Emissions of Pollutants from Coal-Fired Power Plants – Current Issues

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Issues of Concern in Coal-Fired Power Plant Emissions

- Broader fuel use context of power generation
- Recent trends in coal consumption for power generation in U.S.
- Pollutants/emissions of particular concern (sulfur dioxide, nitrogen oxides, mercury, carbon dioxide)
- Recent trends in emissions/impacts
- Current policy context

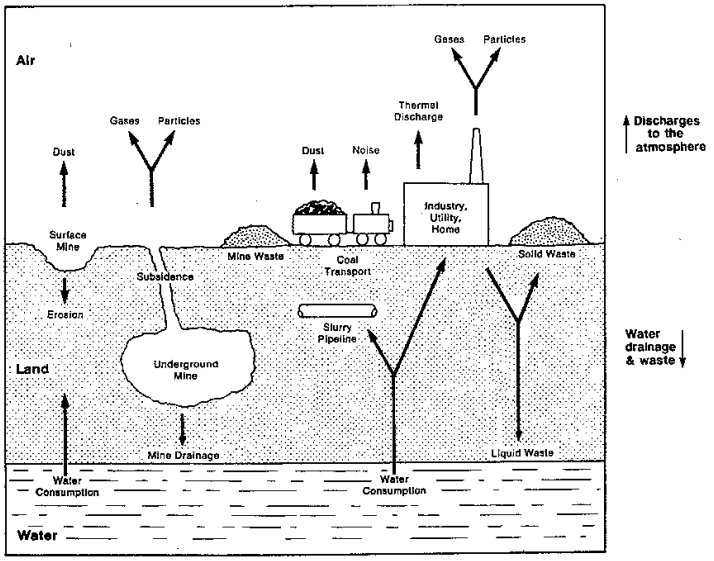
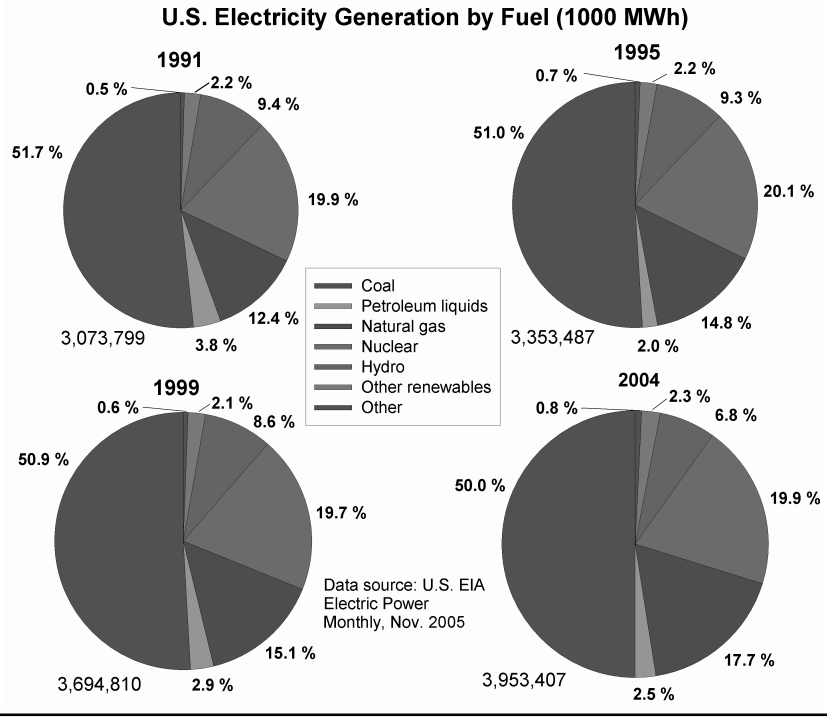


Figure 6.2
The cycle of coal use. Adapted from Wilson (1980) and Office of Technology Assessment, US Congress (1979).

