Global Trends in Coal-to-Power

Dr. Michael Karmis
Stonie Barker Professor, Department of Mining and Minerals Engineering &
Director, Virginia Center for Coal and Energy Research
Virginia Tech

The World Bank, SDN Week
“Sustainable and Inclusive Globalization”
Session 8 - Clean Coal: From Mine to Boiler to Market
February 22, 2008, Washington, DC
What we will discuss:

- Coal and Global Energy Trend
- Coal Production and Utilization
  - Upstream Issues
  - Downstream Challenges
- The Status of CCS in Carbon Management
- A Technology Perspective
- A Sectoral Planning Approach

References: A number of references were used to develop this presentation. A reference list can be provided by the author on request.
What will not discuss:

- Comprehensive Energy Planning
  - Conservation
  - Efficiency
  - Renewable
  - Education/Cultural
- Energy Investment Needs/Strategies
- Policy and Regulatory Solutions or Interventions

“Economic development and poverty eradication depend on secure, affordable energy supplies”

Robert Priddle, Executive Director, International Energy Agency
World Summit on Sustainable Development, September, 2002

Map of Global Energy Poverty

1.6 billion people have no access to electricity, 80% of them in South Asia and sub-Saharan Africa

Electricity Deprivation

In 2030, if no new policies are implemented, there will still be 1.4 billion people without electricity
• World energy consumption will increase by almost 60% between 2007 and 2030

• Energy use in the non-OECD region is projected to surpass the OECD region by 2010 and to be 35% greater in 2030
The Role of Coal

- Coal provides 25% of global primary energy needs and generates 40% of the world's electricity
- Total Hard Coal Production: 2006e, 5370Mt an 8.8 % increase over 2005; 92% past 25 years
- Total Brown Coal/Lignite Production: 2006e, 914Mt an 0.9% increase over 2005
Coal’s share of total world energy use is projected to climb to 28% in 2030 (notwithstanding government policies aimed at reducing coal use).

- USA, China, and India are well-positioned to displace more expensive fuels with coal and the three nations together account for 86% of the expected increase from 2004 to 2030.
• Worldwide, electricity generation in 2030 is projected to total 30,364 billion kWh, nearly double the 2004 generation.

• The strongest growth in net electricity consumption is projected for the non-OECD region, averaging 3.5% per year in the IEO2007 reference case.

In 2004, coal-fired generation accounted for 41% of world electricity supply; in 2030, its share is projected to be 45%.
What about the USA?
EIA, Annual Energy Outlook 2008 (Early Release)

- The generation coal share in the US declines slightly from 49% in 2006 to 48% in 2017, before increasing to 55% in 2030.
- Additions to coal-fired generating capacity in the AEO2008 reference case total 130 gigawatts from 2006 to 2030 including:
  - 9 GW at CTL plants
  - 45 GW at integrated gasification combined-cycle (IGCC) plants
- The reference case projects a 44% increase in coal production from 2005 to 2030, whereas the alternative cases show increases ranging from as little as 15% to as much as 65%
• In 2004, non-OECD emissions of CO2 were greater than OECD emissions for the first time

• In 2030, CO2 emissions from the non-OECD countries are projected to exceed those from the OECD countries by 57%

• Coal’s share in 2004 was the same as in 1990, at 39%

• Its share is projected to increase to 43% in 2030
2. Coal Production and Utilization
The Coal Fuel Cycle (with USA Scales)

Source: Coal Research and Development, NRC, 2007
2.1 Upstream Issues

Reserves
Extraction
Preparation
Transportation

Health & Safety

Social

Human Resources

Environment
Coal Mines of the Future

- Increasing capacity: expanding mines v. new mines
- The mines of the future will be more challenging:
  - deeper underground mines
  - multi-seam environments
  - potentially higher gas content
  - more complex surface mines
  - advanced coal preparation processes
  - monitoring, sensing and remote control
  - coal (energy?) complex/campus
  - aging workforce/new workers
- Implications for mine worker health and safety, environmental protection/reclamation and mine productivity
(a). Reserves
Proved coal reserves at end 2006

Countries Reporting the Largest “Proved Recoverable” Coal Reserves (NRC, 2007)
According to the *Coal Research and Development (NRC, 2007)* study:

“It is possible to undertake the academic exercise of dividing the worldwide proved recoverable reserves by the total world coal production for the same year, to obtain about 188 years of production. Although correct mathematically, this number is of little value because it suffers from the same inconsistencies and deficiencies in input parameters as the equivalent calculations for the United States. Like the United States, the world has vast amounts of coal resources, and like the United States, a clear picture of global coal reserves is difficult to ascertain. In part, this is due to strategic concerns about revealing information on domestic energy resources, absence of governmental recognition of the importance of such information, the lack of trained personnel or funding to carry such studies, and differences in methodology and terminology.”

