CURC's View of What Could Be …

A roadmap for needed advances in coal technology

Presented to Clean Air Act Advisory Committee
Advanced Coal Technologies Workgroup Meeting
March 29, 2007
Doug Carter, Senior Advisor
Coal Utilization Research Council

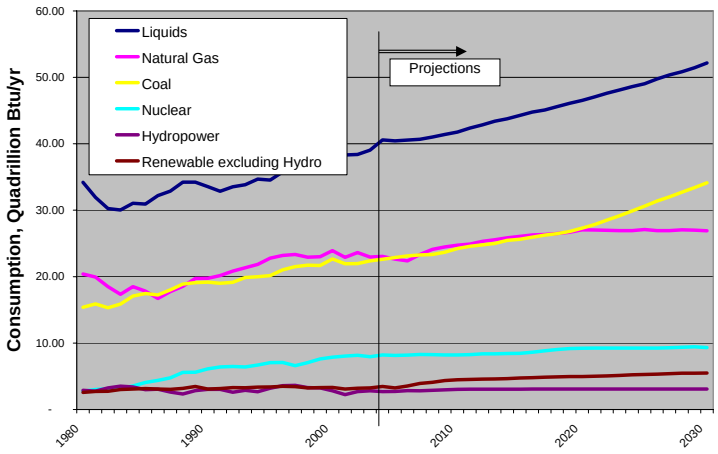
CURC is an association of coal suppliers, users, technology vendors, academics.

Air Products and Chemicals	Murray Energy Company	University of Tennessee Space Institute
Alstom Power, Inc.	National Mining Association	University of Utah
The American Coal Sales Company	National Rural Electric Cooperative Association	University of West Virginia
American Electric Power*	New York Power Authority	University of Wyoming
American Coal Council	North American Coal Corporation	West Virginia Coal Association
Arch Coal, Inc.	Ohio University	Western Research Institute
BabcockPower	Peabody Energy	Wisconsin Energy Corporation
The Babcock & Wilcox Company	PNM Resources	Xcel Energy
Battelle	Praxair, Inc.	
ConocoPhillips	Process Power Plants LLC	
CONSOL Energy, Inc.	Purdue University	Companies in red are Steering Committee members
Duke Energy Company	RW Beck	* Designates co-chairs of CURC
Edison Electric Institute	Salt River Project	
Electric Power Research Institute	Shell Gas & Power	
Energy Industries of Ohio	Siemens Power Generation	
E. On US	Southern Company*	
First Energy	Southern Illinois University	
Fluor	State of Colorado	
Foster Wheeler	State of Illinois	
General Electric Company	State of Ohio, Air Quality Development Authority	
Illinois Department of Commerce & Community Affairs	Tennessee Valley Authority (TVA)	
Kellogg Brown & Root (KBR)	Tri-State Generation & Transmission Association	
Kentucky Office of Energy Policy	United Mine Workers of America	
Kennecott Energy Company/Rio Tinto	University of Kentucky	
Lehigh University		

Why should we care about coal technology, or advances in coal technology?

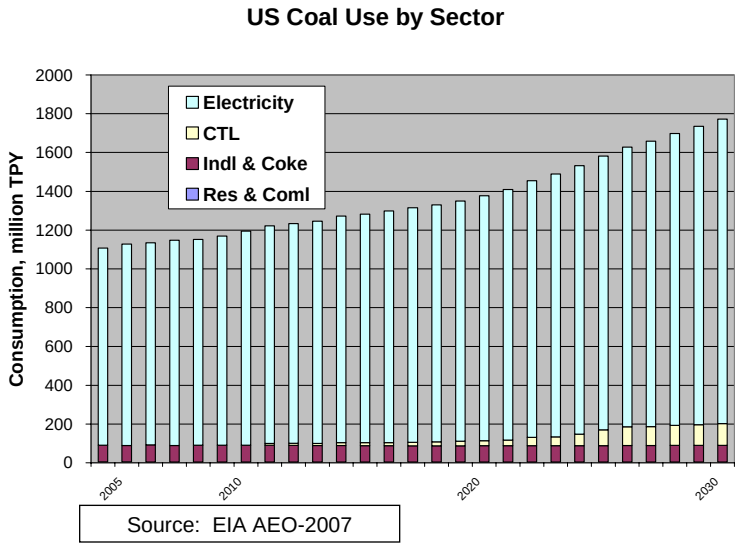
Coal ranks 2nd in consumption in U.S.

Energy Use in the U.S.