Source: Cassedy and Grossman, Introduction to Energy, 1998



Coal Ranks

- Anthracite – highest rank, high energy content
- Bituminous – second highest rank, high energy content; typically higher in chloride; often higher in sulfur as well
- Subbituminous - third highest rank, medium energy content; typically lower in chloride and sulfur
- Lignite – lowest rank, lower energy content

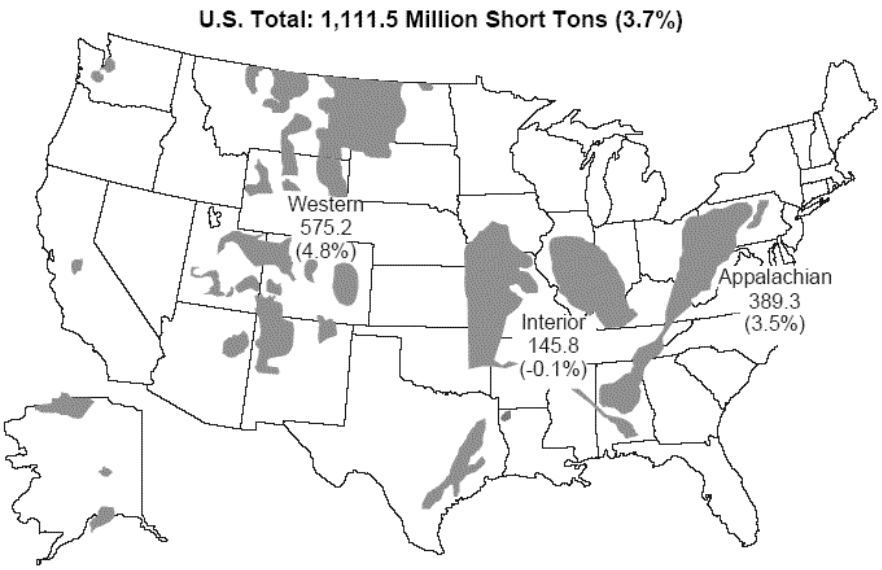
Mercury: on energy basis, concentrations are typically: lignite > bituminous > subbituminous

Coal Quantity and Quality for Deliveries for Electric Power Generation in U.S., 2004

	Coal Rank		
	Bituminous	**Subbituminous**	**Lignite**
Delivery (1000 tons)	413,111	434,490	71,719
%	44.9	47.3	7.8
Avg. sulfur (%)	1.6	0.4	1.0
Avg. ash (%)	10.2	6.1	13.9

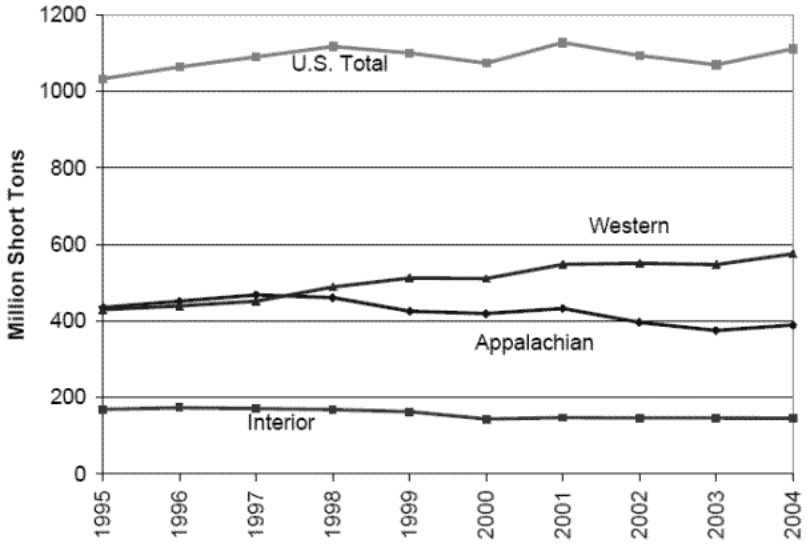
Source: data compiled from U.S. EIA, Electric Power Monthly reports, May 2004 – April 2005

