the Arena and Making a Difference (2006) and a thriller, The Year of the Dangerous Ones.
on direct coal liquefaction and the refining of coal-derived liquids.

Mr. Stiegel has a Bachelors and Masters degree in chemical engineering and a Masters in Business Administration from the University of Pittsburgh.

Prior to joining the Department of Energy, Mr. Stiegel was a process engineer for Union Carbide Corporation. During his career, Mr. Stiegel has published over fifty technical articles and given over one hundred presentations on various aspects of coal conversion and reactor engineering. Mr. Stiegel is a registered Professional Engineer in Pennsylvania.

Monte Atwell
General Manager – Gasification, GE Energy

Monte Atwell is the General Manager of the Gasification group at GE Energy, responsible for a business that offers leading gasification licenses and integrated gasification combined cycle (IGCC) solutions to customers around the globe. The business comprises 65 licensed gasification plants around the globe, nearly 40 of which are using commercial technology to separate carbon.

GE’s gasification technology has been used in some of the world’s first integrated gasification combined cycle (IGCC) “cleaner coal” plants, including Coolwater and Tampa Electric’s Polk Power Station. The technology is currently being deployed at the ~630MW IGCC plant under construction for Duke Energy in Edwardsport, Indiana, the plant is expected to be the largest commercial IGCC plant in the world when it reaches commercial operation in 2012.

Monte has more than 25 years’ experience in the energy industry in technical, operational and commercial roles. Prior to his current assignment, Monte served as the technology leader for the gasification business leading the team in the design and development and commercialization of IGCC “cleaner coal” technology. Monte began his GE career in the company’s Technical Marketing Program in 1984 and has held commercial and technical assignments in several GE businesses and product lines including power systems, controls and global research.

Monte graduated from Oklahoma State University with a B.S. degree in Electrical Engineering Technology, and resides in Sugar Land, Texas.

Fred D. Palmer
Senior Vice President of Government Relations, Peabody Energy

Fred Palmer is Senior Vice President of Government Relations of Peabody Energy. He joined Peabody in February 2001 and is responsible for advancing government policies around the globe to unlock the potential for coal as the world’s future fuel. He is a member of the National Coal Council, serves on the Executive Committee, and is Chairman of the Coal Policy Committee. He also represents Peabody on the Board of Directors of the FutureGen Industrial Alliance and the U.S. Chamber of Commerce. Fred is a 2004 recipient of the Erskine Ramsay Medal Award from the Society for Mining, Metallurgy and Exploration.

Past Positions:
Western Fuels Association: General Manager and Chief Executive Officer, 1985-2000; General Counsel, 1980-1985.

Education:
Chair: Jenny Tennant, Technology Manager, Gasification, NETL, US Dept. of Energy

Harry Morehead, Manager, IGCC and Gasification Sales and Marketing, Siemens Energy, Inc.

Michael Bliderman, Director, Ergo Exergy Technologies – Canada

David Denton, P.E., Director, Energy Policy Development, Eastman Chemical Company

Deborah Murphy, Vice President, Commercial Development, GreatPoint Energy Inc.

BIographies:

Jenny Tennant
Technology Manager, Gasification, NETL, US Dept. of Energy

Jenny has recently been selected to be the technology manager for the DOE gasification program, after acting in the position since January 2010. She has managed gasification projects, including projects that support gasification-based industries, and been a member of the Gasification Technology Product Team for over 10 years. Jenny has also managed a variety of other FE and EE projects, and prior to joining proj-
Harry Morehead
Manager, IGCC and Gasification Sales and Marketing, Siemens Energy, Inc.

Mr. Morehead is the Manager of IGCC and Gasification Sales and Marketing for Siemens Energy, Inc. As such, he leads Siemens IGCC and gasification new unit sales and marketing team in the Americas. Mr. Morehead currently serves as Chairman of the Gasification Technology Council and is the lead Siemens representative for the Coal Utilization Research Council.

Mr. Morehead has played a leading role in Siemens’ U.S. IGCC and gasification activities since 1992 and has lead Siemens’ involvement in the U.S. Department of Energy’s Clean Coal Technology Demonstration and Gas Turbine programs, as well as numerous other R&D projects and advanced technology programs critical to Siemens. He also has been instrumental in identifying and developing numerous domestic and international strategic alliances in support of Siemens’ emerging technologies initiatives, including key technology partnerships with the U.S. and international Government Agencies, NGOs, universities, and other companies.

Mr. Morehead joined Siemens Energy in 1981, holding various positions in engineering and marketing. He received his Bachelor of Mechanical Engineering degree from the Georgia Institute of Technology and his Masters of Business Administration from the University of Central Florida.

Michael Blinderman
Director, Ergo Exergy Technologies – Canada

M. Blinderman is a founding director of Ergo Exergy Technologies Inc (Canada), the world leader in Underground Coal Gasification (UCG) technology, developer and owner of the Exergy UCG™ technology (eUCG™) that is being applied globally in commercial UCG projects.

M. Blinderman is recognized as the world leading expert in UCG. He has over 25 years of experience in its practical application. M. Blinderman had been actively involved in the research, development, and commercial operation of the UCG process in the former Soviet Union.

In the last 10 years, M. Blinderman directed design, construction, commissioning and operations of the Kingaroy UCG plant in Australia, Majuba UCG plant in South Africa and the Chinchilla UCG plant in Australia. He directs Ergo Exergy’s activities in several eUCG™ projects around the world, including South Africa (with Eskom Holdings Ltd), Australia (Cougar Energy Ltd), India (A&E Coal Technologies Pty Ltd), New Zealand (Solid Energy New Zealand Ltd), Canada and USA (Laurus Energy Inc) etc.

M. Blinderman published over 40 papers on science and technology of underground coal gasification. He serves as Adjunct Professor of the School of Engineering at the University of Queensland, Australia. M. Blinderman is a member of the Canadian Institute of Mining, Metallurgy and Petroleum and a member of the International Society of Mining, Metallurgy and Exploration.

David L. Denton, P.E.
Director, Energy Policy Development, Eastman Chemical Company

David Denton is Director, Energy Policy Development, for Eastman Chemical Company. He is also a Technology Fellow within Eastman. David is responsible for coordinating development of energy and climate change policy and advocacy for Eastman Government Relations, including interactions with Congress and federal agencies such as the U.S. Department of Energy (DOE). David has 35 years experience at Eastman Chemical Company. In previous positions with Eastman, David played a key role in the launching of Eastman’s gasification services and gasification development businesses and worked in a number of technical and management positions within Eastman’s Research and Technology organizations.

David received a B.S. degree in chemical engineering from Virginia Tech, with subsequent graduate work in chemical engineering at the University of Tennessee. He is a registered professional engineer in the State of Tennessee. David has spoken on gasification, energy, and climate change at a number of regional, national, and international conferences and before the U.S. Senate Committee on Energy and Natural Resources. He represents Eastman on the board of the Gasification Technologies Council and on the Coal Utilization Research Council, serves on the Program Committee of the Illinois Clean Coal Institute, and has been a member of a number of national and regional working groups for organizations such as the DOE and the National Coal Council.
Deborah Murphy
Vice President, Commercial Development, GreatPoint Energy Inc.

Debbie Murphy is the Vice President of Commercial Development for GreatPoint Energy. Joining the company in 2010, she is responsible for identifying and leading all commercial activities related to GreatPoint Energy’s commercial projects. She has 22 years of development and financing experience in the independent power, oil and gas services, and industrial sectors of the energy industry. She has worked for large international organizations as well as start-up companies, including HYDRA-CO Enterprises, Air Liquide America, Key Energy Services, and DKRW Advanced Fuels. She has a successful track record of developing and financing power and complex industrial utilities projects exceeding $1 billion including direct involvement with cogeneration, gasification, coal, hydroelectric, geothermal, biomass, and inside-the-fence CHP projects. Debbie holds a Bachelor’s of Science from the University of Rhode Island, and an MBA and Masters of Science in Accounting from Syracuse University.

ABSTRACTS:

Siemens Gasification Update
Harry T. Morehead
Siemens Energy, Inc., Orlando, FL USA
Email: harry.morehead@siemens.com

Interest in IGCC and gasification over the last 4 years translated into orders for gasification islands for a wide range of projects around the world. Interest remains strong for those projects that can address the related commercial and technical risks and in North America that have a carbon management plan. Several IGCC projects in North America continue to move forward through the permitting and FEED processes while addressing these issues. The next IGCC project in North America could startup as early as 2014.

Nine Siemens gasifiers for three projects (two in China and one in the US) have been delivered and five of them will startup this year. All three projects are coal to chemicals projects that use basically the same gas island processes needed for IGCC plants (coal milling and drying, gasification, gas cleanup, etc.). Siemens is also working on new technologies to improve the economics of gasification. Siemens power generation technology has been selected or is being evaluated for a range of applications including IGCC and CTL projects.

This presentation will provide an overview of Siemens gasification technology and an update of Siemens’ IGCC and gasification projects in North America and China.

Application of the Exergy UCG Technology in CTX Projects
M. Blinderman
Ergo Exergy Technologies, Inc.
465 rue St-Jean #602 Montreal Quebec H2Y 2R6 CANADA
info@ergoexergy.com

Underground Coal Gasification (UCG) is a gasification process carried on in non-mined coal seams using injection and production wells drilled from the surface, converting coal in situ into a product gas usable for chemical processes and power generation. The UCG process developed, refined and practiced by Ergo Exergy Technologies is called the Exergy UCG Technology or eUCG™ Technology.

The eUCG methods and techniques of environmental management are an effective tool to ensure environmental protection during an industrial application. A eUCG-IGCC power plant will generate electricity at a much lower cost than either existing or proposed fossil fuel power plants. CO2 emissions of the plant can be reduced to a level 55% less than those of a supercritical coal-fired plant and 25% less than the emissions of NG CC.
The EUcg technology is being applied in numerous power generation and chemical projects worldwide. The paper is describing current status of application of the EUcg technology in the Majuba project in South Africa (Eskom Holdings Limited), and in the projects in India (Abhijeet Group), Pakistan (Cougar Energy Ltd), Canada (Laurus Energy Inc.), Australia (Cougar Energy), New Zealand (Solid Energy New Zealand) and the USA (Laurus Energy and CIIRI).

**Eastman Perspective on Gasification Technology Deployment**

*David L. Denton*
*Director, Energy Policy Development, Eastman Chemical Company*
*Email: dl denton@eastman.com*

Eastman Chemical Company has a long history based on use of domestic alternative feedstocks. This includes commercialization in 1983 of the first and longest continuously producing coal gasification facility in the U.S. Eastman now has 27 years of experience in generating chemicals from coal and has gained a worldwide reputation for outstanding coal gasification operating experience. In addition, Eastman has been a leader, and a strong partner with the DOE, in the RDD&D of advanced gasification technologies.

Because of this strong history in gasification, Eastman is perhaps uniquely qualified to understand and represent the requirements and the challenges of the gasification industry. From Eastman’s perspective, future commercial deployment of gasification technology in the U.S. will require two drivers:

1. Near-term, deployment of current gasification technologies in today’s economic environment will require a coordinated and substantial new national early deployment initiative.

2. To be sustainable long-term, overall costs of gasification must be reduced significantly, requiring an accelerated RDD&D program to develop and demonstrate new advanced gasification technologies.

The current business environment creates a number of difficult barriers to successful deployment of conventional state-of-the-art gasification technologies. These barriers include high capital costs (steep escalation from 2006 to 2008), uncertain regulatory and liability environments, lack of adequate carbon dioxide transport and storage infrastructure, strained commodity and capital markets, and a stressed global economy. While a number of current government incentives exist, they exist in multiple inadequate silo programs and are not structured to collectively select and enable projects that advance specific goals and that have a high probability of success. The Administration’s clean coal energy goals could best be served by a new coordinated national early deployment initiative that selects a targeted group of projects that advance specific goals and have a high probability of success, and then provides those targeted projects with bundled incentives that provide adequate levels of overall support and project risk reduction.

But beyond this first step, advanced gasification technologies should be developed, demonstrated, and deployed to significantly reduce overall fixed and variable costs and enable a long-term sustainable model for commercial use of coal and other domestic feedstocks. Both the DOE and Eastman have undertaken extensive independent studies to evaluate the potential for next-generation advanced gasification technologies to substantially reduce the overall costs of gasification and make it more economically sustainable. Eastman evaluated over 700 cases involving combinations of advanced gasification technologies and found that there is potential to significantly reduce the overall costs of gasification for production of both industrial products and of electric power. In particular, Eastman found that advanced gasification technologies have the potential to enable electric power generation with high levels of CCS at capital costs and levelized power costs that are less than those for conventional IGCC without CCS. Both the DOE and Eastman found that advanced gasification technologies with CCS have the potential to reduce overall plant costs and levelized power costs by 30-40% compared to conventional IGCC with CCS.

These advanced gasification technologies should be prioritized based on their ability to lower costs and improve performance and should be aggressively supported through a well-structured RDD&D program and adequate incentives. To accelerate this development, an integrated demonstration of these advanced technologies should also be supported. A durable commitment of substantial government support will be required. But the reward could be acceleration of the overall commercial deployment timeline for these advanced technologies by a decade or more and achievement of DOE’s clean coal energy program goals much faster and at considerably less overall cost to the taxpayer.
Chair: Bob Jensen, CEO Wyoming Business Council

Julio Friedmann, Leader Carbon Management Program, Lawrence Livermore National Laboratory

Prof. Kelly Thambimuthu, FTSE, Director of the Centre for Coal Energy Technology and Professor of Chemical Engineering at The University of Queensland

Nick Welch, North American Representative, Global CCS Institute

BIOGRAPHIES:

Bob Jensen
CEO Wyoming Business Council

Robert Jensen joined the staff of the Wyoming Business Council in March 2004 and has served as CEO since July 2007. Prior to the Business Council, Jensen worked for 27 years with Fleischli Oil Co., a regional petroleum distribution company, the last five years of which he served as president.

Jensen is a 1981 graduate of the University of Wyoming, College of Business. In addition, in his business career he has helped coordinate the feasibility and planning process for redevelopment of the former Union Pacific Depot and Depot Square under the authority of the Cheyenne-Laramie County Economic Development Joint Powers Board, and
was a partner in the renovation of The Historic Plains Hotel in downtown Cheyenne.

Jensen, a fourth-generation Cheyenne native, has been active in civic and economic development organizations and has served on numerous boards including Cheyenne LEADS, Cheyenne Chamber of Commerce, The U.S. Chamber of Commerce, Cheyenne Downtown Development Authority, Laramie County Library Board, University of Wyoming College of Business Advisory Council, Wyoming Workforce Development Council and the Wyoming Chapter-National Multiple Sclerosis Society.

Jensen is married and he and his wife Jill have one daughter, Jessica.

Julio Friedmann
Leader Carbon Management Program, Lawrence Livermore National Laboratory

Julio is one of the most widely known and authoritative experts in the US on carbon capture and sequestration and underground coal gasification. In his current appointment as Carbon Management Program Leader for Lawrence Livermore National Laboratory, he leads initiatives and research into carbon capture, carbon storage, and fossil fuel recovery and utilization. In this role, he has testified before the US house, Senate, and several state legislatures, published in Foreign Affairs and the New York Times, and worked with the EPA, USGS, many private companies, many NGOs, and Dept. of Energy. He is a principle co-author on the MIT “Future of Coal Energy” Report, the National Petroleum Council report “Facing Hard Truths”, and the World Resources Institute “CCS Guidelines” report. Julio has led technical work on In Salah, Weyburn, Sleipner, and large CCS projects in China. Julio received his B.S and M.S. degrees from M.I.T., followed by a Ph.D. at the Univ. So. California. After graduation, he worked for five years as a senior research scientist in Houston, first at Exxon and later ExxonMobil. He next worked as a research scientist at the Univ. of Maryland, collaborating with the Joint Global Change Research Institute (JGCRI) at the Univ. of Maryland, and the Colorado Energy Research Institute at Colorado School of Mines. His research interests include carbon sequestration, underground coal gasification, hydrocarbon systems, deep-water depositional systems, basin & range tectonics and sedimentation, sequence stratigraphy, and landslide physics. A native of Rhode Island, he has worked in CA, WA, UT, WY, CO, Spain, Ireland, the North Sea, Nigeria, Angola, Venezuela, Azerbaijan, and Australia.

Prof. Kelly Thambimuthu FTSE, Director of the Centre for Coal Energy Technology and Professor of Chemical Engineering at The University of Queensland

Prof Thambimuthu has more than 25 years experience in the field of low emission technology. His expertise lies in clean coal technologies, low emission energy and climate change issues. He currently works at the University of Queensland as a professorial fellow at the Faculty of Engineering, Architecture & Information Technology and is a member of the Board of ZeroGen, a company working on the implementation of an IGCC with CCS demonstration project in Queensland, Australia. He was the CEO of cLET (Centre for Low Emission Technology) from 2004-2009. Before this Prof Thambimuthu worked at the CANMET Energy Technology Centre in Ottawa, Canada from 1982 to 2004.

Prof Thambimuthu was awarded a Bachelor of Chemical Engineering, a Masters of Chemical Engineering and a Doctorate in Chemical Engineering. He received his degrees from the University of Birmingham (United Kingdom), McGill University (Canada) and the University of Cambridge (United Kingdom).

Prof Thambimuthu has authored more than 140 publications. Prof Thambimuthu maintains his commitment to the environment through other roles, including:

- Chairman of the IEA Greenhouse Gas R&D Program since 1995 - the leading group within the International Energy Agency/Organisation of Economic Cooperation and Development (IEA/OECD) evaluating options to achieve deep reductions in greenhouse gas emissions from fossil fuel use
- Editorial panel member and coordinating lead author from 2002-2005 of the UN Intergovernmental Panel on Climate Change (IPCC) group of experts formed to write a special report on CO2 capture and storage as a climate change mitigation option.
- Recipient of the 1998 Natural Resources Canada award for innovation in climate change mitigation technologies
- Recipient of The IEA Coal Industry Advisory Board’s 2006 award for the sustainable development of coal
- Contributor to the award of the 2007 Nobel Peace Prize to the Intergovernmental Panel on Climate Change (IPCC)
Nick Welch represents the Global CCS Institute in North America dealing with policy, external relations and public acceptability for CCS as a critical CO2 mitigation option for meeting both the climate change challenge and growing energy demand worldwide.

He previously worked within the Shell group of companies for 14 years in a variety of roles dealing with risk management, business strategy and societal expectations. Most recently, he was Head of Policy and Stakeholder Relations for Royal Dutch Shell plc. In that role he was responsible for promoting Shell’s global public policy objectives, managing relations with a range of international stakeholders and for the Shell General Business Principles, Shell’s ethical, corporate responsibility and policy framework. These cover issues from environment to human rights and from business integrity to social impacts of industrial and commercial activities. Nick advised the Board and Executive Committee on Shell policy, public policy and reputation matters. He has had particular responsibility for leading Shell’s worldwide advocacy activity to promote the company’s policy and strategy on Climate Change.

From 2002 to 2007, Nick was Manager for International Relations based in Washington DC, representing Shell’s international project and policy interests with both domestic and international entities in the US, covering projects from Russia to Nigeria, and Canada to Iraq. He was previously Head of UK External Relations for Shell International in London. Nick joined Shell in February 1996 as Government Relations Manager in the UK, after a number of years in the UK Government. Working first on small firms policy and subsequently on large international infrastructure projects, he served both as Private Secretary to the UK Secretary of State for Trade and Industry, and to the Minister of Energy and Industry.