A coordinated initiative is required to provide a comprehensive accounting of coal reserves.
(b) Extraction: Optimize Resource Recovery

- Development of advanced technologies can present opportunities to recover marginal coal reserves.
- Advanced mining technologies aimed at reducing mine hazards (e.g., continuous monitoring, remote control) have also the potential to increase production and productivity.
- The global transfer of coal mining and processing technology is mainly facilitated by equipment manufacturers working with mining clients on product developments.
- Limited technologies transfer from outside the mining industry, due to the small market of the coal sector for technology suppliers and the lack of coal-related R&D funding at academic institutions and laboratories.
- Minimal government or industry support (possibly with the exception of Australia) devoted to research and development of upstream issues and practices that are necessary to optimize coal production.
(c). Preparation

- Small (often relative inexpensive) improvements in coal preparation can result to significant benefits:
  - Recoverable coal reserves
  - Coal transportation
  - Utility performance
  - Emission reductions
  - Reduction on other pollutant

- Need to encourage developing countries to utilize coal preparation to limit emissions of sulfur and particulates

"Consistent and proper quality coal is the best tool to improve plant operating performance and reduce PM and SO2 emissions. Removal of some of the coal ash (includes rocks) at the mine is more economic than in the pulverizer, boiler, precipitator and scrubber." Doherty, AEP, 2006 (presentation to the Asia Pacific Partnership)
(d). Transportation

- Rail transportation depends on supply and demand, prevailing business practices, the investment climate and regulatory oversight.
- Transportation depends on construction and maintenance of infrastructure and port facilities.
- There is a need to better understand and manage the complex transportation and transmission networks to minimize the risks of cascading system disruptions.

By rail or by wire?

Figure 59. Coal Imports by Major Importing Region, 1995-2030

[Graph showing coal imports by region with projections for 2020 and 2030.]
(i). Improved Mine Worker Health and Safety

- Cultivate a “total safety culture”
- Promote behavior-based safety approaches
- Explore “risk management” concepts
- Reduce exposure of mine workers to hazardous conditions and improve training of workforce
- Expand use of remote sensing and the automation of mining operations

Improve:
- Methane control, mine ventilation, roof control escape and rescue procedures, communications

Reduce:
- Repetitive and traumatic injuries, respiratory diseases, risk of explosions and fires
(ii). Environmental Protection

Mitigate the adverse environmental impacts associated with past, current and future coal mining and processing

- Areas of concern include:
  - Collapse of strata and subsidence over mined areas
  - Hydrological impacts
  - Mine mapping and void detection
  - Waste management
  - Stability of spoils on steep slopes
  - Reclamation and post-mine land use
  - Stability and monitoring of impoundments
  - Noise and dust
  - Use of water
(iii). Human Resources Crisis

- Coalmine workforce size and demographics have changed substantially, coinciding with increased production from surface mines and increased productivity from both surface and underground mines.

- Average age of coalminers, at least in OECD countries, is alarming (50 years!) emphasizing that the industry will have to attract new miners in addition to replacing the retiring pool.

- Similar trend in the entire energy sector, so intense competition for skilled workers.

- Companies that value employ development and have established supportive employee structures will succeed.

- Severe shortage of technical personnel in the minerals disciplines, exacerbated by the current and projected increases in coal and mineral resources production.

- Declining funding for academic support and research in mining engineering has reduced globally the academic programs in the field.

- Significant impact in the recruitment, retention, and development of faculty in mining-related disciplines.

Where are the miners (and the Professors!)?
(iv). The Social Component

- Need to accelerate the transition to sustainable development by the coal industry and supporting community.
- Transparency in identifying and engaging stakeholders and ensure their interest/participation over time is critical.
- Sector participation in on-going global efforts directed towards reporting initiatives and SD indicators.
- Important to develop frameworks for evaluating individual projects in the context of local, regional and national scales.
- Planning must be factored into the development of processes defining the sustainability impacts of coal production, post-mining land and ecosystem restoration.
- Develop project roadmap that identifies how coal production and reclamation activities fit within the framework of sustainability.
2.2 Downstream Issues

- Downstream issues and environmental challenge comprises of three core elements:
  - Improving combustion technologies to increase efficiency and to reduce carbon dioxide and other emissions
  - Eliminating emissions of pollutants such as particulates, oxides of sulphur and nitrogen
  - Reducing carbon dioxide emissions with the development of carbon capture and storage

- Alternative fuels/chemicals from coal require processes such as liquefaction and gasification that must also be assessed on the basis of downstream impacts.
Coal Power Generation: More Efficiency and CCS

The average efficiency of coal power plants is between 26-39%. Over 1.7 GT CO₂ could be saved each year by raising this to 40%.