U.S. Coal Production By Region, 2004



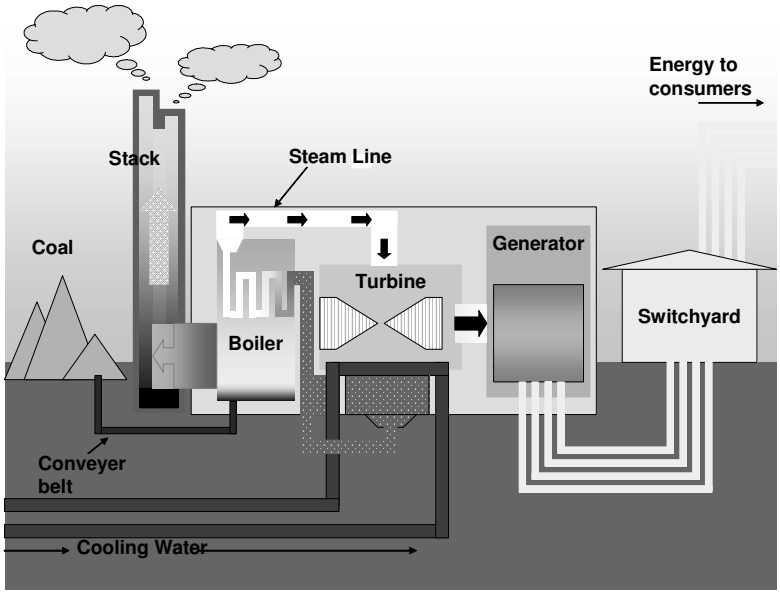
Source: EIA, U.S. Coal Supply and Demand: 2004 Review

U.S. Regional Coal Production Trends



Source: EIA, U.S. Coal Supply and Demand: 2004 Review

Schematic Diagram of a Coal-fired Power Plant



Source: from Tennessee Valley Authority www.tva.gov/power/coalart.htm

Criteria Air Pollutants/Hazardous Air Pollutants

- Under U.S. Clean Air Act (CAA), EPA regulates six "criteria" air pollutants:
  - Sulfur dioxide (SO_2)
  - Nitrogen oxides (NOx)
  - Ozone (O_3)
  - Particulate matter (PM)
  - Carbon monoxide (CO)
  - Lead (Pb)
- EPA has established National Ambient Air Quality Standards for these pollutants; also regulates SO_2 and NOx under acid rain provision of CAA
- EPA also regulates 188 hazardous air pollutants (HAPs) under different section of CAA; includes persistent, bioaccumulative, and toxic (PBT) pollutants

Major Coal-Fired Power Plant Pollutants

Pollutant	Issues/Effects
Sulfur dioxide (SO_2)	• Major contributor to acid precipitation • Contributes to particulate matter formation
Nitogen oxides (NOx)	• Leads to formation of smog (O_3) • Contributor to acid precipitation • Contributes to particulate matter formation • Contributor to nitrogen loadings
Particulate matter (PM)	• Can cause/contribute to respiratory illnesses • Contribute to visibility problems
Mercury (Hg)	• Can transform to methylmercury, build-up in food web • Neurodevelopmental toxicant in humans; reproductive/other toxicant in wildlife
Carbon dioxide (CO_2)	• Greenhouse gas; climate change

2003 Pollutant Emissions from Fossil Fuel Power Plants

Pollutant	% From Power Plants	Other Major Sectors
SO_2	69	Industrial fuel combustion
NOx	22	Highway, off-highway vehicles
$PM_{2.5}$*	23	Industrial and other fuel combustion
Pb**	16	Industrial fuel comb., metals processing, off-highway vehicles