Before joining government service he worked as a Regional Commercial Manager for a multinational brewing company and has also worked as a technical writer and teacher overseas, including a year teaching at the College Militaire de St Cyr in France.
ABSTRACTS:

The Global Context for Low Emission Coal Technologies

Kelly Thambimuthu
University of Queensland, Australia

The projected outlook for energy use over the next few decades suggests that coal will be a dominant fuel source in power generation with its increasing use particularly in the emerging economies of China, India and South Africa.

In the period to 2050, assessments by the International Energy Agency (IEA) suggest that low emission coal technologies with carbon capture and storage (CCS) will have a large role to play in reducing CO₂ emissions consistent with climate change objectives to stabilise atmospheric greenhouse gas emissions in the 450 ppmv CO₂e range. In particular, the contribution of CCS in power generation applications is expected to reduce annual CO₂ emissions by 5.5 Gt/y by 2050 with coal-fired power generation accounting for around 65% of this emission reduction goal. In addition to this projection for emissions reduction from power generation, growth in the use of electric and hydrogen fuel cell vehicles in the transport sector is expected to contribute a further 3.9 Gt/y of CO₂ emissions reduction. Together with the anticipated growth in low emission coal technologies for power generation, it may be expected that coal-fired plants with CCS could also be a source of electricity and hydrogen for the transport sector.

Against this backdrop, we have yet to witness the global deployment of low emission coal technologies even though components of CCS technologies exist and have been in use for several decades in the oil, gas and petrochemical sectors. This presentation will review the critical needs for the global development and deployment of low emission coal technologies and link these to future options for the supply of decarbonised electricity and/or hydrogen together with renewable and nuclear energy in a portfolio approach to reduce global greenhouse gas emissions.

1 Corresponding author, email: k.thambimuthu@uq.edu.au

The Global CCS Institute – Accelerating the commercial deployment of CCS

Nick Welch, Policy and External Relations
nick.welch@globalccsinstitute.com

The Global CCS Institute was formally launched in April 2009 and became an independent legal entity in July 2009. Recognizing the important contribution CCS can make in mitigating CO₂ emissions while we meet the growing demand for energy and economic development worldwide, the Australian Government has committed AUD$100 million annual funding for the Global CCS Institute.

The Global CCS Institute has received widespread international support, with more than 20 national governments and over 80 leading corporations, non-government bodies and research organizations signing on as foundation members or collaborating participants.

The potential for CCS is considerable but barriers exist to the broad commercial deployment of the technology.

The Institute is working to help overcome these barriers on an international basis in collaboration with members, partners and others interested in accelerating CCS deployment.

In addition to a program of targeted project support to increase understanding and share knowledge around issues across the entire CCS chain, the Institute is developing and implementing strategies in the areas of policy, financing, technology, capacity building and public acceptability.
Chair: Rob Ettema, Dean, University of Wyoming College of Engineering and Applied Sciences

Maha Mahasenan, Senior Policy Advisor, Hydrogen Energy

Bob Kelly, Executive Chairman, DKRW

Claudia Miller, Engineering Manager, Dakota Gasification Company

BIOGRAPHIES:

Rob Ettema  
Dean, University of Wyoming College of Engineering and Applied Sciences

Robert Ettema serves as the Dean of the College of Engineering and Applied Science at the University of Wyoming (UW). Prior to joining UW in July 2007, he was a professor at the University of Iowa's (UI) College of Engineering and UI's long-standing Institute for Hydraulic Research. His research interests revolve around problems and processes in hydraulics engineering, water-resources engineering, and diverse aspects of cold-regions engineering. He attained the PhD degree in civil engineering at The University of Auckland, New Zealand in 1980.

He has served as Editor of the American Society of Civil Engineer's Journal of Hydraulic Engineering.
Associate Editor for ASCE’s Journal of Cold Regions Engineering, coordinated various conferences and workshops, written numerous papers, and is a registered professional engineer. In 2004 he received ASCE’s Hunter Rouse Award in civil engineering hydraulics. He served for six years on Iowa’s Highway Research Board. He was the Technical Program Chair for the 2009 Congress of the International Association of Hydraulic Research and Engineering (IAHR). The Congress was being jointly organized by IAHR, ASCE, and the Canadian Society of Civil Engineers, and was held in Vancouver, Canada.

Prior to serving as Dean, he was the Department Head of UI’s Department of Civil and Environmental Engineering. His experience in civil engineering education, research, and consulting practice, as well as in working with the wide range of stakeholders associated with engineering colleges, has extensively engaged him in program-development activities at the university, college, department, and research-unit levels. Additionally, he has extensively consulting on various topics in water-resource engineering, including hydropower, and water-related aspects of thermal powerplants. Besides engineering practice, research and education, his professional interests include the history and heritage of engineering, especially regarding water-resources engineering.

Maha Mahasenan
Senior Policy Advisor, Hydrogen Energy

Maha Mahasenan is Principal Policy Advisor at Hydrogen Energy California, which is focused on developing a low-carbon baseload power project based on integrated gasification combined cycle technology with carbon capture and sequestration in Kern County, California. His responsibilities include liaising with regulatory and policy-making bodies on energy and climate policy, developing policy structures and incentives for clean electricity generation, and coordinating various project applications and filings in collaboration with other project partners.

Bob Kelly
Executive Chairman, DKRW

A founding partner of DKRW Energy, Bob Kelly has more than 25 years of experience in creating renewable energy companies as well as the development, financing, construction and operation of large electric power cogeneration facilities.

Prior to co-founding DKRW in 2002, Bob served as interim CEO of EPV, a New Jersey solar photovoltaic manufacturer, and led the successful effort to raise $14 million of new equity. From 1985 to 1997, he held senior executive positions at Enron including president of Enron Cogeneration Company and co-chairman of Amoco/Enron Solar.

While at Enron, Bob formed a number of asset-based businesses in the power sector including Enron Power Corporation, Enron Wind Corp, Amoco/Enron Solar and Enron Renewable Energy Corporation. He led development of the 1,875 MW Teesside power project in the UK.

Bob entered the energy industry following a 13-year career in the Army that included service in Vietnam and as a tenured Professor of Economics at West Point. He holds an M.P.A. and a Ph.D. in economics from Harvard University in addition to a B.S. in nuclear engineering from the United States Military Academy.

Claudia Miller
Engineering Manager, Dakota Gasification Company

Claudia Miller has a Bachelor of Science degree in Chemical Engineering from the University of North Dakota. She is the Engineering Manager for Dakota Gasification Company, which is a subsidiary of Basin Electric Power Cooperative. Ms. Miller has 23 years experience in industry with 11 years at DGC. She manages the Civil, Mechanical, Electrical and Control Systems design engineering, plant wide project and construction management and records management.

Ms. Miller has worked in the aerospace, chemical production and gasification industries. Her background includes experience in project management, operations, process engineering and plant engineering.
The Hydrogen Energy California (HECA) Project

Natesan “Maha” Mahasenan
1Hydrogen Energy California LLC, maha.mahasenan@hydrogenenergy.com

Hydrogen Energy California LLC is developing a greenfield, commercial scale, fully integrated advanced Integrated Gasification Combined Cycle (IGCC) with carbon capture and sequestration (CCS) in Kern County, California. The HECA Project will help supply base-load, low-carbon electricity to the California electricity grid. The Project will generate approximately 250 MW (net) of electricity while achieving approximately 90% carbon dioxide (CO2) capture efficiency and sequestering approximately 2,000,000 tons per year in an enhanced oil recovery (EOR) application.

The HECA Project received a $308 million award from the U.S. Department of Energy on September 28, 2009 under Round 3 of the Clean Coal Power Initiative (CCPI). The mission of the CCPI program is to enable and accelerate the deployment of advanced technologies to ensure clean, reliable, and affordable electricity for the United States.

The HECA Project utilizes GE gasification technology, and will operate of blends of petroleum coke and coal (as necessary). The captured CO2 will be transported via pipeline to the Elk Hills oil field approximately 5 miles away from the HECA site. The Elk Hills oil fields are well characterized fields operated by Occidental of Elk Hills Inc. (Oxy). The CO2 enables additional domestic oil production, which contributes to our national energy security.

The Rectisol® process will be used for acid gas recovery and to achieve high CO2 capture efficiency. Rectisol® was chosen in part because of its demonstrated capability in achieving the extremely high cleanup levels such as that required under California air emissions regulations.

Other benefits from the project include:

- HECA will provide over 150,000 homes in the local community with new, clean electric power at a time when state agencies are predicting possible power shortages in coming years.
- HECA will enable additional production from existing California oilfields, producing previously unrecoverable oil reserves by injecting the CO2 into oil reservoirs, where the CO2 would also be permanently stored.
- HECA will boost the local economy by creating up to 1,500 construction jobs and up to 100 permanent operational positions.
- HECA will preserve limited fresh water resources by using brackish ground water supplied by a local agricultural water district. Currently the water’s poor quality and shallow location negatively impacts local agricultural activity. Process wastewater will be treated on site and recycled within the gasification and power plant systems.
**Chairs:** Lifa Zhou, Director of Shaanxi Provincial Institute of Energy Resource and Chemical Engineering and John Jiao, Wyoming Geological Survey

Mark Davies, SEO, National Low Emissions Coal Research & Development Centre, Australia

Dr. Richard Boardman, Head, Energy Security Initiative, Idaho National Laboratory

Dr. John Carras, Director, Coal Technology, CSIRO, Australia

**Biographies:**

**Mark Davies**
SEO, National Low Emissions Coal Research & Development Centre, Australia

Mark is currently the managing director for Australian National Low Emissions Coal Research and Development (ANLECR&D) where he is responsible for implementing a national program for low emission coal research and development to address the research priorities identified in the Australian National Low Emission Coal Council (NLECC) strategy. ANLECR&D’s research strategy is focussed on R&D that enables near term risk reduction and technology developments necessary for successful demonstration commercial scale of Low Emission Coal Technology in Australia. He was previously the Director of Technology and Engineering at Hydrogen Energy in the UK, where he was responsible for technology selection, engineering systems and intellectual property strategy for commercial scale CCS projects in the USA and the Middle East.
Prior to this he was General Manager Business Development at Rio Tinto Energy America (RTEA) where he was responsible for identifying and evaluating internal and external investment opportunities and managing the formulation and implementation of RTEA's long-term strategy. This involved resource acquisition as well as managing emerging energy and environmental issues including RTEA's involvement in the FutureGen project, where he is a director of the board. He has over 15 years experience in commercial roles and industrial technology development, including several US patents.

Previous experience has included roles as Manager of Environmental Technology, Manager of Simulation and Process Control and Senior Research Engineer for Rio Tinto Technical Services. He has an Honours degree in mechanical engineering and a PhD in engineering, both from the University of Adelaide in Australia.

**Dr. Richard Boardman**
Head, Energy Security Initiative, Idaho National Laboratory

Richard Boardman has a doctorate degree in chemical engineering with an emphasis in energy and environment applications. As a research student in the Advanced Combustion Engineering Research Center at Brigham Young University and the University of Utah, he gained theoretical and practical experience in combustion and gasification of fossil fuels; including, computational fluid dynamics modeling, measurement of reaction phenomena, and analysis of complex kinetic mechanisms.

He worked for Exxon Production Research (Houston, Texas) and Geneva Steel (Provo, Utah) before joining the Idaho National Laboratory (INL) in 1990 to support the development of a selective catalytic NOx reduction process for nitric waste calcination and vitrification processes. Dr. Boardman is currently the INL Energy Security Initiative lead for establishing capabilities and resources to support clean, reliable, efficient, and secure energy development. His current research activities include system analysis and testing of fossil-renewable-nuclear hybrid energy systems, coal and biomass torrefaction and gasification, and synthetic fuels process modeling. He joins a team of INL investigators developing methods to assess hybrid energy plant design, economics, and life-cycle emissions.

Dr. Boardman currently holds 3 patents, with 2 patents pending for the use of oil shale as a multi-pollutant control agent and the production of ammonia. He is the recipient of the Idaho Academy of Sciences 2004 Engineer/Scientist of the Year Award and has since served as the President of the Academy.

He has been a part-time professor for Brigham Young University and the University of Idaho for course instruction and research collaboration in Combustion Sciences and Nuclear-Chemical Engineering. He has mentored over 30 student interns at the INL.

**Dr. John Carras**
Director, Coal Technology, CSIRO, Australia

John Carras is currently Director of the CSIRO Coal Technology Portfolio which brings together all CSIRO’s research across the entire coal value chain including mining, utilization and carbon dioxide capture and geological storage.

A physicist by training (BSc (Hons), PhD) he has wide research expertise in matters related to emissions from energy use including:

1. Quantification of greenhouse gas and/or air pollution emissions from energy and industrial activities including power stations, metal smelters, motor vehicles and urban regions
2. The transport and diffusion of pollutants in the atmosphere
3. Quantification of fugitive greenhouse gas emissions from coal mining especially seam gas and spontaneous combustion in open cut coal mines
4. Energy technology options for greenhouse gas reduction
5. Interaction and storage in deep coal seams

He has authored or co-authored over 150 publications including journal and conference papers, reports to government and industry, book chapters and specialist encyclopedia articles. He has also edited one book.

His other professional activities include:

- Lead Author for Fugitive Emissions from Coal Mining for the IPCC, 2006, Guidelines for National Greenhouse Gas Inventories
- Member of the Editorial Board for the IPCC Emissions Factor Database
- Member of the Editorial Board for the Open Journal of Environmental Engineering
- Member of the Editorial Board for the Journal of Greenhouse Gas Measurement & Management
- Member of the Research Advisory Board of the University of Newcastle Priority Research Centre for Organic Electronics (2007-present)

He is a member of the American Physical Society, the Australian.
ABSTRACTS:

Low Emissions Coal Research and Development in Australia

M.H Davies ¹
¹ANLECR&D, corresponding author, email: mark.davies@anlecrd.com.au

In July 2008 Australia established a National Low Emissions Coal Council to bring together key stakeholders to develop and implement a national low emissions coal strategy. The national strategy covers the research and development, accelerated demonstration and early commercial deployment of low emission coal technologies, including carbon capture and storage. The NLECC established ANLECR&D to implement a national program for low emission coal research and development and this paper provides a summary of the ANLECR&D’s strategy.

The primary objective of ANLECR&D is to deliver the applied R&D that can reduce the risk of Low Emission Coal Technology (LECT) deployment in the 2015 to 2020 timeframe, thereby underpinning and accelerating the early commercial deployment of LECTs. This focus is driven by the recognition that these early projects must succeed for LECT to be accepted as a viable option in the portfolio of approaches required to achieve substantial global reductions in CO₂ emissions while meeting growing energy demand.

As coal is among Australia’s largest exports by value, there is significant national interest in the development of LECT. This is demonstrated in Australia’s commitment of significant resources to large scale integrated demonstration projects through the CCS Flagships component of the Clean Energy Initiative (CEI). Working closely with these early demonstration projects provides ANLECR&D with unique R&D opportunities.

From a subsurface perspective, the data, knowledge and experience gained from these early demonstration projects, when combined with Australia’s world class subsurface skills can be used to develop an R&D program that builds on Australia’s natural advantages to deliver internationally significant subsurface R&D. Access to subsurface data from integrated early demonstration R&D activities across several sites will enable researchers to advance and verify the tools available for estimating storage capacity, modeling the fate of CO₂ in the sub-surface and designing fit for purpose Measurement, Monitoring and Verification (MMV). The availability of these tools is critical to attaining environmental approvals and will help reduce the cost, time and risk involved in the development of future LECT projects globally.

From a capture perspective, the relatively small market and nature of the Australian power industry means that Australia will necessarily be a utility technology taker. Australian capture and generation R&D must therefore focus on adapting and applying power generation technology for local deployment. This requires:

- A deep understanding of the behavior of Australian coals in the technologies – an issue also of critical importance to the export coal sector.
- Optimizing LECTs to work under local ambient conditions and to meet Australian environmental legislation.
- Integration of the technologies into the local grid, taking into account the impact of the local market conditions on operational practice.

These issues are of lower priority to overseas technology providers. It is therefore essential that Australia carry out this work if project implementation risks are to be successfully managed.

---

Gasification of Wyoming Coal to Produce Clean Energy Products

Authors: Richard Boardman, Tom Foulke, Rick Wood, Dave Bell, Will Schaffers, Anastasia Gribik

Providing clean, safe, and secure energy for a global community exceeding 9 billion persons by 2050 is shaping up to be the defining challenge of this new century. With projected energy increases of over 30% in the next 20 years, and approaching 50% by 2050, energy security takes on increased significance, including the self-evident consequences of relying on conventional crude to produce transportation fuels and uncontrolled release of CO₂ to the atmosphere.

The opportunities for converting Wyoming coal and natural gas into higher value energy and chemical products while managing carbon emissions through proven capture and sequestration technologies has been investigated through a cooperative research and development agreement (CRADA) between the State of Wyoming, the Idaho National Laboratory, and industrial participants. A technical-economical study of five leading gasification-based platforms currently being developed in the U.S., China, and other countries has been completed for Wyoming coals at Wyoming two project sites:

1. Notional five hundred (500) Mega Watts Electricity (MWe) Integrated Gasification-Combined Cycle Plant, including sixty percent (60%) carbon capture and ninety percent (90%) carbon capture alternatives.
2. Notional two thousand (2,000) tons per day ammonia production plant, with carbon capture.

3. Notional thirty thousand (30,000) barrels per day coal to liquids fuels using a Fischer-Tropsch synthesis, with carbon capture.

4. Notional fifty billion (50,000,000,000) cubic feet of synthetic natural gas per year, with carbon capture.

5. Notional five hundred (500) short-ton per day methanol/DME/gasoline commercial manufacture grade product, with carbon capture.

Plant economics and life cycle carbon and water use balances have been examined with the use of detailed models plant models. A comparison of the various cases show the present viability of power generation and fuels/chemicals production versus present energy product costs. A comparison of wet versus dry gasification processes and the use of air coolers rather than cooling towers provides both technical and environmental improvements for Wyoming coal gasification projects.

---

**Low emissions coal research in CSIRO, Australia**

**J. N. Carras, Director CSIRO Coal Technology, PO Box 52, North Ryde, NSW, 1670, Australia**

Australia is the world’s largest exporter of coal and coal is Australia’s largest export earner. Coal provides 80% of Australia’s electricity and is critical to the Australian economy. Yet coal also contributes to some 40% of Australia’s net greenhouse gas emissions.

CSIRO is Australia’s largest research organisation and delivers its research through 12 Portfolios, one of which is Coal Technology.

CSIRO Coal Technology focuses its efforts in:

**Coal Production** – This program aims to improve the efficiency of underground and open pit mining while addressing environmental impacts associated with mining. The mining focus is on longwall and dragline automation, remote controlled roadway development, gas drainage, inertisation and spontaneous combustion control. The environmental focus is on fugitive emissions of greenhouse gases, subsidence control, ground water flows and aquifer interference. There is also a strong program of work focused on coal cleaning for the export market and for alternative coal uses.