© OECD/IEA 2008
Emerging Carbon Capture Technologies

Pre-Combustion: IGCC

Post-Combustion: Solvent Scrubbing

Combustion: Oxy-Coal
3. The Status of CCS in Carbon Management

- Prospects for CCS
  - Key option for CO2 reduction
  - Critical for future coal use
  - Important in the power sector but also for alternate fuel supply options
  - A $25-30/tonne of CO2 is considered as the upper range limit for the cost of CCS
  - Significant costs for R&D&D for industrial deployment
Geologic Storage

1. CO₂ is captured, compressed and piped to the storage site.

2. CO₂ is then injected under pressure via a well into the storage site.
Coal Rank Map
Potential Pilot Test Sites in Central Appalachia
(6,000 CBM Wells)
The Need for a Large Scale Test in Appalachia

- Large scale tests are necessary to demonstrate and confirm geologic storage
- Absence of such tests in a region, or on a specific geologic formation, may delay sequestration demonstration and deployment
- Test will provide acceptable sequestration "assurance" to the investor community seeking to fund energy project that can be impacted by future CO2-limiting legislation
- Significant government, state and community support for a large scale SECARB-Coal Group test in Central Appalachia
In coal, if we do not solve the upstream problems and challenges there is no point worrying about the downstream implication!
Today, and independent of whatever carbon constraints may be chosen, the priority objective with respect to coal should be the successful large-scale demonstration of the technical, economic, and environmental performance of the technologies that make up all of the major components of a large-scale integrated CCS system — capture, transportation and storage. Such demonstrations are a prerequisite for broad deployment at gigatonne scale in response to the adoption of a future carbon mitigation policy, as well as for easing the trade-off between restraining emissions from fossil resource use and meeting the world’s future energy needs.

At present government and private sector programs to implement on a timely basis the required large-scale integrated demonstrations to confirm the suitability of carbon sequestration are completely inadequate. If this deficiency is not remedied, the United States and other governments may find that they are prevented from implementing certain carbon control policies because the necessary work to regulate responsibly carbon sequestration has not been done. Thus, we believe high priority should be given to a program that will demonstrate CO₂ sequestration at a scale of 1 million tonnes CO₂ per year in several geologies.
UA Federal Coal-Related R&D Funding

$538 million in 2005

- Utilization & CCS: 82%
- Transport & Transmission: 9%
- Safety & Health: 4.5%
- Reserve Assessment: 1.9%
- Environment / Reclamation: 1.8%
- Mining and Processing: 0.2%

‘DOWNSTREAM’ R & D
‘UPSTREAM’ R & D
5. A Sectoral Planning Approach

- Develop acceptable guidelines and policies
- Encourage participation of developing nations
- Address issues of competitiveness and cost
- Coordinate and fund R&D
- Resolve institutional challenges
- Address regulatory framework
The US Energy Challenge

- We are still building coal-fired power plants in the USA: currently 20 under construction
- However:
  - In 109th Congress, 106 bills, resolutions or amendments were introduced addressing global climate change and GHG emissions
  - Plans for building nearly two dozen coal-fired power plants have been cancelled in the past two years
  - Yet, energy demands are increasing:
    - By 2030 expected to grow almost 40% in U.S.
    - Globally projected to grow 60%

Where this energy will come from?
As of March 2007

Initial Greenhouse Gas Regulatory Proposals
110th Congress

As of October 2007

Greenhouse Gas Emissions Target
CO₂ Sequestration Timelines

Programmatic

2007
Initiate deployment phase of Regional Carbon Sequestration Partnerships

2008
Large-scale demo: > 1 M tons CO₂ / yr
MM&V protocols: Enable 95% of stored CO₂ to be credited

2011
Carbon sequestration program goals:
90% capture
99% permanence
< 10% added cost

2012
2018
Significant commercial transition to employ capture and storage

2020
Optimized sequestration technology ready for commercial deployment

Legislative*

2008
Legislation requiring / incentivising capture and storage

2013
Equipment, specifications and designs available to industry

2028
Standard commercial and regulatory practice

NETL

C. Bauer, CURC Autumn 2007, 10/04/2007

* Basis 1970 Clean Air Act commercial / regulatory experience
Planning for CCS

- CCS Ready/Compatible Facilities
  - Definitions
  - Examples
  - Due Diligence
- Site Planning
  - Optimum Location
  - Choosing Technologies
  - Assurance and Audit

- Incentives
  - Financial
  - Regulatory
- Project Financing
  - Financial Risk
  - CCS Technology Timeline
Conclusions

- Fossil fuels and coal in particular will remain dominant in the energy mix for decades
- Increase use of fossil fuels means increased emissions
- Developing countries will not reduce energy consumption and, therefore, emissions in the near future
- Stabilizing GHG is a long-term issue
- Coal will continue to provide a major portion of the global energy requirements
A renewed focus on upstream coal-related R&D support is critical for the viability of the sector.

CO₂ emissions pose greatest potential constraint to future coal use.

Large-scale demonstrations of CCS is vital for coal in a carbon-constrained world.

Corollary is the need to characterize geologic formations for CO₂ sequestration.

Geologic sequestration sites are ‘resources’.

Promote and define CCS-compatible facilities.
A sustainable energy future requires significant investment in coal R&D

Wants:
- More capacity
- More efficiency
- More diversity
- More investments
- Cleaner Environment
- Low cost

Haves:
- Upstream Challenges
- CO2 dilemma
- Policy Uncertainty
- Regulatory Uncertainty
- Investment Uncertainty

Technology is the enabler and the bridge to energy future!