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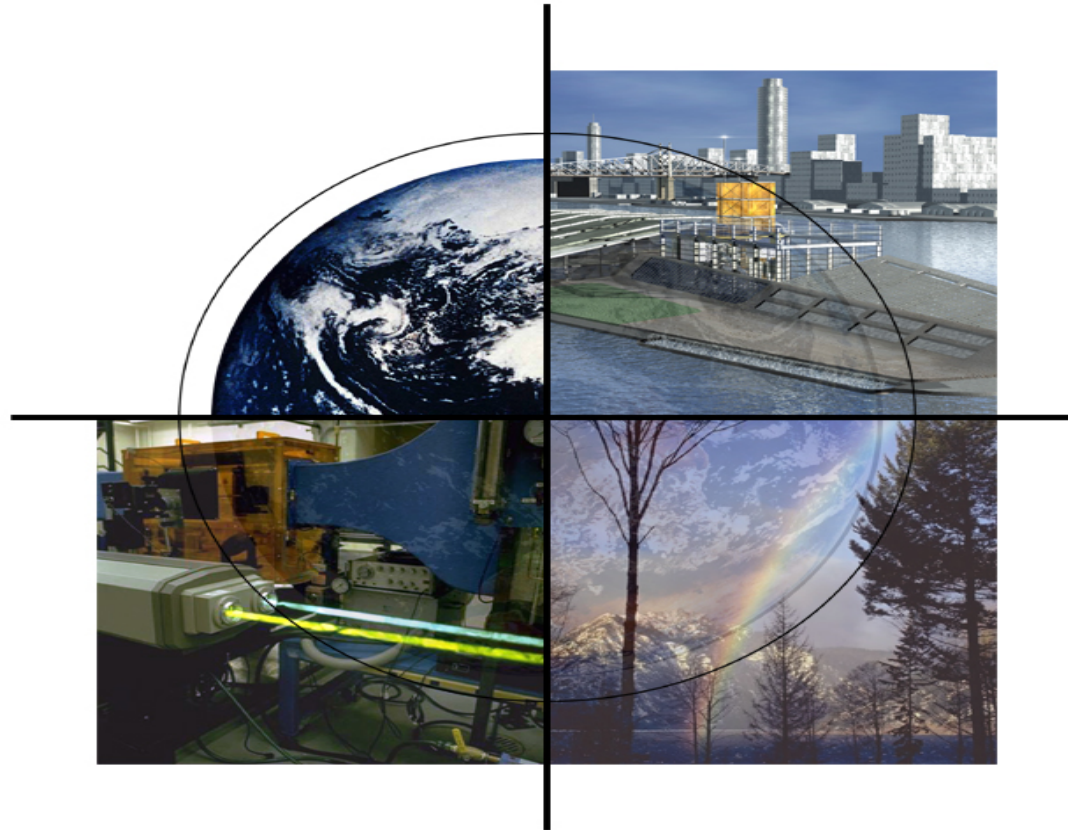
Presented by Frank Burke, CONSOL Energy Inc., at the Coal Utilization Technologies Workshop on September 22, 2004 at the National Research Center for Coal & Energy, Morgantown, WV. This meeting was part of the Energy Roadmap Workshop Series commissioned by West Virginia Governor Bob Wise.

Emissions Control Technologies

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**COAL UTILIZATION TECHNOLOGIES WORKSHOP
National Research Center for Coal and Energy
Morgantown, WV
September 22, 2004**

Clean Coal Technology Roadmap



**The Department of Energy, the Electric Power Research Institute,
and the Coal Utilization Research Council**

Coal Technology Strategic Targets

***In the
Short-term***

Cost effective environmental control technologies enable compliance with emerging regulations

By 2015

*A high-efficiency, near-zero emission power plant **is designed** that is sequestration ready, fuel flexible, capable of producing multiple products*