**Coal Utilisation** – This program aims to develop low emissions technologies for coal use. The focus is on supporting IGCC deployment through developing the necessary understanding of gasification behaviour of Australian coals and development of high efficiency ‘downstream’ syngas processing technologies including advanced gas cleaning and integrated water gas shift reaction and gas separation systems for hydrogen production and CO₂ separation. There is also a significant activity focused on the development of micronized coal water slurries for use in large scale diesel engines and in the development of the direct carbon fuel cell. Key facilities include a pressurized entrained flow reactor (PEFR) and membrane reactor test unit located at the CSIRO QCAT laboratories in Queensland which provides unique capabilities for the study of coal gasification behaviour and advanced syngas processing and separation technologies.

**CO₂ Capture, Transport, Utilisation and Storage** – This program explores the R&D issues associated with carbon dioxide production from coal utilisation. A major focus is on post combustion capture (PCC) using solvent processes through amines and ammonia. CSIRO and partners have developed and deployed 3 pilot scale PCC plants (1000 to 3000 tpa, black and brown coal, amines and ammonia) at three power stations in Australia (Munmorah, Loy Yang and Tarong) and have worked with Huaneng Power in China on developing the Gaobeidian (Beijing) PCC pilot plant. CSIRO also has major projects on mineralisation technologies and establishing the emissions limits of amine based PCC processes. In CO₂ storage and use, CSIRO’s activities focus on deep saline formations and enhanced coal bed methane where major projects are in play. The ECBM project is in collaboration with Japan and China through the Asia Pacific Partnership.

This paper will describe recent advances from CSIRO’s low emissions coal technology research.
Chair: Dr. Kelly Thambimuthu, FTSE, Director of the Centre for Coal Energy Technology and Professor of Chemical Engineering, The University of Queensland

Philip Smith, Director, Institute for Clean and Secure Energy (ICSE), University of Utah

Robert Williams, Senior Research Scientist, Princeton Environmental Institute (PEI), Princeton University

Mark Finkelstein, Vice-President, Luca Technologies

Don Schofield, General Manager, New Projects, Linc Energy

Biographies:

Dr. Kelly Thambimuthu
FTSE, Director of the Centre for Coal Energy Technology and Professor of Chemical Engineering, The University of Queensland

Prof Thambimuthu has more than 25 years experience in the field of low emission technology. His expertise lies in clean coal technologies, low emission energy and climate change issues. He currently works at the University of Queensland as a professorial fellow at the Faculty of Engineering, Architecture & Information Technology and is a member of the Board of
ZeroGen, a company working on the implementation of an IGCC with CCS demonstration project in Queensland, Australia. He was the CEO of cLET (Centre for Low Emission Technology) from 2004-2009. Before this Prof Thambimuthu worked at the CANMET Energy Technology Centre in Ottawa, Canada from 1982 to 2004.

Prof Thambimuthu was awarded a Bachelor of Chemical Engineering, a Masters of Chemical Engineering and a Doctorate in Chemical Engineering. He received his degrees from the University of Birmingham (United Kingdom), McGill University (Canada) and the University of Cambridge (United Kingdom).

Prof Thambimuthu has authored more than 140 publications. Prof Thambimuthu maintains his commitment to the environment through other roles, including:

- Chairman of the IEA Greenhouse Gas R&D Program since 1995 - the leading group within the International Energy Agency/Organization of Economic Cooperation and Development (IEA/OECD) evaluating options to achieve deep reductions in greenhouse gas emissions from fossil fuel use

- Editorial panel member and coordinating lead author from 2002-2005 of the UN Intergovernmental Panel on Climate Change (IPCC) group of experts formed to write a special report on CO₂ capture and storage as a climate change mitigation option.

- Recipient of the 1998 Natural Resources Canada award for innovation in climate change mitigation technologies

- Recipient of The IEA Coal Industry Advisory Board’s 2006 award for the sustainable development of coal

- Contributor to the award of the 2007 Nobel Peace Prize to the Intergovernmental Panel on Climate Change (IPCC)

Prof. J. Smith is the director of the Institute for Clean and Secure Energy (ICSE), a multidisciplinary research program for understanding the technical, policy and environmental issues for clean coal energy production and utilization.

He is a professor of Chemical Engineering at the University of Utah.

He is also the chair of the American Flame Research Committee (AFRC) of the International Flame Research Foundation.

Prof. Smith has been responsible for the hydrocarbon fire simulation aspects of CSAFE, the Center for the Simulation of Accidental Fires and Explosions, for the past 13 years. CSAFE is one of five DOE funded Advanced Simulation and Computing (ASC) university alliance centers with the purpose of advancing simulation science pedagogy.

In 1990 he was one of three founding partners of Reaction Engineering International, a consulting firm that uses coal combustion simulation software developed by him and his students for problem solving and design of coal and natural gas combustion boilers, furnaces and gasifiers.

In the 1980’s he was an Associate Professor in Chemical Engineering and the the lead faculty member for the coal combustion simulation development in the NSF Engineering Research Center (ACERC) at Brigham Young University.

He is a Canadian from Southern Alberta, raises Arabian horses and lives with his wife in Draper, Utah.

Robert Williams
Senior Research Scientist, Princeton Environmental Institute (PEI), Princeton University

A physicist by training (BS, Yale 1962; PhD. UC Berkeley, 1966), Robert Williams is a Senior Research Scientist at Princeton University’s Princeton Environmental Institute, where he heads the Energy Systems Analysis Group and the Carbon Capture Group of PEI’s Carbon Mitigation Initiative—a long-term project supported by BP and Ford.

Although his research has covered all aspects of energy (including energy end-use efficiency, industrial cogeneration, renewable energy, and nuclear energy) much of his recent research has focused on roles for coal and biomass in a carbon-constrained world. He has given particular attention to the importance of gasification technologies for coal and biomass and the coprocessing of coal and biomass to coproduce synthetic fuels plus electricity with CO₂ capture and storage.

Williams was an International Member (1993-2003) of the Working Group on Energy Strategies and Technologies of the China Council for International Cooperation on Environment and Development. During 1998-2004 Williams was a member of the Editorial Board of the World Energy Assessment (a joint project of the UN Development Programme, the UN Department of Economic and Social Affairs, and the World Energy Council) and Convening Lead Author of the Advanced Energy Supply Technologies Chapter of the WEA report Energy and the Challenge of Sustainability, prepared to inform discussion and debate about sustainable energy as an input to both CSD-9 and the “Rio Plus Ten” meeting of the UN General
For the ongoing followup Global Energy Assessment Williams is a Lead Author for the Knowledge Module on Fossil Energy. He was a Lead Author of the 2005 Special Report on CCS of the Intergovernmental Panel on Climate Change. During 2007 Williams was a member of the Coal-to-Liquids Working Group of the Western Governors Association’s Transport Fuels Project and co-author of this working group’s report to the Western Governors Association. During 2008 Williams’ Energy Group prepared the analytical framework for the assessment of synthetic liquid fuels from coal and biomass for the Panel on Alternative Liquid Transport Fuels from Coal and Biomass of the National Research Council’s America’s Energy Future study.

Honors include the Leo Szilard Award for Physics in the Public Interest (American Physical Society, 1988), the Sadi Carnot Award for energy efficiency contributions (US Department of Energy, 1991), a MacArthur Prize (1993), and the Palladium Medal (National Audubon Society, 1995). Williams was a co-recipient of the Volvo Environment Prize in 2000.

Mark Finkelstein
Vice-President, Luca Technologies

Mark joined Luca Technologies in 2004 as the first bio-scientist and Ph.D. on their executive management team. Prior to joining Luca Mark held several management positions at the National Renewable Energy Laboratory including Director of the Biotechnology Center for Fuels and Chemicals. In addition to Mark’s national laboratory experience, he has more than 14 years of senior level scientific knowledge gained from working in some of biotech’s most well respected companies, including: ZeaGen/Coors BioTech and Schering-Plough. Mark obtained his Ph.D. in Molecular Biology from SUNY at Buffalo and has spent his whole career successfully coaxing microorganisms to overproduce a variety of therapeutics, nutritional biochemicals, vitamins and various bioenergy products. At Luca, Mark is helping to develop and implement novel technologies capable of bio-converting buried hydrocarbons such as coal, shale and oil to methane using indigenous microorganisms found in the sub-surface. In addition he is heavily involved in corporate strategic, business and intellectual property development.

Don Schofield
General Manager, New Projects, Linc Energy

Don Schofield has extensive global experience in founding mining related private and public companies and has served in roles including Managing Director, General Manager, Mine Manager, Operations Manager, Exploration Manager and Project Manager within the petroleum, coal bed methane, mineral exploration, mining and drilling industries. He was also previously involved in some of the early UCG work performed in the USA in the early 1980s.

Don’s qualifications include Bachelor of Science majoring in mining engineering and geology and a Master of Arts in sedimentation and marine geology. At Linc Energy, Don is responsible for New Projects including Linc Energy’s expansion into the United States and the evaluation of petroleum exploration potential of the organisation’s seven Petroleum Exploration Licenses in South Australia.
ABSTRACTS:

Accelerating Deployment of Clean and Secure Coal Technologies

Philip J. Smith*, director
Institute for Clean and Secure Energy,
The University of Utah, *corresponding author,
Philip.Smith@utah.edu

There is an ever increasing national awareness that an effective, sustainable response to growing global energy demand in the presence of climate change constraints must include significant, cost-effective utilization of international coal resources. For example, a recent symposium on retrofitting coal-fired power plants concluded that: “The retrofit, rebuild, or re-powering of the existing coal fleet, in the US and in China, to reduce CO₂ emissions dramatically is a necessary step towards achieving greenhouse gases (GHG) stabilization targets. Practical options that will justify the vast investments needed over the next decades require validation from demonstration, development and research. Failure to do so will both drive up CO₂ prices (and the cost of electricity) and leave us with a continuing dearth of appropriate technology options”[1]. What technologies should be implemented? How rapidly can and should we implement a given option? What will be the cost? What will be the consequences?

The largest barrier to the deployment of new coal energy technologies is uncertainty in the quantification of risk. In order to make decisions about future energy options, many different stakeholders need to predict the consequences of various design and build options. Historically, changes in power generation technologies have required decades to implement on any practical scale. It takes time to build, test and scale each element of the power system with ‘cut & try’ methods. Science-based, computational simulation and modeling could accelerate the deployment of these new technologies, but only if tightly coupled with modern measurement and monitoring methods for validation and scale-up of practical energy company applications[2]. However, all stakeholders need confidence that the simulation is appropriately accurate. Specifically, stakeholders need to have available not only the predicted consequences of the decisions but to quantitatively know the uncertainties and errors in those prediction at full scale.

The overall objective of the research at the Institute for Clean and Secure Energy (ICSE) is to produce tools and methods with quantified predictivity that can be used by industry for the technological, economic and environmental consequences of technology options for deployment of technologies for both secure fuel production from coal resources and clean energy utilization from the large installed base of power and thermal energy generation from coal. Predictivity assumes that the simulation inherently holds the ability to extrapolate from a current knowledge base to future effects. To be useful the simulation must simultaneously provide the uncertainty in that estimate. This uncertainty arises from uncertain models and uncertain measurements, requiring a new level of collaboration between measurements and simulations. To rapidly implement a new technology requires quantified predictive capability for scaling and for site specific variations. ICSE is performing the research that integrates simulation, experiment, economics, policy and law to develop a framework suitable for industry in which all components are tightly integrated to provide demonstrated predictive capability for large-scale deployment of coal technology applications.


LucaGas: New Energy from a Depleted Resource

Mark Finkelstein and Jeffrey L. Weber
Luca Technologies Inc, 500 Corporate Circle
Golden, Colorado 80401
mark.finkelstein@lucatechnologies.com

Methane, more familiarly known as natural gas in its purest form, is the cleanest burning, most desirable fossil fuel. Whereas the general public views fossil fuels as an energy source created over geologic time as a consequence of extreme temperature and pressure, an important subset of natural gas is formed biologically. This biogenic gas is frequently found in coal beds and can constitute an enticing resource. Furthermore, it has been discovered that this gas is capable of being created in real-time, and that human intervention can accelerate or inhibit the process.

Hundreds of water, core and microbial samples from coal and other hydrocarbon reserves worldwide have been collected over the past 8 years, and the phenomenon of real-time microbial gas creation in tens of thousands
of tests in the laboratory and in the field have been studied in the author’s laboratory. With a focus on the coals in the Powder River Basin of Wyoming, voluminous biologic, chemical and geologic data has been generated and mined to develop methods to greatly boost methane production both in the laboratory and the field. Although laboratory studies are capable of producing snapshots in time and space that are useful in addressing certain basic questions, such snapshots only provide an entry point in the research of complex in-situ microbial populations and their heterogeneous natural environment. Test results in the field generally followed the results obtained in the laboratory test systems, which include static, batch, and continuous flow experiments that have been ongoing for several years. Hundreds of different microbes are found in this sub-surface, and clear differences were noted in diversity between microbial communities in productive and non-productive fields. Several stimulatory treatment regiments were capable of shifting microbial communities towards enhanced methanogenesis. These treatments are environmentally benign, long-lasting, and recycle the formation water from the reservoir.

The first large-scale field demonstration, in 2006, was conducted in the Tongue River region of the Powder River Basin which had a well-defined declining gas production curve to serve as the baseline. A variety of nutrient packages and injection regimes were deployed over a total of 260 CBM wells encompassing 5 different (discrete) coal seams and water systems. A control area with 185 wells and a decline curve similar to the demonstration area was operated in the same way. A large test area encompassing over 400 wells was required to ensure statistical relevance given the number of variables in this field test (nutrients, treatments, coals, waters, well inter-connectivity). The results demonstrated that successful treatments of only 60 wells in the test area were able to clearly alter the decline kinetics of the entire test field. Adjacent control wells maintained their steady downward decline curve. Both “Proof of Concept” and surprisingly “Commerciality” were achieved during this first field trial. The biogenic gas was pipeline quality, and enough additional new gas was created to heat 20,000 homes for a year. Furthermore, at extrapolated rates, the Powder River Basin coals have the potential to yield 100’s of TCF’s of methane over the next century by taking advantage of existing infrastructure requiring little or no additional drilling. This technology has the potential to make use of a significant portion of the world’s coal deposits with a decreased footprint and in a more environmentally friendly manner. By naturally bioconverting coal to methane in the ground, the energy of coal can be obtained in a manner that results in carbon emissions that are significantly lower than those that would result from mining, transporting, and burning the coal to energy at a power plant.
Chair: Ron Surdam, Wyoming State Geologist / Director of Carbon Management University of Wyoming

Gus Plumb, Director of Clean Coal Technologies, University of Wyoming
Assessing Opportunities and Challenges of Utilizing Coal in Botswana

Vijay Sethi, Ph.D., Western Research Institute
Development of a “Green Coal” for Utilities

Michael Stoellinger, University of Wyoming
Modeling of Turbulent Coal Combustion

Biographies:

Ron Surdam
Wyoming State Geologist / Director of Carbon Management University of Wyoming

Ronald C. Surdam and co-authors have published 220 articles in refereed scientific journals and books. He has presented more than 200 invited lectures, and he and his students have given more than 180 presentations at scientific meetings, nationally and internationally. In 32 years at the University of Wyoming, Surdam raised $32 million in research support. While at UW, he founded and directed the Institute for Energy Research and directed the Enhanced Oil Recovery Institute.
Surdam has consulted for many international energy and mineral exploration corporations: this work along with his tenure at UW has given him extensive experience with energy issues and research around the world. Over the past 44 years, Surdam has focused on oil and gas exploration, oil shale and trona depositional systems, and coal and zeolite deposits in the Rocky Mountain Laramide basins of Wyoming and other states. He has served the State of Wyoming in numerous capacities, most recently as Director of the Wyoming State Geological Survey. Currently, Surdam is helping lead the effort to accomplish commercial geological CO₂ sequestration in the Rocky Mountain region.

Education and Training:
University of California, Los Angeles
A.B. Geology, 1961
University of California, Los Angeles
Ph.D., Geology, 1967
State of Wyoming Professional Geologist, Registration Number PG-1546

Research and Professional Experience:
Instructor of Geology, University of Wyoming (1966–1967); Assistant Professor of Geology, University of Wyoming (1967–1969); Associate Professor of Geology, University of Wyoming (1969–1973); Professor of Geology, University of Wyoming (1973–1998); Professor Emeritus, University of Wyoming (1998–present); Director, University of Wyoming Institute for Energy Research (1993–1998); I.E. Warren Professorship of Energy and the Environment (1994–1998); Director, University of Wyoming Enhanced Oil Recovery Institute (1997–1998); Consultant to University of Wyoming (1998–2000); President, Innovative Discovery Technologies, LLC (2000–2004); Honorary Professor, Nanjing University, Nanjing, China (2002–present); Director, Wyoming State Geological Survey (2004–2010); Member, Wyoming Oil and Gas Conservation Commission (2004–2010); Member, EORI Commission (2004–2010); Honorary Professor, Northwest University, Xian, China (2009–present); Senior Advisor, Shaanxi Provincial Institute of Energy and Chemical Engineering (2009–present); Member, Wyoming Carbon Sequestration Commission (2009–2010); Director, Carbon Management Institute, UW School of Energy Resources (2010–present)

Highlights:

Gus Plumb
Director of Clean Coal Technologies, University of Wyoming

Dr. Plumb received his BS and MS degrees in mechanical engineering from Colorado State University and Ph.D. from the State University of New York at Buffalo. From 1976 to 1999 he was a member of the mechanical engineering faculty at Washington State University where he served as the Assistant/Associate Dean for Instruction and Administration for the College of Engineering and Architecture and the Chair of the Department of Mechanical and Materials Engineering. Dr. Plumb was appointed Dean of the College of Engineering at the University of Wyoming on July 1 of 1999. Since 2007 he has been a Professor of Mechanical Engineering at the University of Wyoming.

Dr. Plumb is active in the Heat Transfer Division of ASME serving on the K-6 Committee (Heat Transfer and Energy Systems) from 1978 to the present and as a member of the Division’s Executive Committee from 1990 to 1998. He was Chair of the Heat Transfer Division during 1996–1997. He was elected to grade of Fellow in ASME in 1995.

Dr. Plumb is the author or co-author of more than 75 technical papers primarily in the areas of heat and mass transfer in porous media and convective heat transfer. The majority of these papers are co-authored with the 8 Ph.D. students and 16 MS students that he supervised at Washington State University. Current research interests include heat transfer during materials processing, heat transfer in energy systems and environmental heat and mass transfer. His research has been supported by the NSF, USDA, NIST, government laboratories and private industry.

Most recently Dr. Plumb was the recipient of a Fulbright Scholar Award to visit the Center for Renewable and Sustainable Energy at the University of Botswana for the spring semester of 2010.
Vijay Sethi, Ph.D.
Western Research Institute

Dr. Sethi received his Ph.D. in 1976 from Case Western Reserve University, Cleveland, Ohio. Since his graduation he has been active in R&D in support of energy production at Argonne National Laboratories, at Kentucky Center for Energy Research, Battelle Memorial Institute, and now at Western Research Institute.