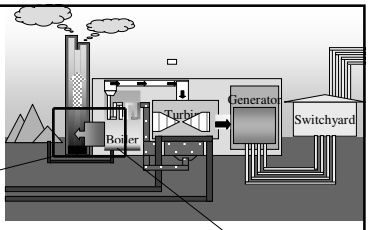
Source: Data table in EPA, National Air Quality and Emissions Trends Report, 2003
*: Particulate matter < 2.5 um; includes "condensables", excludes miscellaneous category (fires, fugitive dust from roads, etc.); **: 1999 data

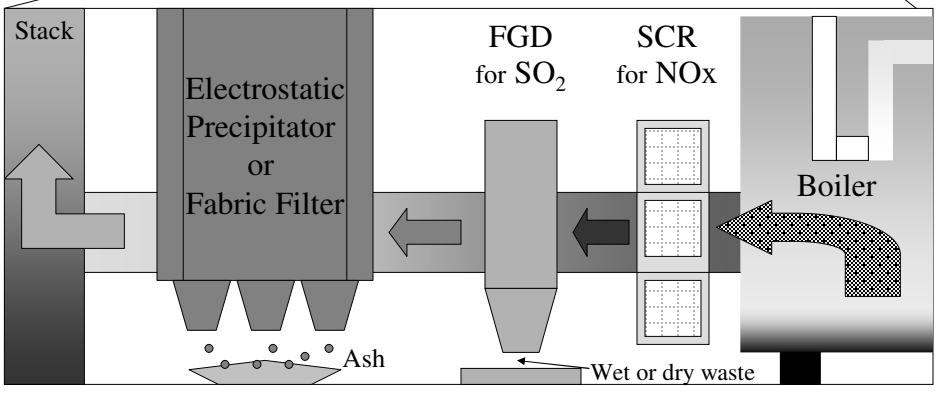
Air Emissions Rates for Three Pollutants in Electricity Generation by Fuel

	Emissions Rate (lbs/MWh)		
Fuel	SO_2	NOx	CO_2
Coal	13	6	2249
Oil	12	4	1672
Natural gas	0.1	1.7	1135

