Welcome and Introduction
Lynn Orr

GCEP Advanced Coal Workshop
Provo, UT
The Grand Challenge

Needs
- Growth in world population to 9 billion from 6 billion, of which 2 billion people currently have no access to modern energy systems
- Improved standard of living in growing economies of developing world
- Increased demands for energy, food, land, and materials.

Component Challenges
- Water supply
- Agricultural systems (strongly linked to water supply)
- Energy (with possible limits on CO$_2$ emission)

Protection, Restoration, and Improvement of the Planetary Biogeochemical Systems
Global Geochemical History

Concentrations of GHGs have risen significantly over the preindustrial levels.

Source: IPCC Third Assessment Report, 2001
Atmospheric CO$_2$ Concentration
- Last Glacial Maximum to Present

Adapted from: http://www.climate.unibe.ch/gallery_co2.html
The oceans have taken up ~400 Gt of fossil fuel CO$_2$. Global surface oceans now remove 20-25 Mt CO$_2$/day.

Decline in pH (0.1 since industrial revolution) affects bicarbonate, carbonate ion concentrations, rates of fixation of CaCO$_3$ by assorted critters in the trophic chain, potential for feedbacks with temperature change.  

Source: Oceanography Vol.17, No.3, Sept. 2004
The Need for Technology

Assumed Advances In:
- Fossil Fuels
- Energy intensity
- Nuclear
- Renewables

Gap Technologies:
- Carbon capture & disposal
  - Adv. fossil
- H₂ and Adv. Transportation
- Biotechnologies
  - Soils, Bioenergy, Adv. Biological Energy

Source: J. Edmonds, PNNL
GCEP Approach

- Focus on potential energy technologies that could be game-changing with respect to greenhouse gas emissions
- Encourage high risk/high reward research
- Apply within a portfolio of technical areas
- Address questions appropriate to pre-commercial research that may have an impact in the 10-50 year timeframe
- Use the best research talent available
- Make all data, results, and other information generated from the project open and available to all
- Involve institutions from developing countries with potential high levels of future greenhouse gas emissions
Step-Out Technology

Scientific Advance to Enable Development of a Game-changing Technology in Reduced Time

Continuing Slow Progress Via Business-As-Usual

Game-changing Technology in Reduced Time

Technology Challenge

Previous Incremental Development

Step back to fundamentals

Step-out Idea

Technology Option

Progress

Time

Present Time
Portfolio Areas

• GCEP portfolio currently includes 11 technical areas:

- Advanced transportation systems
- Electric power generation, storage, distribution
- Hydrogen production, distribution, and use
- Advanced coal utilization
- Energy distribution systems and enabling infrastructures
- Geoengineering
- Advanced nuclear power technologies
- Renewable energy sources (wind, solar, biomass, geothermal)
- CO₂ separation, capture, and storage
- Combustion science and engineering
- Advanced materials

• Portfolio development and maintenance is supported by thorough assessment and analysis efforts
Exergy Flow of Planet Earth (TW)

Current Global Exergy Usage Rate ~ 15 TW (0.5 ZJ per year)

80900/15 = 5400

Source: W. Hermann, GCEP Systems Analysis Group 2004. (1 ZJ = 10^{21} J)
Summary of Progress to Date

- GCEP agreement signed between Stanford University and Sponsors on February 21, 2003
- 22 research projects in five technical areas are either underway or being initiated at Stanford and five outside institutions
- Total awards are ~$42.5M out to 2007
- Examined five topics in three technical areas through assessments and workshops
  - Hydrogen
  - Carbon Capture and Separation
  - Wind
  - Solar
  - Biomass
Figure 2.1: World Primary Energy Demand

### India, China, & the USA in 2002
(with world rankings)

<table>
<thead>
<tr>
<th></th>
<th>India</th>
<th>China</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population, millions</td>
<td>1050 (2)</td>
<td>1280 (1)</td>
<td>288 (3)</td>
</tr>
<tr>
<td>GDP, trillion 2002$ (ppp)</td>
<td>3.1 (3)</td>
<td>5.4 (2)</td>
<td>10.4 (1)</td>
</tr>
<tr>
<td>Total energy use, EJ</td>
<td>26 (4)</td>
<td>55 (2)</td>
<td>105 (1)</td>
</tr>
<tr>
<td>Coal consumption, EJ</td>
<td>8 (3)</td>
<td>30 (1)</td>
<td>25 (2)</td>
</tr>
<tr>
<td>Oil imports (net), EJ</td>
<td>3.3 (9)</td>
<td>3.6 (8)</td>
<td>23 (1)</td>
</tr>
<tr>
<td>Electricity generation, TWh</td>
<td>580 (5)</td>
<td>1650 (2)</td>
<td>4050 (1)</td>
</tr>
<tr>
<td>Electricity from coal, TWh</td>
<td>480 (3)</td>
<td>1200 (2)</td>
<td>2000 (1)</td>
</tr>
<tr>
<td>C emitted in CO₂, MtC</td>
<td>265 (5)</td>
<td>900 (2)</td>
<td>1640 (1)</td>
</tr>
</tbody>
</table>