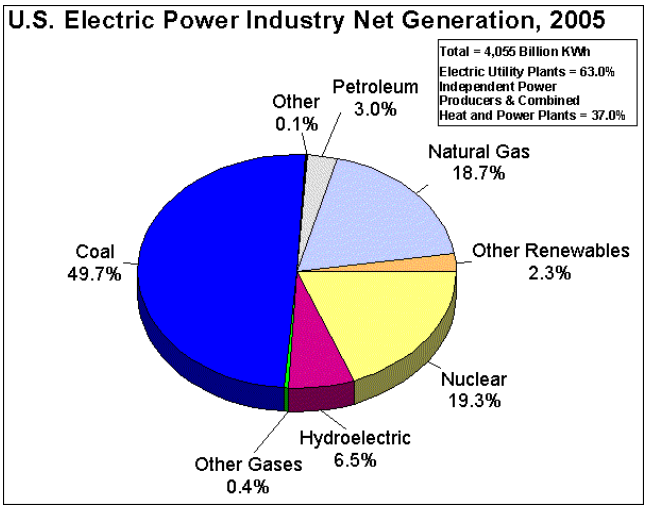
Source: EIA AEO-2007

90% of coal use in the U.S. is for electricity



Source: EIA AEO-2007

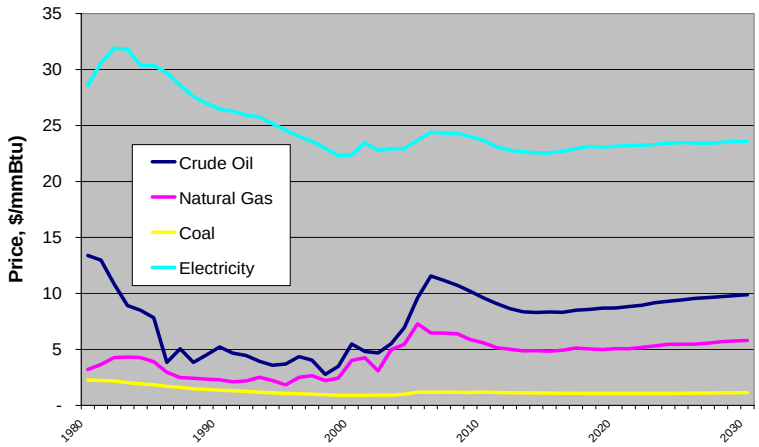
Half of our electricity is from coal



Source: http://www.eia.doe.gov/neic/brochure/elecinfocard.html

We use coal because it is cheap

U.S. Energy Prices (2005 Dollars)

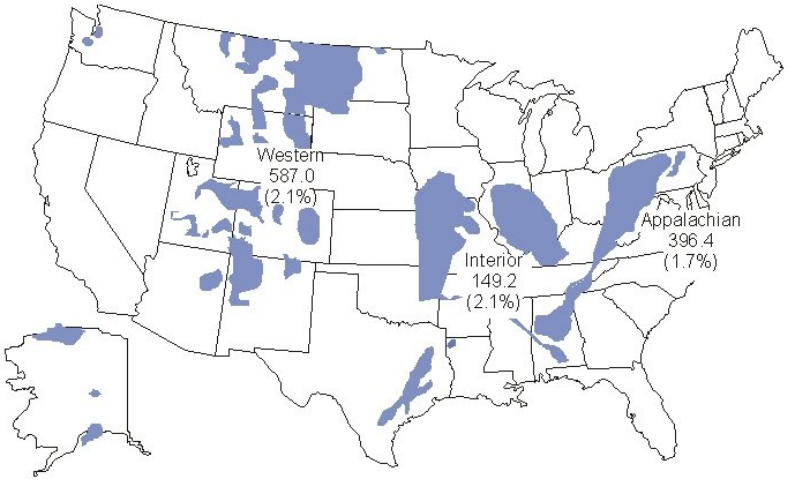


Source: EIA AEO-2007

And because it is here

Coal Production, 2005: 1132 M tons

(Million Short Tons and Percent Change from 2004)