Source: U. S. EPA, Clean Energy, Air Emissions Web site

Coal-Fired Power Plant with Criteria Pollutant Control Devices

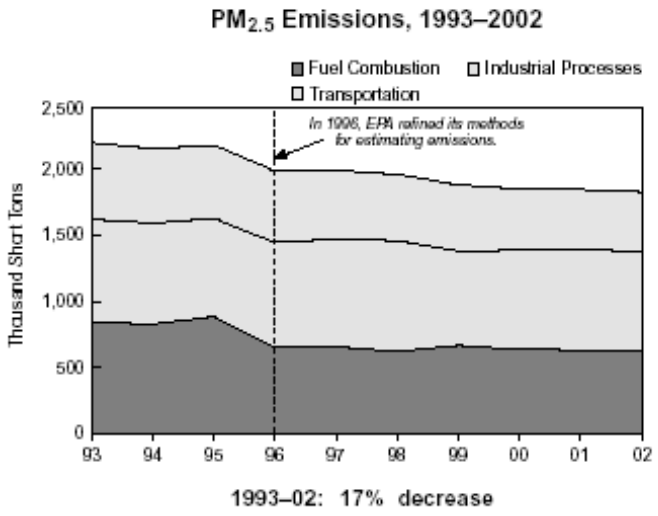




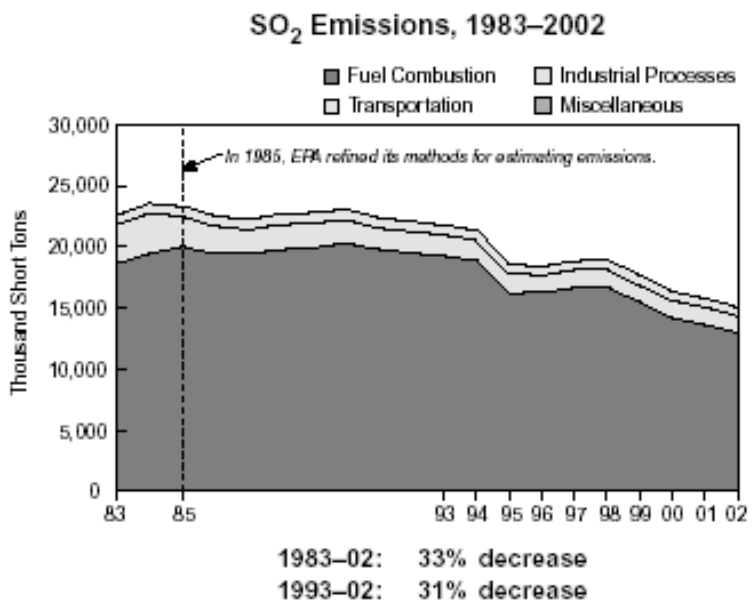
Air Pollution Controls at U.S. Coal-Fired Power Plant Pollutants - 1999

		Number of boilers	% Boilers
Post-combution PM controls only	Electrostatic precipitator (ESP)	791	69.4
	Fabric filter (FF)	80	7.0
	Other	19	1.7
Post-combution PM controls & SO2	ESP and wet scrubber	133	11.7
	FF and spray dryer adsorber	38	3.3
	Other	41	3.6
Post-combustion PM controls & Nox	FF & selective noncatalytic reduction (SNCR)	12	1.0
	ESP & SNCR	11	0.9
	Other	1	0.1
Post-comb. PM, SO2, Nox	Various	14	1.3
	Total	1,140	100.0

Source: Kilgroe et al., 2002



Source: EPA, Latest Findings on National Air Quality - 2002 Status and Trends



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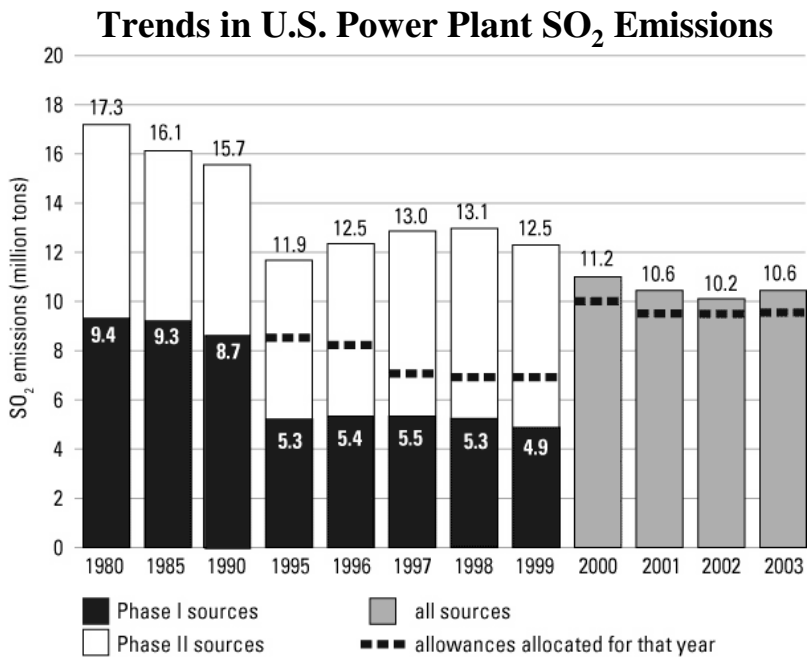