As the Sr. VP for Energy Production and Generation at WRI, Dr. Sethi heads a Business Unit that develops and demonstrates technologies that address energy production and generation, clean and efficient fuels production, and environmental processes related to energy and fuels production. Current activities of the Business Unit include development of coal upgrading technologies, development and testing of coal- and biomass-based combustion and gasification systems, Oxycombustion, catalyst development for F-T synthesis of fuels and chemicals, development of advanced systems for hydrogen production, and materials selection and compatibility studies.

Dr. Sethi is also responsible for managing WRI’s $4M Cooperative Agreement with the US Department of Energy.

Michael Stoellinger
University of Wyoming

Michael got his M.Sc. in Mechanical Engineering from the Technical University Munich in 2005. Since 2006 he is pursuing a PhD in Mathematics at the University of Wyoming. Michael’s research is focused on stochastic methods for turbulent combustion.

NOTES:
ABSTRACTS:

Assessing Opportunities and Challenges of utilizing Coal in Botswana

M.T. Oladiran1*, C. Kiravu1, O.S. Motsamai1 and O.A. Plumb2,
1University of Botswana, Faculty of Engineering and Technology, P/Bag 0061, Gaborone, Botswana
2University of Wyoming, Department of Mechanical Engineering, Laramie, WY 82071, USA

Botswana has abundant reserves of coal estimated at 212 billion tones in various fields though only one field is currently operational. Exploration has also confirmed that there is approximately 60 trillion cubic feet (tcf) of coal bed methane (CBM) and another 136 tcf in associated carbonaceous shale altogether making an estimate of 196 tcf CBM. The country currently depends on electricity generated from a single coal based power plant in the country and imports from the Southern Africa Power Pool, mainly from Eskom of the Republic of South Africa (RSA). The country is a signatory to the UNFCCC and the Kyoto Protocol to control greenhouse gas emission. Several methods have been adopted to reduce the carbon footprint, namely, energy management and energy efficiency (e.g. efficient end use technologies), adoption of renewable energy practices, and enhancing conversion efficiency of power generating systems. Some of the options under consideration to limit CO2 emissions from new power stations include use of advanced power systems such as integrated gasification combined cycle (IGCC) systems and carbon sequestration technologies to recapture and store carbon dioxide (i.e. carbon capture and storage). As the country continues to develop and industrialize, CO2 generated per capita will grow steadily and environmental issues will increasingly be of concern.

Botswana is a land locked country enveloped between South Africa, Namibia, and Zimbabwe and has no direct access to any coastline. With the huge coal resources it is likely that the country will depend on coal fired power stations for future electricity needs. Indeed several such power stations are at various stages of development to make the country self sufficient in electricity and possibly become a power exporter to neighbouring states. Policy on diversification of energy provision to use renewable sources has been adopted. Solar and biomass options are highly favored. Botswana has one of the highest solar radiation regimes in the world because the country receives over 3200 sunshine hours per annum and the average daily insolation on a horizontal surface is approximately 21 MJ/m2.

In the current paper we assess opportunities for harnessing the huge proven coal reserves in a sustainable manner. Issues considered include coal to fuel adoption (i.e. gasification and liquid fuels), beneficiation, export, and carbon storage. From an economic, strategic and environmental point of view it is appropriate to promote the use of solar energy in Botswana. Therefore the paper presents solar-coal hybrid power production as a pragmatic strategy to reduce CO2 emissions and gain low risk experience necessary to operate a full scale solar thermal electricity generation facility.

Keywords: coal, utilization, opportunities, challenges, hybrid systems.

* Corresponding author, email: oladiran@mopipi.ub.bw

Development of a “Green Coal” for Utilities*

Vijay Sethi1, Jerrod Isaak1 and Dianne Wyss2
1Western Research Institute, 365 North 9th Street, Laramie, Wyoming 82072
2River Basin Energy, Inc., 9249 S Broadway – Unit 200; Highlands Ranch, CO 80129
vsethi@uwyo.edu

A Renewable Portfolio Standard (RPS) is a policy that seeks to increase the proportion of renewable electricity used by retail customers. From a utility’s perspective, cofiring biomass in an existing coal-fired facility is the easiest way to achieve these targets. However, biomass cofiring in an existing power plant needs to be hassle-free with little or no equipment modifications. Western Research Institute (WRI) and River Basin Energy (RBE) are collaborating to develop a coal/biomass mixture as a utility fuel which in the most part handles like coal and has the physical and chemical characteristics that are not too different from the coal. Such a solid fuel with heating values approaching 10,500 Btu/lb, produced from many varieties of biomass mixed with abundant low-rank coals supports the nation’s goal of using biomass in an efficient and economical manner and allows the utilities to meet the RPS targets.

The current commodity-scale solid fuel for biomass is wood pellets. For large scale applications such as cofiring,
wood pellets do not have sufficient shelf life because, being hygroscopic and hydrophilic in humid climates they can re-wet, and must be protected from direct precipitation. Additionally, due to the high fiber content of the pellets they can not be co-milled with coal. Biomass, such as wheat straw, corn stover, and other crop residues are difficult to pelletize and even when pelletized, they are susceptible to natural decomposition and biodegradation. Torrefaction, a thermal pre-treatment technology performed at atmospheric pressure in the absence of oxygen at temperatures between 200 and 300°C, is recognized as a technically feasible method of converting raw biomass into a high energy density, hydrophobic, compactable, grindable, and lower O/C ratio solid fuel.

RBE and WRI are jointly developing a novel torrefaction procedure based on a variation of the RBE’s coal upgrading technology, an air-blown fluidized bed-based process. For coal upgrading this process employs an air-blown fluidized bed of coal at 300 – 350°C. All the heat required for coal drying comes from the coal itself and once started the process only requires a coal feeder and a product cooler. Early bench-scale work shows that a similar process configuration is indeed possible with biomass and biomass/coal mixtures. Coal and biomass coprocessing in a single reactor to produce a homogeneous fungible product is more economical than biomass processing alone. The product produced can be used by utilities in existing installations with no equipment modification.

A commercial demonstration plant is being configured to produce sufficient quantities of coal-biomass mixtures (Green Coal) based on Wyoming’s abundant sub-bituminous coals for testing by others.

*Work supported by DOE/NETL under Cooperative Agreement DE-FC08NT43293, R&D for Fossil Energy Resources

PDF Modeling of Turbulent Coal Combustion

Michael Stoellinger1 and Stefan Heinz2 and Dirk Roekaerts3
1 University of Wyoming, Department of Mathematics, corresponding author, email: mstoell@uwyo.edu
2 University of Wyoming, Department of Mathematics, email: heinz@uwyo.edu
3TU Delft, Department of MultiScale Physics, email: dirkr@ws.tn.tudelft.nl

Introduction: Numerical simulations of coal combustion and gasification have become a valuable tool for the design, optimization and upscaling of furnaces and gasifiers. Most industrial scale furnaces and entrained flow gasifiers operate under turbulent flow conditions. Modeling the interactions between the turbulent flow field and the chemical reactions accurately is a main requirement to obtain accurate simulation results. A widely used model for the turbulence/chemistry interactions is the two mixture approaches [1]: the products of devolatilization and char oxidation are each tracked with a separate mixture fraction and the shape of their probability density function (PDF) is assumed to be parametrized by the mean value and variance of the two mixture fractions. A basic problem of the assumed shape PDF is that the choice of the PDF (typically a beta PDF) has a significant effect on the simulation results. Moreover, the method makes assumptions about the statistical independence of the mixture fractions and the enthalpy with unknown validity.

Transported PDF methods: To avoid assumptions on the shape of the PDF, methods have been developed [2] which solve for the one point joint PDF of scalars and velocity directly. In transported PDF methods arbitrarily complex finite rate chemical mechanisms can be considered and they have been applied very successfully in simulations of gaseous combustion [3]. Recently, the transported PDF method has also been applied to account for the presence of a dispersed, dilute second phase [4].

A new approach: transported PDF method for coal combustion: We have extended the transported PDF method to describe turbulent pulverized coal combustion. In particular, we solve for the joint PDF of the two mixture fractions and enthalpy. The dispersion of the coal particle is modeled by a stochastic process for the gas velocity seen by the particles. The chemistry is assumed to be in local equilibrium and the radiative heat transfer is modeled by the discrete transfer method. The knowledge of the joint PDF allows to account for the emission turbulence/radiation interaction.
Application of the transported PDF method:
The transported PDF method is applied in simulations of the pilot scale furnace B1 which has been studied experimentally by the International Flame Research Foundation (IFRF). The burner creates a lifted axisymmetric flame. We will present comparisons of our simulation results with the available measurements to validate our method. Moreover, we will validate some of the assumptions of the assumed shape approach. Such a validation could help to improve the more commonly used assumed shape PDF methods.

References:


Chair: Alex Klimenko, Visiting Professor of UW Mechanical Engineering from The University of Queensland

Dr. Thomas Barton, Western Research Institute
Hydrogen Separation: Membranes, Processes and Engineering

Will Schaffers, University of Wyoming
Coal Fired IGCC Power Plants in Wyoming

Dr. Alan Bland, Western Research Institute
WRITECoal™ Gasification of Low-Rank Coals for Improved Advanced Clean Coal Gasifier Design

Philip Smith, University of Utah
Prediction of Entrained Coal Gasification using Large Eddy Simulation (LES) with the Direct Quadrature Method of Moments (DQMOM)

BIographies:

Alex Klimenko
SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland

A.Y. Klimenko held a number of senior visiting positions at Cornell University, Stanford University, Karlsruhe University and University of Wyoming. He is an author of more than 100 publications in the areas of reacting/adsorbing flows, gasification, vortical dynamics and engineering education, and served as an editor on a number of publications, including Category Editor (gasification) of new Wiley Encyclopedia of Energy and a Regional Editor for Open Thermo-dynamics Journal. A.Y. Klimenko has provided his expertise to several major companies and government departments.

A.Y. Klimenko has made an outstanding contribution to Engineering Science. He and his group at The University of Queensland have developed a series of novel approaches (CMC, MMC, PCMC, IDFE, ASF) that are used and recognized worldwide, suggested theories explaining the key processes utilized in underground gasification of coals and pioneered study of abstract competitive systems. His work has resulted in dramatic (thousandfold) decrease in computational cost of high-quality simulations of turbulent reacting flows.

**Will Schaffers**  
University of Wyoming

Will graduated from Oregon State University with a Bachelor of Science degree in agriculture in 1987 and from Texas A & M University with a Master of Science degree in agriculture in 1989. He worked in the testing and transportation of agricultural chemicals until returning to Oregon State University in 2005 to pursue a degree in Chemical Engineering. On the advice of his advisor there, he decided to pursue and advanced degree rather than a Bachelors degree. Will enrolled in the PhD program at the University of Wyoming in 2007 where he has primarily worked on Aspen modeling of coal gasification and related projects.

**Dr. Alan Bland**  
Vice President, Western Research Institute

Alan Bland is a Vice President at Western Research Institute in Laramie Wyoming. He joined WRI in 1991 and has served in several technical and program management positions. As Vice President he is WRI’s lead for waste and environmental management science and technology R&D that addresses gaseous emissions, water recovery and reuse issues of clean energy generation and the environmental processes related to energy production. Currently, he is heading the development of WRI’s WRITECoal™ coal upgrading technologies in advanced coal-based oxy-combustion and gasification systems. He is also heading water management and treatment options for the power sector and system analysis and techno-economic evaluations of emerging environmental processes and clean fuel technologies, funded by the SER under the Wyoming Clean Coal Technology Program, the United States Department of Energy and industry.

Prior to joining WRI, he spent 12 years at the Kentucky Center for Energy Research (currently the UK Center for Applied Energy Research), where he held a number of technical positions, including Program Manager for Clean Coal Research. Bland was also Technical Director of Ash Management Engineering, a consulting company servicing the power industry related to ash handling and reuse technologies. Bland holds a Ph.D. in Geochemistry from the University of Kentucky in 1978 and a M.Sc. in Geochemistry from the University of North Carolina Chapel Hill in 1972.

**Philip Smith**  
University of Utah

Professor Philip J. Smith is the director of the Institute for Clean and Secure Energy (ICSE), a multidisciplinary research program for understanding the technical, policy and environmental issues for clean coal energy production and utilization.

He is a professor of Chemical Engineering at the University of Utah.

He is also the chair of the American Flame Research Committee (AFRC) of the International Flame Research Foundation

Prof. Smith has been responsible for the hydrocarbon fire simulation aspects of CSafe, the Center for the Simulation of Accidental Fires and Explosions, for the past 13 years. CSafe is one of five DOE funded Advanced Simulation and Comput-
ABSTRACTS:

Hydrogen Separation: Membranes, Processes and Engineering

T.F. Barton
Western Research Institute, 365 North 9th Street, Laramie, WY, 82070, tbarton@uwyo.edu

The production of hydrogen remains one of the principal goals of future coal utilization. The justification of the potential hydrogen uses has become flexible. With all the discussion of a hydrogen economy, hydrogen was to be produced to fuel our cars and run fuel cells for distributed power generation. Now with carbon sequestration the largest driving force for coal gasification, the justification has swung more towards liquid fuel production and hydrogen combustion in gas turbines. In either case, hydrogen separation is a necessary step for efficient plant operation. The cost effectiveness of hydrogen production by separation from coal derived synthesis gas depends very much on the ultimate use of the hydrogen and therefore the purity and pressure requirements for the gas.

When coal derived hydrogen was expected to be used for PEM fuel cells and hydrogen driven cars, high purity was an essential goal, and dense hydrogen membranes were thought to be the most likely method for producing that purity. A range of materials for hydrogen separation was examined, mostly at bench scale. These materials which can be 100% selective for hydrogen include Perovskite ceramics, cermets, palladium alloys and group V metals like vanadium and niobium. Other materials which can be used to separate hydrogen, but not necessarily with 100% selectivity include certain polymer species and molecular sieves. Another category of hydrogen separation includes processes like pressure swing absorption which uses cyclic loading and unloading to generate hydrogen rich gas mixtures without the requirement for leak tight membranes.

The Department of Energy has long supported hydrogen separation membrane research, including our own. Initially tested on bottled gas at bench scale, these membrane materials have advanced through modeling, compositional modification, engineering design and eventual testing in coal derived syngas containing impurities. No one material has stood out for use in all applications, pressures and impurity levels. The DOE has now begun emphasizing scale up for commercial application as the next logical step in the hydrogen separation evolution. There are technological hurdles yet to defeat.

In this presentation the author will discuss WRI’s hydrogen program which has several parallel facets: 1) bench scale testing of new hydrogen membrane materials including polymer materials and amorphous alloys 2,3 ; 2) development of a...
Coal Fired IGCC Power Plants in Wyoming

William C. Schaffers¹ and Dr. David Bell²
¹University of Wyoming, Dept. of Chemical and Petroleum Engr., wschaffe@uwyo.edu
²University of Wyoming, Dept. of Chemical and Petroleum Engr., davebell@uwyo.edu

Coal fired Integrated Gasification Combined Cycle (IGCC) power plants may become an important power source if carbon dioxide emission regulations are implemented. These plants allow for the production of a more concentrated carbon dioxide (CO₂) stream already partially pressurized. Further compression and sequestration of the CO₂ is thus more economical than with conventional pulverized coal fired power plants. In addition, it is possible to combine IGCC plants with other types of chemical or synthetic fuel plants to utilize the synthesis gas produced in the gasifier.

This study compares IGCC power plants utilizing slurry and dry fed gasifiers at various levels of CO₂ capture. The purpose is to determine how the configurations respond to the use of Powder River Basin coal. IGCC plant models of various configurations were constructed using Aspen Plus software. These models were then utilized to determine the effect of gasifier type and level of CO₂ capture on net power production. Aspen models constructed include:

- Dry and slurry fed gasifiers with:
  - 0% CO₂ capture
  - 70% CO₂ capture
  - 90+% CO₂ capture.

An additional aim of the study was to look at the effects of the above configurations on water consumption by the plants.

Water availability can play a critical role in plant location in Wyoming and other arid locations. This role is likely to become increasingly important as future demands on the state and world’s water supplies grow. As part of this evaluation, another IGCC model was added which attempted to minimize water requirements. This model replaced conventional cooling towers with air cooling and made maximum use of water recycling. Water recovery from the coal drying process as well as from flue gas was also considered.

Finally, an economic analysis was conducted on various models. The goal was to determine the effects of the different configurations on the cost of the electricity produced. Past analysis by the authors has shown up to a 30% increase in power costs for IGCC with carbon capture and sequestration over historic U.S. average electricity prices (1).

It is hoped that these IGCC plant models can be used to help evaluate the costs and benefits of plant placement in Wyoming as well as other locations with similar conditions. The models can be used to help determine which plant configuration may be the most appropriate for the given location and circumstances based upon water availability, water costs and current CO₂ emissions requirements. In addition, the models can be further customized to fit specific cases and evaluate unique requirements of given sites or situations.

WRITECoaT™ Gasification of Low-Rank Coals for Improved Advanced Clean Coal Gasifier Design

A. Bland1, J. Newcomer2, T. Zhang3, K.M. Sellakumar3, M. Roberts4 and R. Keeth5
1Western Research Institute; email:abland@uwyo.edu
2Western Research Institute;
3 Etaa Energy, Inc;
4 Gas Technology Institute;
5 URS

Western high-moisture coal-based gasification technologies must address specific issues such as priority emissions control, low cycle efficiencies, high costs due to coal quality, site elevation and more recently CO2 capture and storage (CCS). Integrated gasification combined cycle (IGCC) with CO2 capture, appears to be one of the leading options for new coal-based power plants in that they can produce energy at higher efficiencies and at reduced CO2 emissions per MWh. The use of western coal is at an efficiency disadvantage both from low heating value (high moisture) and plant siting elevation. As such, western low-rank coal use is hampered by (1) plant efficiency, (2) environmental performance, and (3) overall IGCC costs.

With the support of the State of Wyoming SER Clean Coal Technology Program, the United States Department of Energy, National Energy Technology Laboratory, Western research Institute (WRI) has teamed with Gas Technology Institute (GTI), Etaa Energy, Inc. (EEI), and Washington Division of URS to address the development and testing of WRI’s patented process. The key objective is to evaluate the WRITECoaT™ gasification process that can overcome these disadvantages by developing an advanced gasification process designed for western low-rank coals by improving efficiency, reducing fresh water consumption, reducing emissions and making IGCC at high elevation fuel neutral.

**Key Results**

Initial reactivity tests under gasification conditions show that the WRITECoaT™-processed PRB coal takes less than half the time for near 100% carbon conversion. Typical test results at 1800F and 300psia are summarized:

- Modeling studies on the gasifier performance with WRITECoaT™ products show that desired syngas composition can be achieved. The HHV for the syngas product shown on the right is 356 Btu/scf. Cold gas efficiency with the WRITECoaT™ product was 88.2% compared to 83.1% with raw coal for O2/no steam, Bench-scale gasification tests have confirmed the laboratory-scale and modeling results.