*Source: John Holdren, US-India Energy R&D Workshop, New Delhi, August, 2004*
United States CO₂ Emissions in 2000

Millions of metric tons per year carbon equivalent

Natural Gas
Petroleum
Coal

Residential: ~7%
Commercial: ~4%
Industrial: 14%
Transportation: 32%
Electric Generation: 42%

Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2002
Research Questions Concerning Advanced Coal Technologies

- What are the technological barriers and challenges to coal utilization with reduced greenhouse emissions and other environmental impacts?
- Which key technologies, if developed, could change the game for future coal use in both the developed and developing world?
- What are the research opportunities for developing these technologies?
- How can GCEP best contribute to solving these problems and expanding the opportunities and benefits?
Thank You!

- **Larry Baxter and Reggie Mitchell**
  - for selecting the topics and bringing this group together

- **BYU**
  - for hosting this meeting

- **Emilie Hung**
  - for working hard to arrange this meeting

- **Kersti Miller and Nancy Sandoval**
  - for organizing everything else!

- **Our Sponsors**
  - for making this project possible

- **Our Speakers**
  - for sharing your time, expertise, and opinions with us

- **The Energy Community**
  - for taking time to participate in our discussions
Welcome and Introduction
8:30  GCEP Introduction and Workshop Purpose  Lynn Orr
9:00  Coal Utilization and Overview  Stephen Gehl

Gasification and IGCC  Chair: Douglas Smoot
9:30  Overview of Gasification Technologies  Gary Stiegel
10:00 Break
10:15  Producer Gas Products  Eric van de Venter
10:45  Gasification Design Issues  Neville Holt
11:15  Panel Discussion
11:45  Lunch

Oxy-Fuel Combustion  Chair: Philip Smith
12:45  Oxy-Fuel Combustion in the GHG Context  Rajender Parshad Gupta
1:15  Large Scale Oxy-Fuel Systems: The Role of Laboratory Combustor Research  Jost Wendt
1:45  CO₂ Reduction by Oxy-Fuel Combustion: Economics and Opportunities  Sho Kobayashi
2:15  Break

Fuels and Fundamentals  Chair: Reginald Mitchell
2:30  Relationships Between Particle Chemistry and Decomposition Products  Thomas Fletcher
3:00  Review of Condensed-Phase Reaction Kinetics  Stephen Niksa
3:30  Panel Discussion

China Perspectives Panel  Zhongyang Luo and Ni Weidou
5:00  Reception
### Workshop Agenda - Day 2

#### Liquid Fuels  Chair: Ronald Pugmire

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
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</thead>
<tbody>
<tr>
<td>8:30</td>
<td>System Analysis of Liquid Fuels from Coal and Biomass with CCS</td>
<td>Robert Williams</td>
</tr>
<tr>
<td>9:00</td>
<td>Coal and Liquid Fuels</td>
<td>Richard Bajura</td>
</tr>
<tr>
<td>9:30</td>
<td>Break</td>
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<tr>
<td>9:45</td>
<td>Direct Coal Liquefaction: Lessons Learned</td>
<td>Ripudaman Malhotra</td>
</tr>
<tr>
<td>10:15</td>
<td>Biological Utilization of CO, H2, and CO2</td>
<td>Randy Lewis</td>
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<tr>
<td>10:45</td>
<td>Panel Discussion</td>
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<tr>
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<td>Lunch</td>
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#### Co-Firing  Chair: Dale Tree

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<tr>
<td>12:15</td>
<td>Co-Firing Switch Grass</td>
<td>Gary Walling</td>
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<tr>
<td>12:45</td>
<td>Attractions and challenges in Co-Firing</td>
<td>Larry Baxter</td>
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<tr>
<td>1:15</td>
<td>Biomass Co-Firing—Technology, Barriers and Experiences in Europe</td>
<td>Gerrit Brem</td>
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<tr>
<td>1:45</td>
<td>Panel Discussion</td>
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### Closing Remarks