Source: EPA, Acid Rain Program 2003 Progress Report

Trends in Total U.S. NOx Emissions

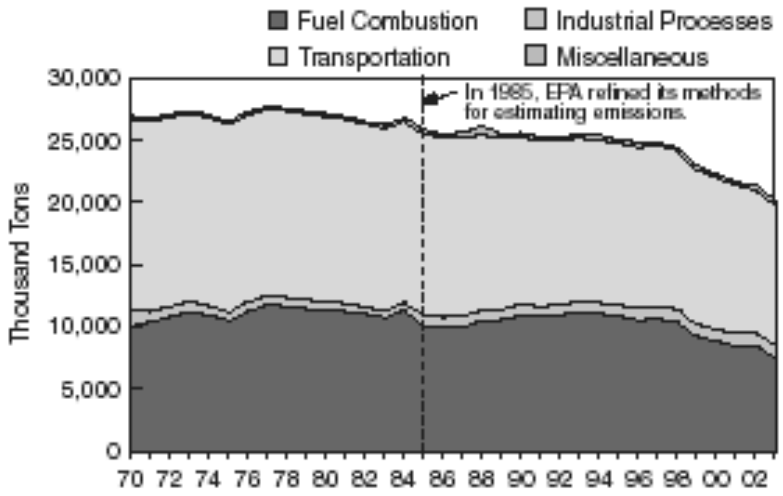
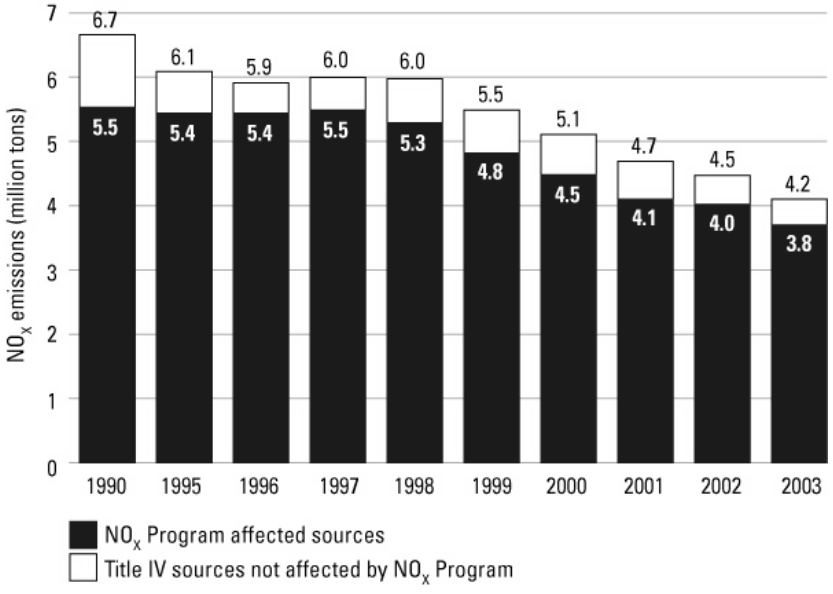


Figure 12. National Trends in NO_x Emissions, 1970–2003.

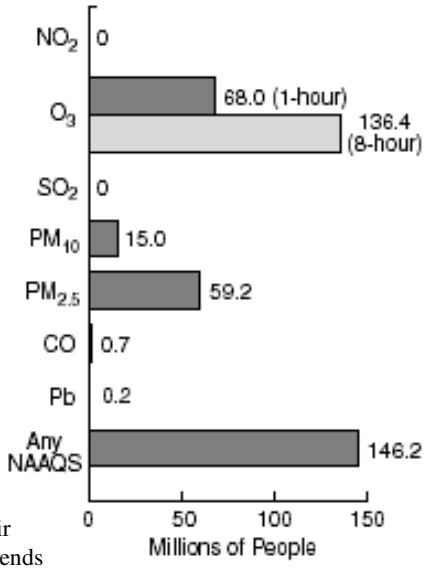
Source: EPA, The Ozone Report: Measuring Progress Through 2003, April 2004.