By 2020

*The first of these advanced power plants **is commercially introduced***

Coal Power Plant Performance Criteria

- **Air Emissions**
 - SO₂
 - NO_x
 - Particulate
 - Hg
- **CO₂ Management**
- **By-Product Utilization**
- **Water Use and Discharge**
- **Plant Efficiency**
- **Reliability/Availability**
- **Capital and Product Cost**

Power Generation Options

- **Pulverized Coal (PC) Combustion**
 - Predominant system in use today
 - Coal is burned in air
 - Heat produces steam to drive turbine
- **Integrated Gasification Combined Cycle (IGCC)**
 - Four units operating world-wide
 - Coal is gasified in air or oxygen
 - Gas is combusted in gas turbine
 - Heat is recovered to drive steam turbine
- **Others (AFBC, PFBC)**

Air Emissions Control: Pulverized Coal Combustion

- SO₂: Wet Flue Gas Desulfurization (FGD)
- NO_x: Combustion Controls/SCR
- Particulate:
 - Electrostatic Precipitator (ESP)
 - Fabric Filter
- Mercury
 - “Co-benefits” of SO_x, NO_x and PM Control
 - No Mercury-Specific Technology in Use
 - Activated Carbon Injection (?)
 - ???

Air Emissions Control: IGCC

- SO₂: Solvent-based Acid Gas Cleanup (H₂S)
- NO_x: Turbine Combustion Controls/SCR
- Particulate:
 - Slag formation
 - Raw gas filtration
- Mercury
 - Carbon bed
 - ???

Roadmap Performance Targets

(Represents best integrated plant technology capability)

	Reference Plant*	2010	2020
Air Emissions	98% SO₂ removal	99%	>99%
	0.10 lb/10⁶ Btu NOx	0.05 lb/10⁶ Btu	<0.01 lb/10⁶ Btu
	0.01 lb/10⁶ Btu Particulate Matter	0.005 lb/10⁶ Btu	0.002 lb/10⁶ Btu
	Hg “Co-benefits”	90% Hg removal	95% Hg removal
By-Product Utilization	30%	50%	near 100%

* Reference plant has performance typical of today’s technology;
Improved performance achievable with cost/efficiency tradeoffs.

SOx and NOx

- **Current technology can give low emissions**
 - 98% SOx ~ <1 MM ton annual emission
 - 0.10 lb/MM Btu NOx ~ <1 MM ton annual emission
- **Compare to “Clear Skies” 2018 targets**
 - 3 MM ton SOx
 - 1.7 MM ton NOx (7% of current US emissions)
- **Issue is economic, not technical**
 - Not all existing plants are retrofit candidates
 - Replacement of current fleet is long-term

Mercury (Hg)

- Level of co-benefit removal is uncertain
- No commercial Hg-specific technology for power plant application
- Promising R&D, but few long-term tests
- Utilities need high reliability to avoid shutdown or derate
- Expect in 2010-2015 timeframe

Roadmap Performance Targets⁽¹⁾

(Represents best integrated new plant technology capability)

	Reference Plant	2010	2020
Plant Efficiency (HHV)⁽²⁾	40%	45-50%	50-60%
Availability⁽³⁾	>80%	>85%	≥90%
Plant Capital Cost⁽²⁾ \$/kW	1000 – 1300	900 – 1000	800 – 900
Cost of Electricity⁽⁴⁾ ¢/kWh	3.5	3.0-3.2	<3.0

- (1) Targets are w/o carbon capture and sequestration and reflect current cooling tower technology for water use
- (2) Range reflects performance projected for different plant technologies that will achieve environmental performance and energy cost targets
- (3) Percent of time capable of generating power (ref. North American Electric Reliability Council)
- (4) Bus-bar cost-of-electricity in today's dollars; Reference plant based on \$1000/kW capital cost, \$1.20/10⁶ Btu coal cost

Summary

- Emissions of criteria pollutants unlikely to be factor for “zero-emissions” plant
- SO_x and NO_x technology is well established and further improvements are possible
- Mercury technology is less certain, but progress seems likely
- Economics and regulatory requirements will be deciding factors