**Prediction of Entrained Coal Gasification using Large Eddy Simulation (LES) with the Direct Quadrature Method of Moments (DQMOM)**

Jeremy N. Thornock and Philip J. Smith1
Institute for Clean and Secure Energy, The University of Utah
1corresponding author, Philip.Smith@utah.edu

There is a critical need for accurate prediction tools of large-scale entrained coal gasification. Such tools promise to aid in design and scale-up of new technologies for addressing energy efficiency, gasifier performance and carbon emissions. Tera to Peta-scale computing power has opened the opportunity for high fidelity, multi-physics/multi-scale simulation tools to be used to address a wider range of length and time scales. Presumably, increasing thus increasing accuracy and decreasing the dependency on modeling assumptions. In this work, we focus on using Large Eddy Simulation (LES) combined with the Direct Quadrature Method of Moments (DQMOM) [1] for simulating the near injector regions of coal gasification systems; and in using uncertainty quantification to provide formal uncertainty bounds on these predictions. The simulation tool, named ARCHES, produces temporally and spatially resolved data of the reacting, multiphase flow field, including the moment description and evolution of the particle number density function. ARCHES simulation results demonstrate the capture of three key particle behaviors; particle size segregation (Stokes number effects), particle clustering, and particle devolatilization. The ARCHES results are compared to laboratory scale gasification experiments through a technique called data collaboration..

The purpose of this work is to demonstrate the process of Validation and Uncertainty Quantification (V/UQ) for coal gasification using LES. That is, using ARCHES as the simulation tool, we set out to determine the uncertainty of the prediction by requiring a consistent data set formed from ARCHES simulation results and experimentally observed coal gasification studies. We narrow our experimental observations to a set of gasification results obtain by Soelberg [2] for a laboratory scale entrained-flow gasifier. Within this data set, uncertainty is defined as $ym(x) - ye \leq u$, where $ym$ is the simulation prediction as a function of input parameters $x$, $ye$ is the set of experimentally observed data and $u$ is the total uncertainty of a prediction. The process of discovering the consistent data set with the feasible parameter space has been termed ‘data collaboration’ (see Frenchlach et al. [3]) and reduces to a constrained optimization problem. Each function evaluation of our simulation tool ARCHES requires a substantial amount of computational resources. Consequently, we
utilize methods to minimize the total function evaluations by choosing them in optimum locations within x and using presumed function descriptions (surrogates) to describe ym(x). In this manner we attempt to perform as few function evaluations as necessary.

Here we demonstrate prediction uncertainty quantification by exploring uncertainty space in two important model parameters: the coal feed rate (scenario parameter) and the coal activation energy and pre-exponential factors (model parameter) pair. For the coal feed rate parameter, we assume a 50% variation in the coal feed rate. For the activation energy and pre-exponential factor pair, we chose a range of rate constants from $A = 1.314 \times 10^{13}$ and $E = 5.4 \times 10^4$ to $A = 1.606 \times 10^{13}$ to $E = 6.6 \times 10^4$. To limit the total number of function evaluations, we execute simulations at strategic points within the parameter space and fit the results with a quadratic function where the cross terms are neglected. Once the quadratic function is obtained, we then use it as a surrogate model to explore the uncertainty space. Each simulation consisted of 3.5 million cells and required roughly 60,000 CPU hours.

The resulting analysis shows the capability of LES and DQMOM to simulate a pilot-scale entrained-coal gasifier by showing predictions with uncertainty bounds quantified.


Chair: Mark Northam, Director, University of Wyoming School of Energy Resources

Eric Eddings, University of Utah
Oxy-Coal Combustion Research Activities at the University of Utah

Bo Feng, Senior Lecturer, The University of Queensland
CO₂ adsorbing material for coal-fuelled zero emission power generation

Lyman Frost, Ceramatec, Inc
Renewable Energy Storage by CO₂ Recycling

Mohammad Piri, Ph.D., University of Wyoming
Morteza Akbarabadi, Ph.D., Student, University of Wyoming
The effects of hysteresis and wetting on permanent geologic storage of carbon dioxide: An experimental study of capillary trapping and relative permeability

Biographies:

Dr. Mark Northam
Director, University of Wyoming School of Energy Resources

Mark Northam is the Director of the School of Energy Resources at the University of Wyoming. He came to the university after a year and a half with Saudi Aramco in Dhahran, Saudi Arabia where he worked
as a Research Science Consultant in the Research and Development Center. Prior to joining Saudi Aramco, Mark worked for over twenty years at Mobil and ExxonMobil. He held a variety of positions during that time, including:

- Technical Coordinator/Business Advisor in Geoscience Research at ExxonMobil
- Technology Consultant in the Office of the Chief Technology Officer for Mobil Oil Corporation
- Technology Manager for Mobil Exploration Norway, Inc.
- Manager of Tectonics and Sedimentology
- Manager of Basin Analysis
- Manager of Organic Geochemistry for Mobil R & D
- Exploration/Operations Geologist for Mobil E&P in New Orleans
- Research Scientist – Organic Geochemistry for Mobil R&D

Mark earned a Ph.D. degree in Organic Geochemistry from the University of Texas at Austin and a Bachelor of Science degree in Chemistry from Wake Forest University. He is originally from Virginia. Mark has been Director of the School of Energy resources for 3 years.

---

**Bo Feng**  
Senior Lecturer, The University of Queensland

*Qualifications:*

- PhD (Chemical Engineering), The University of Queensland, 2003
- D.Eng (Power Engineering), Huazhong University of Science and Technology (China), 1994
- BE (Power and Energy Engineering), Xi'an Jiaotong University (China), 1990

*Academic Appointment Record:*

- Senior Lecturer, School of Engineering, The University of Queensland (2004-present); Research Associate, Center for Fuel and Energy, Curtin University of Technology (2002-2003); Lecturer, National Key Laboratory of Coal Combustion, Huazhong University of Science and Technology, Wuhan, China (1994-1998); Research Assistant, Tokyo Institute of Technology, Tokyo, Japan (1995-1996)

---

**Engineering Research Field and Publication Count:**

- CO₂ control technologies for power generation systems. A range of CO₂ capture technologies are under investigation, including CO₂ adsorbing material (CAM) for zero emission power generation, CAM for post-combustion CO₂ capture and CAM for low-temperature CO₂ capture applications.

- Coal combustion and gasification. The main focus is on the mechanisms and kinetics of coal combustion and gasification under various conditions including pressurized gasification and underground coal gasification (UCG) conditions.

- Mechanisms and control of NOX and SOX. The focus is on the control strategies for NOX and SOX emitted from power generation systems.

- Combustion of dimethyl ether (DME) in diesel engines. The focus is on the control strategies for the minimization of NOX and particulate emissions from DME combustion.

**Number of refereed journal and conference publications:** 81

**Number of non-refereed journal and conference publications:** 37

**Number of technical reports:** 10

**Number of patents:** 3

---

**Lyman Frost**  
Ceramatec, Inc

*Education:*

- MSIA, Purdue University, 1970
- BS Chemistry, Clemson University, 1965

*Experience:*

Mr. Frost is currently working as an independent contractor with a number of companies. He is assisting Ceramatec, Inc with the development of high temperature...
electrolysis, fuel cells, reforming, and Fischer Tropsch technology. He is also the Chief Technology Officer for a Canadian start-up company involved in developing a new technology for production of hydrogen from refinery waste. He serves on the board of directors of several small start-up technology companies.

From 1999 – 2007, Mr. Frost was employed by the Idaho National Laboratory, a US Department of Energy laboratory. His final position at the INL was Director of Alternative Energy. Prior to the INL, Mr. Frost worked for The Babcock & Wilcox Company managing corporate research programs.

During the last year, Mr. Frost has presented papers at AIChE, the Air Force Alternative Energy Conference, the Fuel Cell Seminar, the Offshore Technology Conference, and the Oil Sands Conference.

Current Civic Activities:
• Utah Governor’s Science Advisory Council
• President, Idaho Nevada Community Development Financial Institution

Mohammad Piri, Ph.D.
University of Wyoming

Dr. Mohammad Piri is an Assistant Professor of Petroleum Engineering at the University of Wyoming. He received his PhD in Petroleum Engineering at Imperial College London in 2004. Before joining the faculty at the University of Wyoming, he worked as a postdoctoral research associate in the Department of Civil and Environmental Engineering at Princeton University. His research interests include pore-level physics of two- and three-phase flow in porous media with applications to oil and gas recovery, three-phase relative permeability (measurement and prediction), direct pore-level modeling of flow in porous media, and CO₂ sequestration and leakage. He currently leads a research group with nine graduate students and is the Associate Director of the Center for Fundamentals of Subsurface Flow at the School of Energy Resources of the University of Wyoming.

Morteza Akbarabadi, Ph.D.
Student, University of Wyoming

Morteza Akbarabadi is a PhD student of Petroleum Engineering at the University of Wyoming. He obtained his B.Sc. and M.Sc degrees both in Chemical Engineering in Iran from Ferdowsi University (2001) and Iran University of Science and Technology (2005), respectively. He was working as a researcher for Niroo Research Institute (NRI) in Iran on waste water treatment and feasibility study of coal fired power plants before joining UW. He is currently doing his dissertation under the supervision of Dr. Mohammad Piri on the measurement of flow properties relevant to sequestration of supercritical CO₂ in geologic formations.
**Abstracts:**

**Oxy-Coal Combustion Research Activities at the University of Utah**

**Eric G. Eddings, JoAnn S. Lighty, Terry A. Ring and Jost O.L. Wendt**  
Dept. of Chemical Engineering and Institute for Clean and Secure Energy, University of Utah  
Corresponding Author, eric.eddings@utah.edu

Oxy-coal combustion to facilitate carbon capture and sequestration is the focus of numerous research and development activities at university and corporate research laboratories around the world. In oxy-coal combustion, relatively pure oxygen is used to burn the coal to provide a flue gas stream that is primarily carbon dioxide and water. The water is condensed to yield a relatively pure carbon dioxide stream that can be further processed for sequestration. To control temperatures in the combustion zone, a portion of the flue gas stream, either with or without moisture, is recycled to the combustion chamber and is mixed with the oxygen to temper the combustion process. Thus, the essential difference between air- and oxy-fired combustion is the replacement of nitrogen in the combustion air with carbon dioxide to produce a synthetic “air” stream for use in the combustion process.

There is significant interest in the utilization of oxy-coal combustion for carbon capture, as it has the potential to be retrofitted to existing coal-fired utility boilers. An international workshop, sponsored by the International Energy Agency (IEA), has been held for several years, and the 1st International Oxyfuel Combustion Conference was held in the Fall of 2009 in Cottbus, Germany [1] with several hundred participants from all over the world. Over a dozen different commercial-scale demonstrations are either planned, in development or in operation, and the 30 MWth oxy-coal demonstration, sponsored by Vattenfall AB at the Schwarze Pumpe power plant, has been in operation since October of 2008.

The University of Utah has initiated a significant research effort in the area of oxy-coal combustion, and has attracted significant funding from both government and industry to address this important technology option. The research program encompasses both pulverized-coal (PC) and circulating-fluidized-bed (CFB) firing systems, and parallel efforts in experimental work and computer simulation development have been underway for several years. The modeling and experimental efforts are coupled through a hierarchical application of a formalized Validation & Verification and Uncertainty Quantification (V/VUQ) methodology.

The experimental work includes fundamental experiments to identify controlling mechanisms and to quantify kinetic rates for use in model development and application, as well as bench- and pilot-scale experimental facilities to provide opportunities for detailed model validation. A significant investment in oxy-coal firing capabilities for both PC- and CFB-fired systems has been made with industrial and government funding, including a 6000-gallon liquid oxygen storage and delivery system. Advanced optical diagnostic techniques are also being adopted for these oxy-coal firing systems to facilitate high-fidelity model validation data. The ultimate objective of this effort will be a validated simulation tool that can be utilized for the design and optimization of oxy-coal-fired boilers.

This presentation will provide an overview of the oxy-coal experimental research activities at the University of Utah, with specific highlights from individual government- and industry-sponsored programs.


**CO₂ adsorbing material for coal-fuelled zero emission power generation**

**B. Feng*, 1, W. Liu 1, G.X. Wang 2, J. Diniz da Costa 2**  
1 School of Mechanical and Mining Engineering,  
2 School of Chemical Engineering,  
The University of Queensland, Qld 4072, Australia  
* Corresponding author. Email: b.feng@uq.edu.au, Phone: 61 7 3346 9193

Zero emission power generation technologies with high efficiencies are in great demand due to the increasing public concern on global warming. Therefore in recent years some new zero emission power generation concepts have been proposed. Fig. 1 shows an example of such a system. In the system, coal is gasified in a gasifier together with a CO₂ adsorbing material (CAM). As a result, high purity hydrogen is produced which can be used in a fuel cell for electricity generation. The used CAM is regenerated in a separate reactor and CO₂ is released for storage. Such a system has a high efficiency of over 50% even after CO₂ is captured.

A key component in the concept and other concepts is CO₂ adsorbing material which is still not available commercially. Such material must meet several requirements in chemi-
The United States has significantly greater renewable energy resources (e.g., solar, wind, biomass, etc.) than can effectively be utilized by the electric grid due to the intermittent nature of the generation and remoteness of the renewable resources from large load centers. A further barrier to greater exploitation of renewable energy is that in some locales the renewable energy may be competing with very low cost generation resources.

Many countries are considering taxing CO₂ emissions, which will increase the cost of power generation methods that generate CO₂. The most common method currently considered for dealing with CO₂ emissions is the capture of the CO₂, pressurization, and then sequestration in either rock formations or saline aquifers. This is relatively costly in both capital investment and operation of the equipment. It is anticipated that separation, capture, pressurization, pumping, and sequestering of CO₂ could cost as much as $91 per ton of CO₂. Since a typical 500 MW coal-fired power plant can generate more than 500 tons of CO₂ per hour, this can significantly increase the cost of generated electricity. Also, there is the possibility that the CO₂ could escape from sequestration at some point in the future, subjecting the companies generating the CO₂ generators to a perpetual and unquantifiable liability.

An additional concern faced by the country is the cost and assured availability of transportation fuels. The United States now imports over 50% of its petroleum-based fuels. There is a strong need to develop domestic resources of transportation fuels to the maximum extent possible. If a means of storing intermittent renewable energy and off-peak nuclear energy as liquid transportation fuels could be developed, this storage would reduce imports of petroleum and refined products. The energy security of the United States would be improved.

Ceramatec is currently involved with a number of projects that have the potential to assist in solving the problems identified above. The Office of Naval Research (ONR) is currently funding a project related to co-electrolysis of steam and CO₂ to produce synthesis gas. ONR is also funding a project for development of an advanced Fischer Tropsch catalyst that increases yields in the liquid range. A United States Army project is providing experience on the integration of small power systems. Finally, funding is being provided by Wyoming on the generation of liquid fuels from Wyoming coal.
It is possible that renewable electricity can be stored in liquid transportation fuels by creating synthesis gas through co-electrolysis of steam and carbon dioxide. By using the solid oxide fuel cell materials set in conjunction with a non-carbon electric energy sources (e.g. wind, solar, etc), it is possible to generate synthesis gas (CO and H2) and oxygen from CO2 and H2O. This high temperature co-electrolysis (HTCE) process uses both thermal and electric energy inputs to electrolyze the CO2 and H2O at high thermodynamic efficiency. This is possible because the high temperature co-electrolysis reactions are endothermic, and the heat generated by resistance in the electrochemical device is chemically recuperated in the process. The synthesis gas generated from the CO2 and H2O can be converted to liquid transportation fuels via the Fischer Tropsch process. This presentation will describe the process and the results of experiments that generated both synthetic natural gas and liquid fuels. An emphasis will be placed on use of wind and solar as non-carbon sources of electricity that could be used to recycle carbon dioxide generated by coal fired power plants.

The effects of hysteresis and wetting on permanent geologic storage of carbon dioxide: An experimental study of capillary trapping and relative permeability

M. Akbarabadi1 and M. Piri1
1Department of Chemical and Petroleum Engineering, University of Wyoming, Laramie, WY 82071-2000, USA, email: mpiri@uwyo.edu

We present the results of an extensive experimental study on the effects of hysteresis and wetting on permanent capillary trapping and relative permeability of CO2/brine systems. We performed 48 unsteady-state drainage and imbibition full-recirculation flow experiments in two different sandstone rock samples, i.e., Berea and Nugget. A state-of-the-art reservoir condition core-flooding system was used to perform the tests. This system included nine cylinder Quizix pumping system that allowed a high-quality full-recirculation flow and pressure control conditions leading to a superior equilibrium maintenance between CO2 and brine. We utilized a medical CT scanner to measure in-situ saturations along the length of the samples during the flow experiments. The scanner was rotated to the horizontal orientation allowing flow tests through vertically-placed rock samples. The samples were about 3.8 cm in diameter and 15 cm long. The Berea and Nugget sandstone cores had about 20.1\% and 14.3 \% porosities and 50 and 312 mD absolute brine permeabilities, respectively. Both supercritical CO2/brine and gaseous CO2/brine fluid systems were used. We used high purity CO2 and brine with 10% NaI, 5.0% NaCl and 0.5% CaCl2 (all by weight) composition. The gaseous and supercritical CO2/brine experiments were carried out at 502 and 1595.5 psig back pressures and 20 and 55 °C, respectively. Under the above-mentioned conditions, the gaseous and supercritical CO2 have 0.081 and 0.393 gr/cm3 densities, respectively. The samples were first saturated with brine and then flooded with CO2 at different maximum flow rates. In each experiment, injection of CO2 was continued until constant pressure drop and saturation distribution along the core were reached. The drainage process was followed by a low flow rate (0.375 cm3/min) imbibition until residual CO2 saturation was achieved. Wide flow rate ranges of 0.25 to 20 cm3/min for supercritical CO2 and 0.125 to 120 cm3/min for gaseous CO2 were used to investigate the variation of irreducible brine saturation (Swirr) with maximum CO2 flow rate and variation of trapped CO2 saturation (SCO2r) with Swirr. For a given Swirr, the trapped supercritical CO2 saturation was less than that of gaseous CO2 in the same sample. This was attributed to brine being less wetting in the presence of supercritical CO2 than in the presence of gaseous CO2. The ratio of SCO2r to initial CO2 saturation (1- Swirr) was found to be much higher for low initial CO2 saturations. This means that greater fractions of injected CO2 can be permanently trapped at higher initial brine saturations. The results indicate that very promising fractions (about 50 to 70 \%) of the initial CO2 saturation can be permanently trapped. Maximum CO2 and brine relative permeabilities at the end of drainage and imbibition and also variation of brine relative permeability due to post-imbibition CO2 dissolution were also studied.
LUNCH SESSION

Director Zouli Zhu, Director of Shaanxi Provincial Development and Reform Commission, China

BIOGRAPHIES:

Zouli Zhu
Director of Shaanxi Provincial Development and Reform Commission, China

Dr. Zouli Zhu is Director of the Shaanxi Provincial Development and Reform Commission, Director of Shaanxi Provincial Western Development Office, President of the Shaanxi Equipment Manufacturing Industry Association, and Professor of Northwest University. He has worked for the Shaanxi Provincial Government since 1982. His responsibilities include: Director of Shaanxi Provincial Economic and Trade Commission Research, Director of Shaanxi Provincial Economic and Trade Commission, and Deputy Director of the Office of Economic Restructuring Committee. He is former Deputy Secretary General of CPC Shaanxi Provincial Committee. Most importantly, he manages all major projects developed in the Shaanxi Province. Today, he will speak on the development and the future of the Coal Chemical Industry in Shaanxi, China.