Trends in U.S. Power Plant NOx Emissions



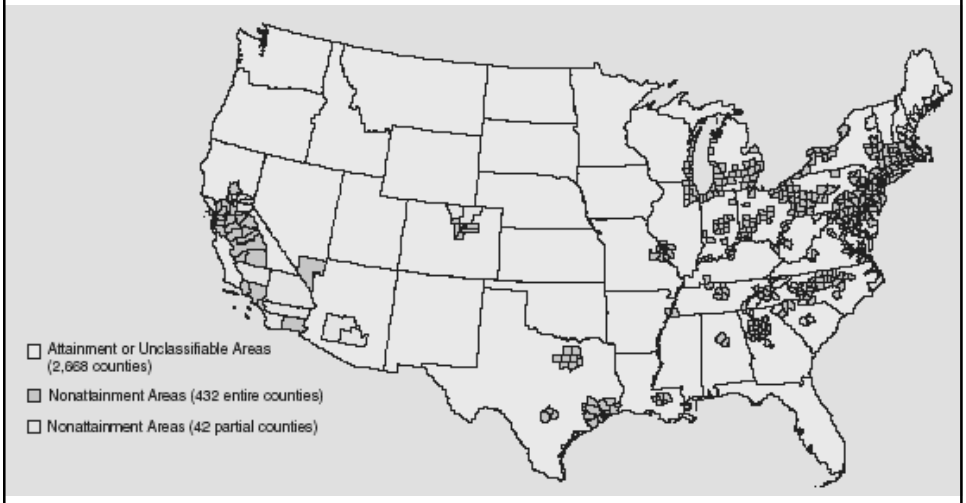
Source: EPA, Acid Rain Program 2003 Progress Report

Number of People Living in Counties With Air Quality Concentrations Above NAAQS in 2002



Source: EPA, National Air Quality and Emissions Trends Report, 2003.

8-Hour Ozone Nonattainment Areas: 474 Counties Home to 159 million people

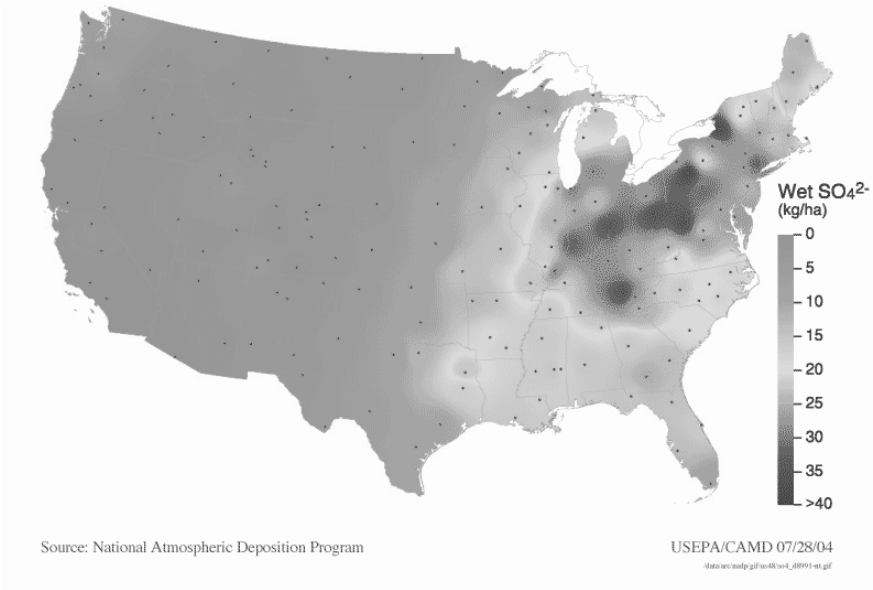


EPA, The Ozone Report: Measuring Progress Through 2003, April 2004.

Acid Deposition (incl. "Acid Rain")