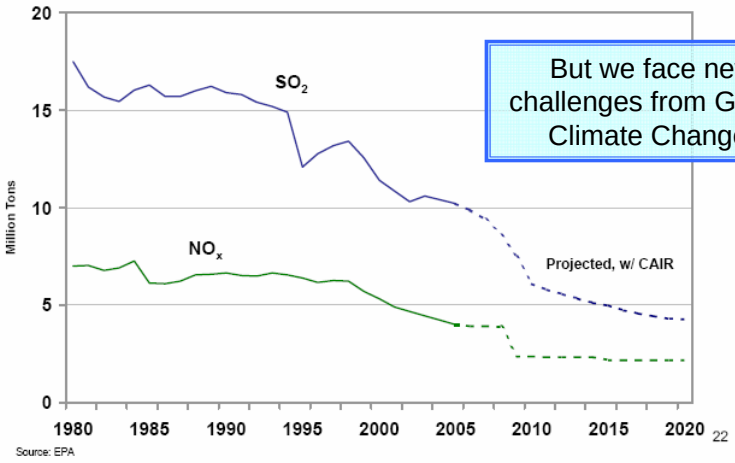


Source: http://www.eia.doe.gov/cneaf/coal/page/special/fig1.html

Emissions from Coal Use Continue to DECLINE

(despite 60% increase in coal use since 1980)

National NO_x and SO_2 Power Plant Emissions: Historic and Projected with CAIR

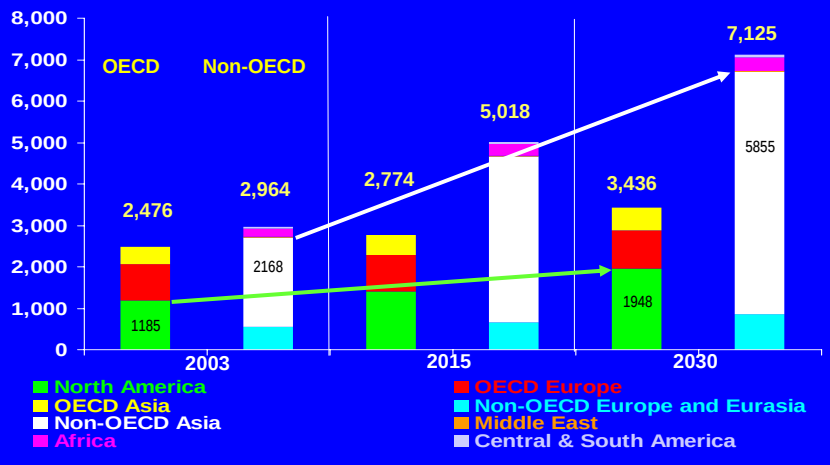


But we face new challenges from Global Climate Change.

US technology development may be vital to others

(China added 93GW of coal capacity in 2006)

World Coal Consumption, 2003, 2015, and 2030 (million short tons)



International Energy Outlook 2006

OECD = Organization for Economic Cooperation and Development

CURC & EPRI have developed a roadmap for improvements in coal using technology

- The roadmap was a collaborative effort
- We met with DOE/NETL and discussed their RD&D program as well as our perspective on technology
- The roadmap identifies a family of technologies needed to achieve the goal of near-zero emission coal-based technology by 2025 (>90% CO2 capture).
- Available at: www.coal.org
- The remaining slides draw from that roadmap

Principal Contributors

Mark Gray (AEP)
Glen Jukkola , Nancy Mohn (Alstom)
Marshall Mazer, Kevin McCauley (B&W)
Frank Burke, Dick Winschel (CONSOL Energy)
Phil Amick (Conoco Phillips)
Shannon Angielski, Doug Carter (CURC)
Stu Dalton, Jeff Phillips (EPRI)
John Wootten (Peabody Energy)
Harry Morehead, Jim Ciesar (Siemens Westinghouse)
Randall Rush (Southern Company)
Ari Geertsema (UKy)
Dick Bajura (WVU)

Roadmap: Take-home Messages

- Success is based on R&D => Demonstrations => Commercial deployment
- With successful RD&D, sequestered coal-based generation in 2025 will cost about the same as unsequestered coal-based generation today.
- With technology development, future PC and IGCC will be highly competitive, and both will cost less than either technology costs today. I.E., win-win for users.
- R&D funding is significantly inadequate. Demonstration funding is completely inadequate.

The analysis was conducted on a disaggregated level

- **Differing power systems**
  - Combustion based
  - Gasification based (IGCC)
- **Two Base Coals**
  - Pittsburgh Seam (bituminous)
  - PRB (subbituminous)
- **Three Locations**
  - PRB/West
  - PRB/Midwest
  - Pittsburgh Seam/East
- **BUT: Results are presented in aggregate**

Emission Performance: An order of magnitude reduction for traditional pollutants by 2025.