Wyoming and Shaanxi Provincial have a MOU to collaborate with CCS research and development in both Shaanxi and Wyoming. This collaboration is real and underway with the design of a CO2 storage demonstration in the Ordos Basin.
fuels and chemicals from coal

INVITED SESSION I

Chair: Maohoung Fan, Associate Professor of Chemical and Petroleum Engineering, University of Wyoming

John Pope, Ph.D., NDCPower
Advanced Fuel Cell Technology for Co-Production of Electric Power and Carboxylic Acids using Coal-derived Alcohols

Dr. Gerardine G. Botte and Ana-Maria Valenzuela Muniz, Ohio University
Hydrogen Production Via Coal Electrolysis

Rodolfo Monterroso University of Wyoming
Development of New Mercury Sorbents

BIOGRAPHIES:

Maohoung Fan
Associate Professor of Chemical and Petroleum Engineering, University of Wyoming

Professional Preparation: Ph.D. Environmental Engineering and Chemistry, Chinese Academy of Sciences, Beijing, 1997; Ph.D. Mechanical Engineering, Iowa State University, 2000; Ph.D. Chemical Engineering, Osaka University, Osaka, Japan, 2003

Current Professional Appointments: Associate Professor, School of Energy Resources, and Dept. of Chemical & Petroleum Engineering, University of
Wyoming; Adjunct Associate Professor, School of Civil and Environmental Engineering, Georgia Institute of Technology

Publications: He has more than 100 publications including books and journal papers. He has edited and co-edited 10 special issues for the journals of ACS, Elsevier, and ASCE.

Projects: Currently, he is leading more than $4.0M R&D and education projects in the areas of green chemical and energy production as well as environmental protection, especially those associated with the application of nanotechnology.

Synergistic Activities:

1. Taught and co-taught various courses in the areas of chemistry, chemical and environmental engineering
2. Has served as an Associated Editor, an Editorial Board Member, a Guest Editor, an Advisor Board Member, a Reader Board Member for a number of chemistry, and material, chemical and environmental engineering journals including Nature, Current Nanoscience, Chemical Engineering Journal, Journal of Separation and Purification, Journal of Physical Chemistry, Journal of Environmental Engineering, Energy & Fuels, and Critical Reviews in Environmental Science and Technology
3. Being a member for various professional societies including American Association for the Advancement of Science, American Chemical Society, and American Institute of Chemical Engineers
4. Sponsored and supervised a number of undergraduate and graduate students
5. Have a wide range of collaborations with domestic and international universities and national laboratories including Oak Ridge National Lab
6. Being a frequently invited research proposal reviewer for different entities including NSF, DOE, EPA, and AAAS

John Pope, Ph. D.
NDCPower

Dr. Gerardine G. Botte
Ohio University

Dr. Gerardine G. Botte is a professor at Ohio University in the Chemical and Biomolecular Engineering Department. She is the director of the Center for Electrochemical Engineering Research. Dr. Botte and members of her research group are working on projects in the areas of electrochemical engineering, power sources and fuel cells, numerical methods, mathematical modeling, material science, and electro-catalysis. Their research consists in the application of chemical engineering principles to study fundamental problems associated with electrochemical technologies. Current research has to do with the understanding, the development, and the design of fuel cells, hydrogen generators (from the electrolysis of unconventional domestic fuels), and advance battery systems.

Dr. Botte holds a Ph.D. in Chemical Engineering from the University of South Carolina. Before going to graduate school she worked as a process engineer for three years at a Petrochemical Company.

Dr. Botte has twenty-six publications in peer review journals, three book chapters, one granted patent and twelve pending patent applications, and over 90 presentations in international conferences (including invited speaker for the Gordon Research Conference in Electrochemistry 2008). She is the Editor in Chief of the Journal of Applied Electrochemistry. She is also the elected treasurer of the Industrial Electrochemistry and Electrochemical Engineering Division of the Electrochemical Society and an appointed member of the Honors and Awards Committee of the Electrochemical Society. Nominated by the Scientific Secretariat for an ENI 2010 award.
**Abstracts:**

**Advanced Fuel Cell Technology for Co-Production of Electric Power and Carboxylic Acids using Coal-derived Alcohols**

*D. Montgomery¹ and J. Pope²*

¹NDCPower, dmont@ndcpower.com, ²The Blue Sky Group, j pope@theblueskygroup.com

NDCPower has developed a new class of advanced alkaline fuel cell technology that converts feedstock of primary alcohols into the corresponding carboxylic acids and electric power. Carboxylic acid yield is quantitative. This technology has enabled the development of the largest direct liquid fuel cells ever produced.

Because fuel cells are not constrained by the Carnot cycle, fuel cell CHP system efficiencies can easily exceed 80% [1]. As a result, use of hydrogen and syngas produced by coal gasification in fuel cells has been discussed, but the economic models for these systems remain problematic. A new economic paradigm is described in which fuel cells are used with coal-derived syngas plants for production both of electric power and of high value industrial commodity chemicals. NDCPower’s advanced alkaline fuel cell technology is well suited to this approach to improving the economic prospects for coal-based syngas facilities.

<table>
<thead>
<tr>
<th>Coal-fired Steam Plant</th>
<th>Coal-fired Fuel Cell Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2 MWh Electric Power</td>
<td>3.3 MWh Electric Power</td>
</tr>
<tr>
<td>- Value ~$90</td>
<td>- Value ~$130</td>
</tr>
<tr>
<td>Over 2 tons of CO₂ produced</td>
<td>About 1 ton CO₂ produced</td>
</tr>
<tr>
<td>- Remaining carbon captured as carboxylic acid products</td>
<td></td>
</tr>
<tr>
<td>- All CO₂ used in processing carboxylic acids</td>
<td></td>
</tr>
<tr>
<td>- No CO₂ emitted</td>
<td></td>
</tr>
<tr>
<td>~1.4 ton of carboxylic acids produced</td>
<td>- Value $880 to $1,900</td>
</tr>
</tbody>
</table>

No CO₂ is emitted from the fuel cell power plant because it is all used beneficially in processing the carboxylic acid products. In addition to producing high value commodity chemicals as a by-product, NDCPower advanced alkaline fuel cells have attractive reliability and cost features. The installed cost of the fuel cell power system is expected to be comparable to the cost of conventional steam turbines on a per kilowatt basis.

---

**Ana-Maria Valenzuela Muniz**
Ohio University

Dr. Ana Valenzuela-Muniz is a postdoctoral researcher associate in the Center for Electrochemical Engineering Research (CEER) at Ohio University.

Dr. Valenzuela-Muniz holds a Ph.D. in Material Science from the Advanced Materials Research Center (CIMAV, S.C.) in Mexico. She worked in synthesis and characterization of nanostructured catalyst for fuel cells during the graduate studies. She joined the CEER one year ago and is working in the development of new technologies for the electrochemical production of hydrogen.

---

**Rodolfo Monterroso**
University of Wyoming

He was born in Guatemala in 1984; He graduated in 2007 of B.S. in Chemical Engineering at Universidad Del Valle of Guatemala. He worked for Colgate and Kimberly Clark in his native country. In 2008 he started working on a Master’s program in Chemical Engineering at the University of Wyoming and has been working since then on the development of new cost-effective mercury sorbents. As part of the research, a literature review was performed and it will be published as a chapter of the book called “Coal gasification technology”. He is currently working on the development of new Thief carbon based sorbents. His interests include soccer, swimming and literature. In 2008 he published a fiction book called “Laberinto Indefinido” (“Undefined Labyrinth”) in Guatemala.
Use of advanced alkaline fuel cells for co-production of electric power and carboxylic acid products offer the following desirable features:

- Revenue stream from high value commodity chemicals significantly improves NPV and ROI
- No carbon dioxide emissions
- Capital costs comparable with steam turbine power systems
- Scalable from small local to large regional utility power
- Instant turn on/off for facile load balancing


---

Hydrogen Production Via Coal Electrolysis

Ana M. Valenzuela-Muñiz, Michael Prudich and Gerardine G. Botte

Center for Electrochemical Engineering Research, Chemical and Biomolecular Engineering Department
Russ College of Engineering and Technology, Ohio University, Athens, OH 45701 valenzue@ohio.edu

Clean technologies for the production of hydrogen and liquid fuels from coal are very important for national security purposes and preservation of the environment. When using coal gasification, in order to produce a hydrogen product, the hydrogen must be removed from a mixture that includes carbon monoxide, carbon dioxide, hydrogen sulfide, particulates, and other gases. Additionally, carbon dioxide needs to be captured and sequestered from the gas stream to reduce the emissions of this gas to the environment. These separations become an extremely complex and costly consideration.

The use of coal electrolysis to produce hydrogen from coal was proposed many years ago [1], but research work in this area was largely abandoned at that time. Using electrolysis, coal molecules can be broken down into smaller fragments producing hydrogen, carbon dioxide, liquid products, and char. The gas separation problems inherent in conversion processes based on conventional coal gasification are avoided because the hydrogen and the carbon dioxide are produced at different locations in the electrolytic cell. Recently, the extensive research in this area, performed at Ohio University, has improved the efficiency of this low temperature, low pressure hydrogen production process. Process parameters such as the effect of catalyst, electrode design [2] and working temperature [3], have been tested to optimize coal utilization, energy usage, and hydrogen production.

This presentation will describe preliminary results obtained from the electrolytic gasification of a subbituminous Wyoming coal (Wyodak). Hydrogen yields versus process conditions (temperature and energy input) will be reported. Additionally, initial results on the production of liquid products will be discussed.

Development of New Mercury Sorbents

Rodolfo Abraham Monterrozo, Maohong Fan, Morris D. Argyle
1 Department of Chemical and Petroleum Engineering, University of Wyoming, Wyoming, 82070, USA
2 Department of Chemical Engineering, Brigham Young University, Utah, 84602, USA

Mercury emissions will be regulated in the United States through the Environmental Protection Agency’s Clean Air Mercury Rule, which starts with the first phase-cap in 2010 and ends with a final cap set in 2018, resulting in nearly 70% reductions from 1999 emission levels. Different techniques have been studied in order to obtain cost-effective mercury removal, including use of sorbents, catalysts, scrubbing liquors, flue gas or coal additives, combustion modifications, and chemical reaction.

In this study, the elemental mercury adsorption performance of commercially produced Thief carbon and Thief carbon modified with ferric chloride and sodium chloride was evaluated. Thief carbon mainly consists of partially combusted coal, which is extracted from furnaces of power plants. The sorption tests indicated that the surface modification enhanced the mercury adsorption capacity of Thief carbon, as shown in Figure 1, although it decreased the surface area relative to the raw Thief carbon.

For the highest surface area (326 m²/g) raw Thief carbon, modification with ferric chloride and sodium chloride decreased its surface area to 202 m²/g and 98 m²/g, respectively. The sorption capacities of Thief carbon modified with ferric chloride and sodium chloride reach 206 and 108 6g-Hg/g-sorbent, respectively, which are much higher than 216g- Hg/g-sorbent achieved with raw Thief carbon. Ferric chloride impregnated Thief carbon has the highest sorption capacity. Therefore, modification of Thief carbon is a viable procedure to produce high capacity Hg sorbents with low costs. The sorption mechanisms were studied with SEM and XPS. The analyses showed differences between the Hg sorption mechanisms of the different sorbents, which result from the modification of Thief carbon. Specifically, a combination of physical and chemical adsorption was detected for modified Thief carbon, while only physical adsorption was involved with the raw Thief carbon-based Hg sorption. The modified Thief carbon sorbents could provide a cost-effective solution for removal of mercury because they can be produced in situ, they possess high mercury sorption capacities, and they are inexpensive compared to activated carbon and other conventional sorbent materials.

Figure 1. Effect of surface area on the different tested sorbents.
Chair: Bo Feng, Senior Lecturer, School of Mechanical and Mining Engineering, UQ

Ron Surdam, Wyoming State Geological Survey
The key to commercial-scale geological CO₂ sequestration: Displaced fluid management

Dr. Alan Bland, Western Research Institute
A Novel Integrated Oxy-Combustion and Flue Gas Purification Technology: A Near-Zero Emissions Pathway

Hollis Weber, University of Wyoming
Direct Mineralization of Carbon Dioxide from Coal Combustion Flue Gas

Ying Li, University of Wyoming
Effect of Co on promoting Ru₃Co₅/Al₂O₃ based catalytic water gas shift reaction

BIOGRAPHIES:

Bo Feng
Senior Lecturer, School of Mechanical and Mining Engineering, UQ

Qualifications:
PhD (Chemical Engineering), The University of Queensland, 2003
D.Eng (Power Engineering), Huazhong University of Science and Technology (China), 1994
Ron Surdam
Wyoming State Geological Survey

Ronald C. Surdam and co-authors have published 220 articles in refereed scientific journals and books. He has presented more than 200 invited lectures, and he and his students have given more than 180 presentations at scientific meetings, nationally and internationally. In 32 years at the University of Wyoming, Surdam raised $32 million in research support. While at UW, he founded and directed the Institute for Energy Research and directed the Enhanced Oil Recovery Institute. Surdam has consulted for many international energy and mineral exploration corporations; this work along with his tenure at UW has given him extensive experience with energy issues and research around the world. Over the past 44 years, Surdam has focused on oil and gas exploration, oil shale and trona depositional systems, and coal and zeolite deposits in the Rocky Mountain Laramide basins of Wyoming and other states. He has served the State of Wyoming in numerous capacities, most recently as Director of the Wyoming State Geological Survey. Currently, Surdam is helping lead the effort to accomplish commercial geological CO2 sequestration in the Rocky Mountain region.

Education and Training:
University of California, Los Angeles
A.B. Geology, 1961
University of California, Los Angeles
Ph.D. Geology, 1967
State of Wyoming Professional Geologist, Registration Number PG-1546

Research and Professional Experience:
Instructor of Geology, University of Wyoming (1966–1967); Assistant Professor of Geology, University of Wyoming (1967–1969); Associate Professor of Geology, University of Wyoming (1969–1973); Professor of Geology, University of Wyoming (1973–1998); Professor Emeritus, University of Wyoming (1998–present); Director, University of Wyoming Institute for Energy Research (1993–1998); I.E. Warren Professorship of Energy and the Environment (1994–1998); Director, University of Wyoming Enhanced Oil Recovery Institute (1997–1998); Consultant to University of Wyoming (1998–2000); President, Innovative Discovery Technologies, LLC (2000–2004); Honorary Professor, Nanjing University, Nanjing, China (2002–present); Director, Wyoming State Geological Survey (2004–2010); Member, Wyoming Oil and Gas Conservation Commission (2004–2010); Member, EORI Commission (2004–2010); Honorary Professor, Northwest University, Xian, China (2009–present); Senior Advisor, Shaanxi Provincial Institute of Energy and Chemical Engineering (2009–present); Director, Wyoming Carbon Sequestration Commission (2009–2010); Director, Carbon Management Institute, UW School of Energy Resources (2010–present)

Highlights:
National Science Foundation Geology/Geochemistry Advisory Panel member (1980–1983); Invited to address the Royal Society of London (1984); American Association of Petroleum Geologists Distinguished Lecturer (1985–1986); American Chemical Society Advisory Panel member (1988–1993); Elected a Fellow in the Geological Society of America (1989); Associated Editor, Bulletin of the Geological Society of America (1989); U.S. Continental Scientific Drilling and Review Group member (1990); Don R. and Patricia Boyd Distinguished Lecturer in Petroleum Exploration, University of Texas, Austin (1990); University of Wyoming President’s Achievement Award (1992); Outstanding Merit in Research, College of Arts and Sciences, University of Wyoming (1992); J.E. Warren Professorship of Energy and the Environment, University of Wyoming (1994); 1995–1996 AAPG Roy M. Huffington International Distinguished Lecturer

Dr. Alan Bland
Vice President, Western Research Institute

Alan Bland is a Vice President at Western Research Institute in Laramie, Wyoming. He joined WRI in 1991 and has served in several technical and program management positions. As Vice President he is WRI's lead for waste and environmental management science and technology R&D that addresses gaseous emissions, water recovery and reuse issues of clean energy generation and the environmental processes related to energy production. Currently, he is heading the development of WRI's WRITECoal™ coal upgrading technologies in advanced coal-based oxy-combustion and gasification systems. He is also heading water management and treatment options for the power sector and system analysis and techno-economic evaluations of emerging environmental processes and clean fuel technologies, funded by the SER under the Wyoming Clean Coal Technology Program, the United States Department of Energy and industry.

Prior to joining WRI, he spent 12 years at the Kentucky Center for Energy Research (currently the UK Center for Applied Energy Research), where he held a number of technical positions, including Program Manager for Clean Coal Research. Bland was also Technical Director of Ash Management Engineering, a consulting company servicing the power industry related to ash handling and reuse technologies. Bland holds a Ph.D. in Geochemistry from the University of Kentucky in 1978 and a M.Sc. in Geochemistry from the University of North Carolina Chapel Hill in 1972.

Hollis Weber
University of Wyoming

Hollis received his Bachelor of Science from Upper Iowa University in environmental science and is currently pursuing his Master’s degree in Renewable Resources under the guidance of Dr. KJ Reddy at the University of Wyoming.

Ying Li
University of Wyoming
ABSTRACTS:

The key to commercial-scale geological CO₂ sequestration: Displaced fluid management

Ronald C. Surdam¹ Zunsheng Jiao¹
Philip Stauffer² Terry Miller²
¹ Wyoming State Geological Survey
² Los Alamos National Laboratory

The Paleozoic Tensleep/Weber and Madison Limestone (and stratigraphic equivalent units) are the leading clastic and carbonate reservoir candidates for commercial-scale geological CO₂ sequestration in Wyoming. This conclusion was based on unit thickness, overlying low permeability lithofacies, reservoir storage and continuity properties, regional distribution patterns, formation fluid chemistry characteristics, and preliminary fluid-flow modeling. This inventory also identified the Rock Springs Uplift in southwestern Wyoming as the most promising geological CO₂ sequestration site in Wyoming and probably in any Rocky Mountain basin. This ranking for the Rock Springs Uplift was based on the following attributes:

• Presence of a thick saline aquifer sequence (~ 750 feet of Weber Sandstone and 400 feet of Madison Limestone) overlain by a thick sequence of sealing lithologies
• A double-plunging anticline with more than 10,000 feet of closed structural relief
• Huge structural element (50 × 35 miles)
• The targeted reservoir units (Weber Sandstone and Madison Limestone) have characteristics required for CO₂ sequestration, including fluid chemistry, porosity, fluid-flow attributes, burial history (i.e., relatively recent basin inversion resulting in sufficient temperature and pressure at depths between 6,000 to 10,000 feet)

The results of the WSGS CO₂ geological sequestration inventory led the agency to collect all available geological, petrophysical, geochemical, and geophysical data on the Rock Springs Uplift, and to build a regional 3-D geologic framework model of the Uplift. From the results of these tasks and using the FutureGen protocol, the WSGS showed that on the Rock Springs Uplift, the Weber Sandstone has sufficient pore space to sequester 18 billion tons (Gt) of CO₂, and the Madison Limestone has sufficient pore space to sequester 8 Gt of CO₂.

In cooperation with the Los Alamos National Laboratory (LANL), the WSGS geologic databases were combined with numerical models to improve estimates of the CO₂ sequestration potential of the Rock Springs Uplift. The WSGS 3-D geologic model constructed with EarthVision® software was gridded using LaGrit software. Shallow and deep sequestration sites on the Rock Springs Uplift have been evaluated using the LANL CO₂-PENS software.