(Represents best integrated plant technology capability)

PC and IGCC Systems	Year				
	2005	**2010**	**2015**	**2020**	**2025**
Emissions					
PM, lbs/MWhr	0.09	0.04-0.09	0.02-0.04	0.04-0.02	0.01-0.02
SO2, lbs/MWhr	0.8-0.3 (90-99%)	0.2-0.4 (90-99.6%)	0.2-0.04 (95-99.9%)	0.1-0.02 (97-99.9%)	0.07-0.01 (98-99.9%)
NOx, lbs/MWhr	0.5-0.4	0.3-0.2	0.2	0.2-0.1	0.2-0.1
Mercury, %	80-90%	93-95%	95-99%	97-99%	98-99%
CO2, lbs/MW-hr	1770-1940	1750-1900	1600-1870	1500-1750	1410-1670
Efficiency Btu/kWh (HHV)	38-39%	38-41%	39-43%	42-46%	44-49%

Cost Performance: Cost in 2025 with carbon capture equal to cost in 2005 without.

(Represents best integrated new plant technology capability)

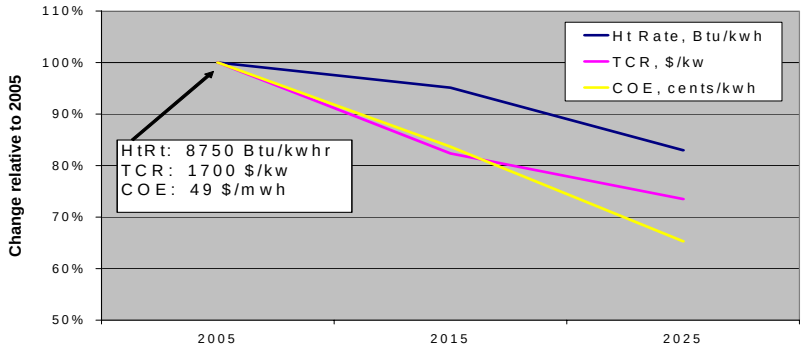
PC & IGCC systems	**Year**				
	2005	**2010**	**2015**	**2020**	**2025**
Efficiency	38-39%	38-41%	39-43%	42-46%	44-49%
Cost (2005 $s)					
Capital cost, TPC, $/kw	1260-1720	1265-1590	1240-1540	1220-1350	1200-1330
Capital cost, TCR, $/kw	1440-1980	1470-1840	1450-1790	1430-1570	1400-1550
COE, $/MW-hr (Lev. 2005 $s)	**42-55**	40-47	37-44	34-37	31-33
With Carbon Capture					
Efficiency Btu/kWh (HHV)	27-33%	31-32%	31-35%	33-39%	39-46%
CO2, lbs/MWhr	220-270	220-240	200-220	180-210	150-190
Capital cost,TPC, $/kw	1950-2370	1790-2200	1590-2120	1510-1810	1340-1610
Capital cost, TCR, $/kw	2240-2720	2070-2550	1830-2470	1740-2110	1570-1870
COE with CO2 capture, but w/o storage, $/MW-hr	64-69	58-62	46-57	41-49	**37-39**
Additional cost for CO2 storage, $/MW-hr	2-7	2-7	2-7	2-7	**2-7**
Total R&D and Demo costs, $Biln		3.9	3.5	1.9	0.5

Note that the roadmap costs are reflective of both the federal and industry commitments expected for both research projects (80% federal – 20 % industry) and demonstration projects (50% federal – industry cost share)

Summary of Technical Needs

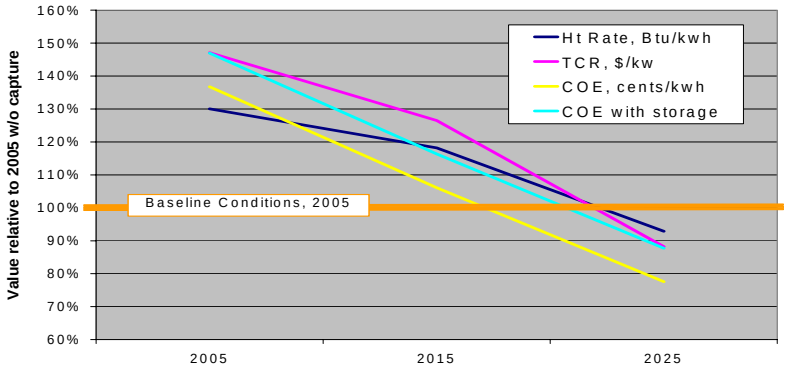
- Existing Plants - demonstrations of mercury control technologies to meet CAMR rules
- IGCC – improved reliability of gasifier and cost reductions for oxygen, advanced turbines and fuel cells, and carbon capture
- Combustion – advanced materials for USC stress and low cost carbon capture technologies
- Turbines – Rich Hydrogen combustion (for CO_2 capture)
- Fuel cells – decrease costs and increase size
- Carbon Sequestration – issue is need for large long-term demonstrations of storage, versus competing $$ needs of earmarks, FutureGen. (3 storage demos could cost $160M plus $500M for the CO_2)
- Must also recognize gap in Policy: long term liability issue.

Technology Progress without CO_2 Capture



Necessary Technologies	IGCC	-Improved refractory -Gasifier scale-up -G to H Class CTurbine -ITM Oxygen	-Warm gas cleanup -CO2/Slurry feed or dry feed -Fuel Cell hybrid
	PC	-1150 F UltraSupercritical -Materials	-5000 psig / 1400 F USC -Materials

Technology Progress with CO_2 Capture



Necessary Technologies

IGCC	-Demonstrated C storage -Hydrogen turbine	-Membrane CO2 separation -Multi-pollutant disposal / sour gas water shift
PC	-Advanced Sorbent CO2 capture (e.g., chilled ammonia) -Oxy-Firing	-Advanced sorbents -Chemical looping

Summary of Federal and Private Sector Costs of Roadmap (in Billions US $)

Research & Development (80% Federal - 20% Industry)	**$4.3**
Demonstrations (50% Federal – 50% Industry)	**$6.7**
TOTAL COST of ROADMAP	**$11.0**
Total Industry Share	**$4.1**
Total Federal Share	**$6.9**

•Note that federal costs will be higher in the first five years of the roadmap when government R&D project cost sharing commitments are approximately 80% of total project costs.

•These costs only include the costs of NEW demonstrations, not currently supported by DOE. Thus, neither the Excelsior nor the Orlando IGCC projects costs are included.

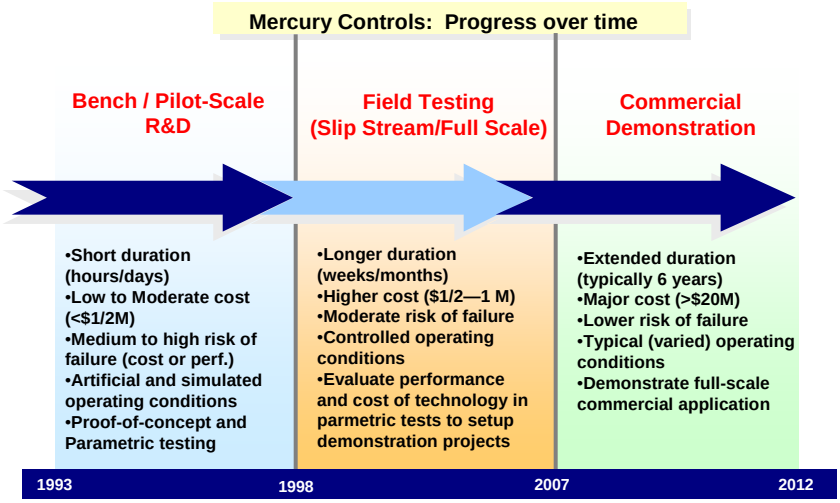
Programmatic Federal and Private Sector Costs of Roadmap

(in Millions US $)

	IGCC	Combustion	IEP	Sequestration (Storage)	Fuel Cells	Turbines	TOTALS
R&D	$2,150	$375	$360	$225	$730	$450	**$4,290**
Demos	$3,050	$2,040	$800	$160	$475	$180	**$6,705**
Industry Share	$1,955	$1,095	$470	**Costs borne by federal government**	$385	$180	**$4,085**
Federal Share	$3,245	$1,320	$690	$385	$820	$450	**$6,910**
TOTALS	**$5,200**	**$2,415**	**$1,160**	**$385**	**$1,205**	**$630**	**$10,995**

Technology requires time to develop

Mercury control systems required 20 years to commercialize;
Carbon capture is much more complex.



Bottom Lines

- Improved technology is the key to continuing to receive the economic and energy security benefits of coal
- The CURC-EPRI Roadmap presents a coherent set of goals, and a pathway to achieve them
- Adequate RD&D funding is essential to achieving these goals
- Current resources for R&D are not adequate
- Resources for Demonstrations are completely inadequate

Notes