A variety of CO₂ performance assessment scenarios for Rock Springs Uplift have been evaluated using the LANL numerical simulator (FEHM).

The results of this research are significant in the global effort to accomplish substantial commercial-scale CO₂ sequestration. For example, one evaluated scenario is the sequestration of 15 million tons (Mt) of CO₂ per year for 50 years in a nine-point injector pattern within a 16 km × 16 km (10 mile × 10 mile) area on the Rock Springs Uplift. These parameters were chosen because the Jim Bridger power plant (2,200 MW) is located on the Uplift and emits 18 Mt of CO₂ per year. The modeled nine-point injection pattern was located near the power plant on the east flank of the RSU. The nine simulated injection wells, each injecting 1.7 Mt of CO₂ per year, were spaced approximately one mile apart. For the commercial-scale sequestration scenario, no fluid flow was allowed down-dip and the initial pressure up-dip was specified as below fracture pressure. After 50 years of injection, the CO₂ plumes around the injection wells just barely impinged on one another. All of the CO₂ (750 Mt) was contained within the 16 km × 16 km storage area. Moreover, the modeling in this scenario demonstrates that once injection stops, the pressure buildup in the individual injection wells decreases to near initial pressure in 25 years.

The most critical problem in this geological CO₂ sequestration simulation is the relationship between the volume of injected CO₂ and the displaced fluid that must leave the storage area. In the example cited above, 750 Mt of CO₂ is sequestered in the storage domain and 1 cubic kilometer of fluid must leave the domain over a 75-year period (50 years of CO₂ injection and 25 years post-injection). The key questions are as follows: Can the accommodation space be found within the geologic site to accept this huge volume of fluid that must leave the storage domain? If so, given the heterogeneity of most geological settings (fluid-flow compartmentalization), can fluid migration pathways be maintained so the displaced fluid can migrate from the storage domain to some external accommodation space without disrupting the confining units and destroying the integrity of the rock/fluid system?

These preliminary numerical simulations of commercial-scale geological CO₂ sequestration on the Rock Springs Uplift strongly suggest that displaced fluids resulting from subsurface CO₂ injection must be managed. To solve this problem, the WSGS proposes a strategy that includes integration of fluid production/water treatment with injection of CO₂. Using this strategy, 750 Mt of CO₂ can be injected and sequestered in the 16 km × 16 km storage domain over a 50-year period, and the 1 cubic kilometer of fluid produced from the structure can be treated at the surface.
A Novel Integrated Oxy-Combustion and Flue Gas Purification Technology: A Near-Zero Emissions Pathway


1 Vice President, Western Research Institute; email:abland@uwyo.edu
2 Western Research Institute; 3 Etaa Energy, Inc;
4 Foster Wheeler, 5 Southern Research Institute

Retrofitting the existing fleet of Powder River Basin (PRB) coal-fired plants to meet carbon emissions control can have significant impacts on cost of electricity (COE). Current post combustion carbon capture, such as monoethanolamine (MEA) process, increases the COE by over 80%. In addition, conventional retrofitting of existing plants with oxy-combustion results in higher COE as a result of the large parasitic power associated with oxygen production.

Western Research Institute, with funding from the State of Wyoming SER Clean Coal technology Program and the United States Department of Energy, National Energy Technology Laboratory, has teamed with Southern Research Institute (SRI), Foster Wheeler North America, Praxair, Etaa Energy, Nalco and URS to conduct the technology development. The project brings together a novel coal upgrading technology (WRITECoal™) with advanced oxy-fired burner design and novel CO₂ flue gas purification technology in an oxy-combustion integrated system. The project objectives are to confirm at a 1MWth scale an integrated WRITECoal™ upgrading/oxy-combustion system with 90% carbon capture at less than 35% COE.

Scope of Work
A three-Phase 30-month effort is in progress with completion in 2012.

Phase I (Tasks 1-4) - project planning; integrated system optimization, design, acquisition and installation of integrated system components and selection, preparation and characterization of test coals;

Phase II (Tasks 5-6) – integrated system testing at 1 MWth scale to achieve desired gas purity; and

Phase III (Task 7) – the final design and costing of an integrated oxy-combustion system at 550MWhe(net) commercial scale, its impact on parasitic power and boiler efficiency, plant costs, costs of electricity and costs of CO₂ capture and purification.

Progress To-date
An in-house–designed mobile WRITECoal™ process unit has been constructed. It can process nominally 350-500 pph of raw Wyoming PRB coal (1MWth equivalent of product). In addition, the gas purification system equipment has been specified and is being engineered.

Based on ASPEN Plus modeling and mass and energy balances for each subsystem, the integrated WRITECoal™ process has been shown to be capable of generating approximately a 6.3% increase in power output from a retrofitted plant with only a 2% increase in coal input.

The integrated system yields a net increase power of 34 MW for a 570 MWe (net) plant. Although still preliminary, the testing shows favorable trends towards WRI’s initial performance goals of 90% carbon capture with <35% increase in COE. Additional tasks address integration into a 1MWth oxy-fired pilot plant at SRI.
Effect of Co on promoting Ru₅Co₇/Al₂O₃ based catalytic water gas shift reaction

Ying Li¹, Zhijian Mei¹, Maohong Fan¹*, Morris Argyle²

¹ Department of Chemical and Petroleum Engineering, University of Wyoming, Wyoming, 82070, USA,
² Department of Chemical Engineering, Brigham Young University, Utah, 84602, USA
*Corresponding author. E-mail address: mfan@uwyo.edu

The promoting effect of Co on Ru/Al₂O₃ based catalytic water-gas shift reaction (WGSR) was studied. Several Ru₅Co₇/Al₂O₃ catalysts were prepared using impregnation and characterized with XRD, BET, TPR-H₂, TPR-CO, and SEM methods. The effects of various parameters, such as calcination temperature, total RuCo loading, Ru/Co ratio, CO concentration, and H₂O/CO ratio on the activity of these catalysts were studied. The experimental results show that addition of Co can considerably improve the catalytic activities of Ru/Al₂O₃'s. The RuCo/Al₂O₃ calcined at 350 can achieve 98.6% CO conversion and the highest total conversion exceeds the thermodynamic equilibrium limit of the WGSR alone due to the co-occurring methanation reaction. Kinetic studies show that the RuCo/Al₂O₃ calcined at 350 could reduce the apparent activation energy (Ea) of WGS to 37.8 kJ/mol, the apparent activation energy of the reverse WGSR accelerated with the same catalyst is 74.6 kJ/mol, and the difference between two Ea values corresponds well to the calculated enthalpy change of the WGSR (-41.1 kJ/mol).

Keyword: WGS, Ru, Co, H₂
Chair: Bob Ballard, University of Wyoming, Project Manager for High Plains Gasification – Advanced Technology Center

Kevin Whitty, University of Utah
Initial Experience with a 500 kWth Pressurized Entrained Flow Coal Gasifier

Alex Klimenko, SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland
Utilization of Unmined Coal – Centennial of the Invention

Karl Libsch, P.E., Principal Engineer, Emery Energy Company
Emery Energy’s Pilot Gasifier for PRB Coal and Coal/Biomass Blends

Adel Sarofim, University of Utah
Chemical Looping With Copper Oxide as Carrier

BIographies:

Bob Ballard
University of Wyoming, Project Manager for High Plains Gasification – Advanced Technology Center
Bob Ballard came to the University of Wyoming with over 35 years of electrical power development, engineering and construction experi-
ence with nearly 20 years in nuclear power and 15 years in international fossil and renewable power project development. He has successfully completed power and energy projects throughout the US and in Poland, Turkey, Italy, Egypt, Tunisia, Oman and India.

After receiving his BS in Mechanical Engineering at Virginia Tech, Bob entered the Army where he tested weapons and weapon systems at the Army’s Test and Evaluation Command. As a young 1st Lieutenant he was responsible for testing small arms, aircraft weapons and the weapons on the Army’s first armored air cushion vehicles. He joined Westinghouse Nuclear Energy Systems and throughout the ‘70s worked in Quality Engineering, Nuclear Safety & Licensing and NSSS Projects. While working at Westinghouse, Bob completed an MBA attending night school at the Katz Graduate School of Business Administration of the University of Pittsburgh.

In early 1979, he was recruited to join Gibbs & Hill, a noted nuclear and fossil architect-engineer in NYC. He joined the firm as a Senior Project Engineer and rose to Director of Power Projects by his departure in 1988. His largest project was as design Project Manager for a two unit 2300 MWe nuclear power plant, Comanche Peak near Fort Worth, TX.

Since 1990 Bob has worked for various Architect-Engineers (Nuclear Energy Services, Kuljian Corp., & Parsons Brinckerhoff); OEM/Contractors (Alstom Power & Conti Corp.); and Power Project Developers (Community Energy Alternatives, Alternity Wind Power and NRG Energy) always in the forefront of international power project development and construction. His experience spans nuclear, coal, natural gas, biomass, gasification, oil, hydro, solar and wind projects.

Bob is currently working for the University of Wyoming as Project Director of the High Plains Gasification - Advanced Technology Center, a sub-Bituminous coal gasification research facility, in conjunction with GE Energy. The Joint Development & Implementation Agreement was signed in October 2008, and the facility will be commissioned in late 2013.

Kevin Whitty  
University of Utah

Kevin Whitty is an associate professor in the Department of Chemical Engineering at the University of Utah and a member of the university’s Institute for Clean and Secure Energy. Dr. Whitty has nearly 20 years’ experience working with advanced thermochemical conversion technologies, especially gasification, for fossil and renewable fuels. He received his B.Sc. in Chemical Engineering from Oregon State University (1990) and his Master’s (1993) and Ph.D. (1998) from Åbo Akademi University in Turku, Finland. Prior to joining the University of Utah, Dr. Whitty spent three years supervising R&D and pilot activities for Chemrec’s entrained-flow black liquor gasification process in Stockholm, Sweden. During the nine years he has been at the University of Utah, he has established Gasification Research Group and gasification research facility housing two small pilot-scale reactors at the university’s Industrial Combustion and Gasification Research Facility. Dr. Whitty is currently PI of several government- and industry-funded projects and advisor for seven graduate students.

Alex Klimenko  
SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland


is Reader in Fluid Mechanics and Thermodynamics at the School of Mechanical and Mining Engineering, The University of Queensland. A.Y.Klimenko held a number of senior visiting positions at Cornell University, Stanford University, Karlsruhe University and University of Wyoming. He is an author of more than 100 publications in the areas of reacting/adsorbing flows, gasification, vortical dynamics and engineering education, and served as an editor on a number of publications, including Category Editor (gasification) of new Wiley Encyclopedia of Energy and a Regional Editor for Open Thermodynamics Journal. A.Y.Klimenko has provided his expertise to several major companies and government departments.

A.Y.Klimenko has made an outstanding contribution to Engineering Science. He and his group at The University of Queensland have developed a series of novel approaches (CME, MMC, PCMC, IDFE, ASF) that are used and recognized worldwide, suggested theories explaining the key processes utilized in underground gasification of coals and pioneered study of abstract competitive systems. His work has resulted in dramatic (thousandfold) decrease in computational cost of high-quality simulations of turbulent reacting flows.

Karl Libsch, P.E.  
Emery Energy Company

Functions as both the Lead Process Engineer and Manager of Projects. Karl has over 35 years of technical and managerial experience in both the U.S. and overseas in chemical and metallurgical process industries. His experience includes development and operation of pyrometallurgical and chemical processes, facility engineering and project management, and hazardous waste environmental compliance. He is a licensed Professional Engineer.
Adel Sarofim
University of Utah

Adel F. Sarofim is Presidential Professor and Associate Director of the Institute of Clean and Secure Energy at the University of Utah and Senior Technical Advisor to Reaction Engineering International in Salt Lake City. He was affiliated with MIT from 1958-1996, most recently as Lamont du Pont Professor of Chemical Engineering at MIT from 1989-1996, Emeritus from October 1, 1996. Dr. Sarofim has published over 200 papers with recent emphasis on the clean and efficient utilization of coal. He received the Sir Alfred Egerton Gold Medal from the Combustion Institute in 1984; the U.S. Department of Energy’s 1996 Homer H. Lowry Award in Fossil Energy, and an honorary doctorate in chemical engineering from the University of Naples “Federico II” in 1998. He was elected to the National Academy of Engineering in 2003.

ABSTRACTS:

Initial Experience with a 500 kWth Pressurized Entrained Flow Coal Gasifier

K.J. Whitty, T. Waind and D. Wagner
Institute for Clean and Secure Energy, University of Utah, Salt Lake City, Utah 84112

Interest and investment in coal gasification technology has grown significantly in recent years. Most of the gasifiers used and planned for IGCC applications are pressurized, oxygen-blown, entrained flow systems from suppliers such as GE, ConocoPhillips and Siemens. Despite the surge of interest in the technology, the processes that take place in pressurized entrained coal flow gasifiers are still not well understood. Hundreds of lab-scale studies have been performed in recent decades, but almost no detailed information has been published regarding performance of pilot or full-scale systems.

The University of Utah recently commissioned a small-scale, pressurized, oxygen-blown coal gasifier (Fig. 1) as part of a larger effort aimed at improving the understanding of, and developing simulation tools for, entrained-flow gasifiers. The gasifier has a maximum operating pressure of 450 psig (32 bara) and is rated for 150 lb/hr coal (~500 kWth) at maximum pressure. Operation to date has been limited to 100 psi pressure. So far, the system performs well and is able to generate syngas representative of syngas from an industrial entrained-flow gasifier.

The gasifier is a slurry-fed system capable of processing slurry concentrations of at least 60% coal by weight. Performance has been found to be very sensitive to the configuration of the injector, which is a two-stream design that uses oxygen to atomize the slurry. The prototype injector was designed to be adjustable so that the oxygen pressure drop/velocity could be changed during operation. With a relatively large oxygen injection annulus (~2 mm), atomization was poor enough that the temperatures in the gasifier were “reversed” with the bottom of the gasifier being the hottest. Syngas quality was poor, with low concentrations of CO and H2, suggesting that much of the fuel was not being converted. As this
gap was tightened, the temperature in the top of the reactor increased and the syngas quality improved. The optimum oxygen annulus has been found to be roughly 0.4 mm, which provides a pressure drop of about 40 psi across the injector. With this configuration, performance is stable and syngas quality is good.

Major species in the syngas (H2, CO, CO2 and CH4) are continuously monitored through a combination of thermal conductivity and IR-based analyzers.

Additionally a process micro-GC measures the concentrations of 17 gas species about once every three minutes. Fig. 2 shows a typical progression of syngas composition over the course of one hour as the system was approaching steady state.

This presentation describes experience to date with the entrained-flow gasifier, including startup, operation, analysis and overall performance. Future plans and acquisition of data for validation of the simulation tools being developed at the University of Utah will also be discussed.

Utilization of Unmined Coal – Centennial of the Invention

A.Y. Klimenko1, 2
1 Dept. of Mechanical Eng., University of Wyoming; aklimenk@uwyo.edu
2 permanent address: Div. of Mechanical Eng. The University of Queensland; klimenko@mech.uq.edu.au

In 1910, three patents dedicated to utilization of unmined coal were issued by patenting authorities in US, Canada and UK [1]. The inventor and applicant on these patents was American chemical engineer and graduate of the Yale University Anson G. Betts, who is best known for his pioneering book on producing lead by electrolysis [2]. Anson Betts was born in 1876 into a prominent family of early settlers of upstate New-York. His grandfather Henry Betts is credited with several inventions in printing and steel making. His father and brother were successful industrialists. During early years of his career, Anson Betts lived with his parents and made a number of patented inventions. Later in his life, he ran a chemical engineering business and moved extensively around the country but returned to his native Northeast USA during the years of Great Depression. He died in 1976, only few years after the major American UCG (underground coal gasification) program was opened in 1972.

The three patents by Betts are very similar in contents with one essential difference, the earlier US and Canadian patents refer to a general idea of utilization of unmined coal while the UK patent excludes coal bed methane (CBM) recovery and claims only improvement to utilization of unmined coal through underground gasification. In the UK patent, Betts noted that the idea of utilizing CBM has been proposed but did not give any specific reference. The author of this presentation has conducted a search but was not able to find any patented documents that may have been implicitly referred to by Betts.

Although the idea of gasifying coal underground was previously mentioned in general terms by notable German-born British engineer William Siemens and by the famous Russian chemist Dimitri Mendeleev, it was Betts who gave a detailed description of the UCG process, which constitutes an invention and looks remarkably relevant even today. Ideas of Betts can be found in the UCG experiment planned by prominent British chemist William Ramsay and in first successful Soviet UCG trials [3]. It also seems that the Betts patents have even wider significance – they represent the first known mention in patented documents of the ideas of using coal without conventionally mining it. These ideas are effectively utilized in UCG, CBM recovery, CO2 storage in coal seams and other applications. The technologies that were initially developed and advanced in numerous UCG trials of 1950s (horizontal directional drilling, hydro-fracturing,
combustion linking and drilling, electro-linking, etc) are now widely used by the world’s leading companies in many other areas of advanced resource exploration.

Historically, the key role of Anson G. Betts in inventing the utilization of unmined coal in general and UCG in particular was overshadowed by more prominent figures of Siemens, Mendeleev and especially by that of Ramsay. While Ramsay was repeatedly referred to as inventor of UCG, historic evidence does not support this thesis [3] and he can be credited only with making UCG widely known and with planning the first UCG trial. We use this opportunity to correct the historic inaccuracy and celebrate the centennial of one of the most prominent inventions of 20th century -- utilization of unmined coal. The presentation will focus on both technological and historical issues associated with this invention.


---

**Emery Energy’s Pilot Gasifier for PRB Coal and Coal/Biomass Blends**

B.D. Phillips¹ and K.D. Libsch²
¹Emery Energy Company, 159 Pierpont Avenue, Salt Lake City, Utah 84101, bphillips@emeryenergy.com
²Emery Energy Company, 159 Pierpont Avenue, Salt Lake City, Utah 84101, klibsch@emeryenergy.com

Emery Energy Company (Emery) is currently constructing a 10 ton/day pilot-scale gasifier system at the Western Research Institute (WRI) in Laramie, Wyoming. Funding support for the project is provided by: 1) Emery Energy Company, 2) the State of Wyoming Clean Coal Technology Fund, 3) U.S. DOE National Energy Technology Laboratory (NETL, via the Western Research Institute Cooperative Agreement DE-FC08NT43293) and 4) U.S. DOE Energy Efficiency & Renewable Energy (EERE) Biomass Program. Under the State of Wyoming contract, the pilot gasifier unit will be used to evaluate Emery’s industrial-scale gasifier for use with PRB coals and coal/biomass blends. The Emery hybrid gasifier configuration integrates both updraft and downdraft fixed-bed principles while optionally enabling the recirculation and/or partial oxidation of pyrolysis gases to minimize tar products in the raw syngas. Additionally, a separate tar reforming technology will be tested downstream of the gasifier and supplied by Ceramatec, Inc. of Salt Lake City.

The gasifier will be commissioned by August of this year and ready for testing in September. Planned operations include multiple 100 hour baseline runs in order to validate basic heat/mass balances. Subsequently, Emery and WRI will conduct longer extended runs, including coal/biomass blends, to evaluate system reliability and feedstock blending capabilities.

The plant will initially operate with oxygen and steam to produce a nitrogen free raw synthesis gas necessary for analysis and testing as a synthesis feedstock. Air-blown tests will also be considered in the future. Subsequent to the operations, data will be used to complete feasibility and modeling studies (using Aspen-PlusTM) to evaluate scale-up opportunities and carbon reduction/capture methods in a number of power, fuels and chemical production configurations. This work will be used to prepare the technology for near-term commercial applications for various market segments. Emery plans to pursue multiple commercial market applications including:

- Mid-scale IGCC (i.e. 50 to 200MWe)
- Chemical production (methanol, fertilizer, other chemicals)
- Hydrogen and/or Substitute Natural Gas
- Liquid Fuels via synthesis (fischer tropsch, alcohols, etc.)

Separately, and under a contract with the U.S. DOE EERE Biomass Program, Emery will also be testing 100% dedicated biomass feedstocks (i.e. wood) to produce biomass derived syngas to test tar removal and impurity removal systems for liquid biofuels production via a downstream mixed-alcohol reactor system owned by WRI.

---

![3-D Model of the Emery Energy Gasifier System](image-url)
Chemical Looping With Copper Oxide As Carrier

R. Baraki, E. Eyring, G. Konya, J. Lighty, A. Sahir, A. Sarofim1, K. Whitty
Institute for Clean and Secure Energy, University of Utah, Salt Lake City, UT 84112
1A. Sarofim, email: sarofim@mit.edu

Introduction: The cycling of copper oxide for the production of CO₂ from solid carbonaceous fuels was first proposed by Lewis and Gilliland in 1954. They identified that in the fuel reactor the contribution to the gasification of carbon by the decomposition of CuO “could be very large.” Independently, Lyngfelt and coworkers discovered the importance of this char gasification reaction for chemical looping, which they defined as chemical looping with oxygen uncoupling (CLOU) to distinguish it from conventional chemical looping combustion (CLC). They proposed that in the fuel reactor coupled reactions occur such as the endothermic dissociation 4CuO = 2Cu₂O + O₂ and the exothermic reaction C + O₂ = CO₂ to provide the net reaction 4CuO + C = 2Cu₂O + CO₂ [3]. The Cu₂O is transported to the air reactor where it is oxidized to CuO, which is then recycled to the fuel reactor. The current study provides an assessment of this process with emphasis on the determination of the 1. temperature range over which unsupported Cu₂O and CuO can be used, 2. circulation rate of the oxygen carrier, 3. the amounts of oxygen carrier in the fuel and air reactor, and 4. the carbon loading in the fuel reactor.

Conceptual Design of a CLOU Reactor: The chemical kinetics of the oxidation and decomposition of the oxygen carrier are being studied using a TGA. These experiments have shown that, during decomposition, the CuO can be completely converted to Cu₂O and, during oxidation, the Cu₂O the oxidation can be completely converted to CuO, providing complete utilization of the theoretical oxygen carrier capacity of 10% by weight of the CuO. Kinetics were determined for both the oxidation and decomposition reactions. The decomposition reactions increase monotonically with temperature, but operation above 950 °C is undesirable as it may lead to agglomeration of the oxide particles. A temperature of 950°C is therefore selected for the operation of the fuel reactor in which the oxygen released by the CuO reacts with the carbonaceous fuel. The oxidation reactions show a peak at 850°C as a consequence of complex grain boundary diffusion through the CuO layer formed around the Cu₃O as it oxidizes. This identifies 850°C as an optimum temperature for the operation of the oxidation (or air) reactor. The kinetics for the CuO and Cu₃O were utilized in a simulation of a CLOU system for carbon oxidation. Rates of circulation of the oxygen carrier and the amount of oxygen carrier needed in the fuel and air reactor were calculated using a well stirred approximation for the air and fuel reactor.

The circulation rate of the oxygen carrier is selected so that the difference between the oxygen flux to and from the fuel reactor is equal to the oxygen demand of the carbon. The oxygen carrier loadings are determined by the circulation rate of the oxygen carrier and the time required to decompose the CuO in the fuel reactor and to oxidize the Cu₂O in the air reactor. The summary of the calculations are provided in Fig. 1. The presentation will discuss how the values were obtained and the advantages of CLOU over CLC.

Fig. 1 Material and Energy Flows for Chemical Looping With Oxygen Uncoupling
Chair: KJ Reddy, Professor Renewable Resources – UW

Richard Baraki, University of Utah
*Copper Functioning as an Oxygen Carrier in Chemical Looping Combustion*

Maciej Radosz, University of Wyoming
*Carbon Filter Process for Separating CO₂ from Power-Plant Flue Gas*

Dmitry Saulov, The University of Queensland
*Adsorption Thermodynamics in the Framework of Modified Associate Formalism*

Peter Sallans, Liberty Resources Limited
*Choosing the Best Coals in the Best Locations for Underground Coal Gasification*

BIOGRAPHIES:

K.J. Reddy
Professor Renewable Resources – UW

Professor Reddy developed and taught interdisciplinary courses focused on energy and agriculture production and sustainability of natural resources (e.g., air quality and water quality). He is best known for his work on "Mineral Carbonation Process" to store anthropogenic carbon dioxide (CO₂) in industrial solid wastes. He has made original contributions
like proposing an effective and simple technique to accelerate the otherwise slow mineral carbonation process of industrial residues using CO₂. This work has stimulated a number of subsequent studies by other groups of scientists and engineers around the world. Currently, his research group is demonstrating the feasibility of one-step simultaneous capture and mineralization of flue gas CO₂ at a coal-fired power plant using accelerated mineral carbonation process. Professor Reddy is also well known for his innovative and ecologically effective arsenic filtration method, and for his research work on water quality and beneficial uses of coalbed natural gas (CBNG) produced water. He authored (or co-authored) over 310 technical publications and numerous national and international presentations. He advised several post-doctoral, graduate, and undergraduate students. His present research group members include 2 post-doctoral students, 5 graduate students and several undergraduates. Some of Professor Reddy’s awards and honors include: George Duke Humphrey Distinguished Faculty Award (highest UW Faculty honor), John Elbogen Meritorious Classroom Teaching Award, 2008 (highest UW teaching award), Outstanding Educator-Of-The-Year Award (2006), Lawrence Meeboer Teaching Award (2003), and Outstanding Master’s Thesis Advising Award 2007, 2006, 2004, and 2003. Professor Reddy is a founding member of the Council for Energy Research and Education Leaders (CEREL), and a member of the Energy Education Steering Committee (EES), National Council for Science and Environment (NCSE), Washington, DC.

Richard Baraki
University of Utah

Richard Baraki is a research assistant under the guidance of Professor Edward M. Eyring (Department of Chemistry), his area of study is focused on the kinetics of various oxygen carriers used in Chemical Looping Combustion, namely copper and nickel. Richard is a Masters candidate in the Department of Chemical Engineering at the University of Utah. He completed his Bachelors of Science degree in Chemistry from the University of Utah. Richard participates in weekly activities to encourage and motivate high school and junior high students to explore the world of science and engineering. With his free time he likes to play backgammon and chess.

Maciej Radosz
University of Wyoming

Prof. Radosz joined UW in 2000 as Professor and Department Head of Chemical and Petroleum Engineering. He came from Louisiana State University where he was a Distinguished Professor and Gauvreau Endowed Chair in Chemical Engineering and Adjunct Professor of Chemistry. Following his PhD from Cracow University of Technology and two postdoc assignments, in Norway and at Purdue University, Prof. Radosz spent 15 years with ExxonMobil’s Engineering and Corporate Research Science Laboratories in New Jersey. While there, he also served as Visiting Professor at Rutgers University and a member of PhD committees at Princeton, Lehigh, Cornell and Johns Hopkins Universities. Prof. Radosz is co-author of 2 books, several patents, and over 200 peer-reviewed publications that generated over 4,000 citations. He has led numerous research projects for government and industrial organizations, many of which have been commercialized. Prof. Radosz served as an Editor of Fluid Phase Equilibria, a member of four editorial boards (Fluid Phase Equilibria, Journal of Chemical and Engineering Data, Industrial and Engineering Chemistry Research, and Recent Patents on Engineering), and Distinguished Lecturer for the Japan Society for the Promotion of Science. Prof. Radosz is a Fellow of American Institute of Chemical Engineers.

Dmitry Saulov
The University of Queensland

Dmitry Saulov, Ph.D., M.Eng./Sci., is a researcher at the School of Mechanical and Mining Engineering, The University of Queensland. He is working in the research group headed by A.Y.Klimenko. The group developed a series of novel approaches and suggested theories explaining the key processes utilized in underground gasification of coals. Dmitry Saulov specializes in thermodynamic modeling of complex solution phase relevant to coal utilization processes.

Peter Sallans
General Manager UCG, Liberty Resources Ltd

Peter started his career as a research economist at Flinders University (Australia), and progressed to safety and environmental risk management consulting and senior management roles in the construction and resources industries, including at Olympic Dam – the world’s largest underground uranium and copper mine.

Peter has considerable experience in the coal bed methane and coal exploration industry, and during the rapid growth in Australia’s coal bed methane industry, Peter variously had responsibility for commercial development, oil and gas operations, and risk management at Mitchell Energy. With the
emergence of UCG in Australia, Peter contracted the provision of consulting and drilling services for Carbon Energy’s Bloodwood Creek UCG pilot, as well as exploration and directional drilling services for Linc’s UCG pilot program and the initial exploration and production drilling for Cougar Energy ahead of their Kingaroy UCG project. He has since been passionately involved in UCG, designing of underground gasification chambers based upon CBM directional drilling methods, evaluating prospective UCG projects in Australia and overseas, developing risk management procedures for UCG.

ABSTRACTS:

Copper Functioning as an Oxygen Carrier in Chemical Looping Combustion

R. Baraki¹, G. Konya², E. Eyring², A. Sarofim³
¹Department of Chemical Engineering, University of Utah, richard.baraki@utah.edu
²Department of Chemistry, University of Utah
³Institute for Clean and Secure Energy, University of Utah, Salt Lake City, UT 84112

Chemical looping combustion (CLC) is a technology utilizing metal/metal oxide systems as oxygen carrying materials. In the air reactor the metal is oxidized with air. The metal oxide is transferred into the fuel reactor, providing the oxygen for the combustion. The metal is transported back to the air reactor; and the cycle repeats.

After the removal of the water, the pure CO₂ can be processed or sequestered. Using copper and its oxides as the oxygen carrying material(s) opens the way to an interesting variant of the CLC, termed chemical looping with oxygen uncoupling (CLOU). The CuO produced in the air reactor can spontaneously decompose to Cu₂O, releasing oxygen under “fuel conditions”.

Laboratory experiments were conducted by thermogravimetric analysis (TGA), using neat (unsupported) materials. The “looping” – according to equation (3) – was simulated by changing the atmosphere over the sample from air to N₂, repeatedly. The observed weight changes suggest a complete reaction according to equation (3). The solid samples were sintered, but the “looping” was still carried out successfully under isothermal conditions, for up to 200+ cycles.

The initial analysis of the data followed the methodology already published. The first order kinetics (3, to the left) and the corresponding pseudo first order kinetics (3, to the right) were found to be reasonable approximations. The analysis of the discrepancies of the measured data and the fitted data revealed systematic deviations.

The – limited – observations under elevated pressures clearly indicate that the pseudo first order model (3, to the right) is not correct.

A detailed picture of our observations – temperature, pressure – will be presented.
Carbon Filter Process for Separating CO2 from Power-Plant Flue Gas: Steam-Aided-Vacuum Sorbent Regeneration for Retrofit Applications

Maciej Radosz (Speaker), Kaspars Krutkramelis, Bryce Dutcher, Hertanto Adidharma
Soft Materials Laboratory, Department of Chemical and Petroleum Engineering, University of Wyoming
radosz@uwyo.edu

A Carbon Filter Process (CFP) captures CO2 on a carbonaceous sorbent that requires no compression or refrigeration. Such a sorbent is CO2-phlic and hence uniquely selective at near ambient temperatures, easy to keep at constant sorption temperature, and easy to regenerate, because its heat of sorption is low. CFP allows for flexible recovery (up to at least 90%) and flexible purity (up to at least 95%). This technology has been scaled-up for pilot tests at two coal-fired power plants in summer 2010, one at Pacificorp’s Jim Bridger Power Plant in Wyoming and one at Xcel’s Pawnee Power Plant in Colorado. These tests are funded by the State of Wyoming’s Clean Coal Program, Electric Power Research Institute, Pacificorp Energy, and Excel Energy. This talk will focus on a new approach to sorbent regeneration, namely, a steam-aided-vacuum regeneration. The steam-aided-vacuum regeneration is a hybrid approach where CO2 is recovered under mild vacuum alone followed by cold steam purge under vacuum as well. The principal advantage of this method is no need for deep vacuum, which is costly, and no need for heating and cooling the sorbent, which is energy intensive and time consuming. Preliminary technical and economic data are reported in reference.


Adsorption Thermodynamics in the Framework of Modified Associate Formalism

D.N. Saulov 1, *, and A.Y. Klimenko 1
1School of Mechanical and Mining Engineering, The University of Queensland, Australia
* Corresponding author, email: d.saulov@uq.edu.au

Underground storage of carbon dioxide is one of the prominent options of reducing its release in the atmosphere in order to tackle the problem of climate change. CO2 injection into coal seams also enhances the recovery of Coal Base Methane (CBM). This, in turn, reduces the overall cost of carbon storage and maximizes resource utilization. Since gas species are present in coal mainly in adsorbed state, accurate modeling of adsorption of gas mixtures on coal is of a particular importance for development of advanced technologies of both CO2 sequestration and enhanced CBM recovery.

A new thermodynamic model of adsorption of gas mixtures is suggested. The proposed model is based on the Vacancy Solution Theory (VST) pioneered by Bering and Serpinskii [1], where the surface phase is treated as a chemical solution of several adsorbates and vacancies. VST has been used in many studies to describe adsorption processes on various adsorbents for wide ranges of temperature and pressure. It has also been demonstrated that several currently used adsorption models (adsorption isotherms) can be derived from VST.

It is well understood that the quality of the isotherm derived from VST drastically depends on the quality of the solution model used to describe the surface phase. In the proposed adsorption model the recently suggested Modified Associate Formalism (MAF) [2] is used to model the surface solution. MAF is capable of taking into account strong and complex (multi-particle) interactions between mixing species in a thermodynamically and mathematically consistent way. At the same time, MAF correctly reduces to the ideal solution model in the case of zero Gibbs free energy of mixing. Advantages of MAF over other models currently used to describe solution phases with strong interactions between mixing particles have been demonstrated [3]. MAF utilizes the expression for configurational entropy which is thermodynamically correct and free from the entropy paradox. The adjustable parameters used have clear physical meaning, while providing sufficient flexibility for fitting experimental data. The model is applicable to the entire compositional range, which is of particular importance for modeling high loading regimes. Ability to model multicomponent adsorption is an integral part of the proposed model. The advantages of MAF provide a potential for development of the adsorption model of high quality.

In order to develop integrated models of the processes of CO2 storage and enhanced CBM recovery, the thermodynamic model of adsorption needs to be coupled with a comprehensive model of transport in porous media with volume reactions in the fluid phase and surface reactions at the fluid/solid interface. Since coal is characterized by
Choosing the Best Coals in the Best Locations For Underground Coal Gasification

P. Sallans¹, A. Haythorpe²

¹, ² Liberty Resources Limited, Australia
Corresponding Author: psallans@libertyresources.com.au

Underground coal gasification (UCG) is being promoted as an economically viable and environmentally responsible method of energy production from deep and stranded coals. While there are developing UCG technologies, it is necessary to better understand how and where those technologies might be profitably utilized. This paper examines important issues impacting upon the viability of UCG in particular locations, and demonstrates that UCG projects will only be successful where key selection criteria are met, and where rigorous environmental risk management standards are maintained.

This paper examines UCG selection criteria in the context of technological, economic, and environmental considerations, and demonstrates the importance of maintaining the highest standards for the design, construction, and operation of gasification chambers to ensure energy conversion efficiency and long term containment and management of pollutants. Matters impacting upon the viability of UCG prospects, including regulatory framework, surface land uses, valued aquifers, lithology, hydrogeology, faulting, depth of coals, coal chemistry, seam thickness, access to markets, and opportunities for CO₂ sequestration are addressed as important selection criteria.

The range of coals amenable to UCG is dependent upon economic considerations including UCG chamber construction costs, energy produced per chamber, surface plant costs, proximity to markets, and energy prices. While it is true that thin seams and extremely deep seams can be gasified, economic modeling is used to demonstrate that the depth and thickness of coal seams, along with coal quality, are critical determinants of the economic viability of any specific project. Coal prospects in Queensland, Wyoming, Alberta, and Hungary are discussed as examples of the different coals, circumstances, and challenges which arise for an emerging international UCG industry.


ACKNOWLEDGEMENTS

Advanced Coal Conference Steering Committee
Rob Ettema, Dean, College of Engineering and Applied Science, University of Wyoming
Rob Hurless, Energy and Telecom Advisor, Office of the Governor, State of Wyoming
Bob Jensen, CEO, Wyoming Business Council
John Morris, Director, Future Technologies, Queensland Mines and Energy Department of Employment, Economic, Development and Innovation, Queensland Government
Mark Northam, Director, School of Energy Resources, University of Wyoming
Victor Rudolph, Professor, School of Chemical Engineering, University of Queensland
Graham Schaffer, Dean, Faculty of Engineering, Architecture & Information Technology, University of Queensland
Gary Stiegel, Director, Major Projects Division, Office of Major Demonstrations, U.S. Department of Energy, National Energy Technology Laboratory
Jenny Tennant, Technology Manager, Gasification, Office of Coal and Power R&D, National Energy Technology Laboratory, US Department of Energy

Abstract Reviewers and Editors
Maohoung Fan, Associate Professor of Chemical and Petroleum Engineering, University of Wyoming
Alex Klimenko, SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland
Gus Plumb, Director of Clean Coal Technologies, University of Wyoming
Ron Surdam, Wyoming State Geologist / Director of Carbon Management, University of Wyoming
Yaun Zheng, Assistant Professor of Mechanical Engineering, University of Wyoming

Session Chairs
Bob Ballard, University of Wyoming, Project Manager for High Plains Gasification – Advanced Technology Center
Rob Ettema, Dean, University of Wyoming College of Engineering and Applied Sciences
Maohoung Fan, Associate Professor of Chemical and Petroleum Engineering, University of Wyoming
Bo Feng, Senior Lecturer, School of Mechanical and Mining Engineering, UQ
Bob Jensen, CEO Wyoming Business Council
John Jiao, Chief Geologist, Geology Program Manager, Wyoming Geologic Survey
Alex Klimenko, SER Visiting Professor, University of Wyoming and Reader in Mechanical Engineering, The University of Queensland

We’d like to express our sincere thanks to our invited presenters as well as our abstract presenters. We appreciate your commitment to your profession and to the Advanced Coal Conference.

Special Thanks to:
UW School of Energy Resources Linden
Em-Powered – Emily Sorenson
Kelly Garvey
Scott Nelson
WyoCast - Boulware
PSAV - Caleb Hebbert
Laramie Hilton Garden Inn