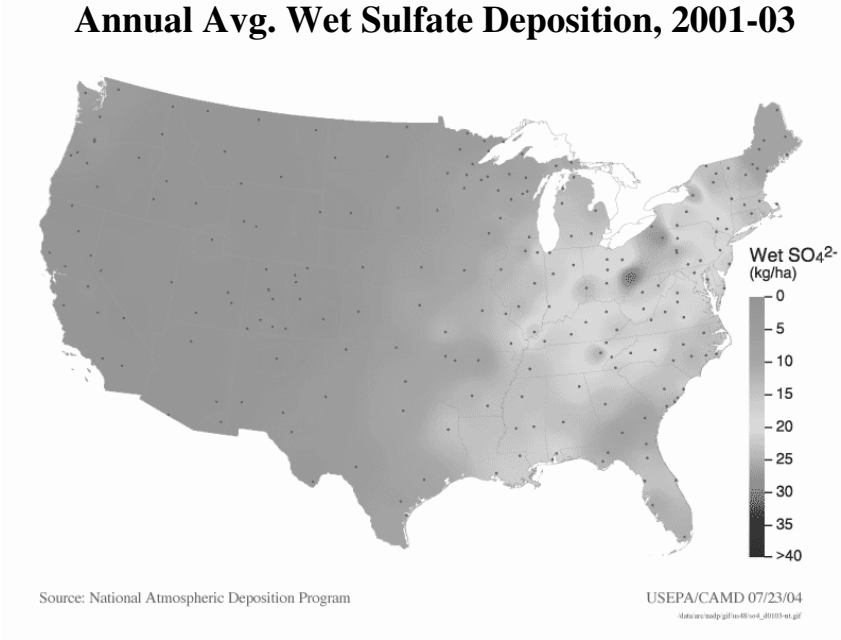
- Acid gases (sulfur oxides, nitrogen oxides) released from power plants can react in atmospheric to form sulfuric and nitric acid
- These acids can then deposit (both with wet and dry deposition) back to land and water surfaces
- Impacts in parts of U.S. and Canada have been significant, including:
  - > 90 % of streams in NJ Pine Barrens acidic
  - 1350 streams in MidAtlantic Highlands acidic (much of this due to acid deposition)
  - > 14,000 acidic lakes in Eastern Canada
- Young of most fish species are most sensitive, with general viability problems below pH of 5
- Acid deposition also implicated in forest declines

Annual Avg. Wet Sulfate Deposition, 1989-91



Source: EPA, Acid Rain Program 2003 Progress Report

Annual Avg. Wet Sulfate Deposition, 2001-03

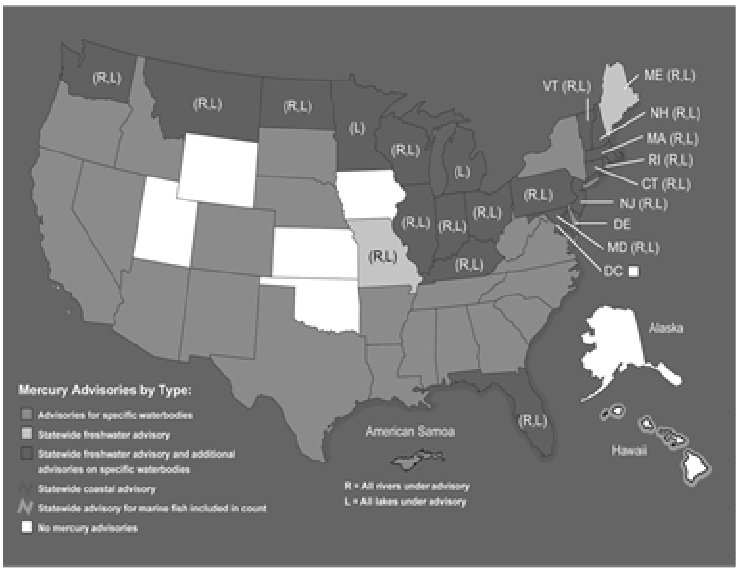


Source: EPA, Acid Rain Program 2003 Progress Report

Mercury - A Heavy Metal of Concern

- Widely used in various products and processes, both in the U.S. and internationally
- Most common cause of fish consumption advisories in U.S. and Canada
- Can cause severe impacts on nervous and other systems in humans at high exposure levels, and more subtle neurodevelopmental impacts at lower levels
- Methylmercury is form of concern in environmental exposures
- Also presents threat to certain fish and wildlife
- A global pollutant, readily transported through the atmosphere

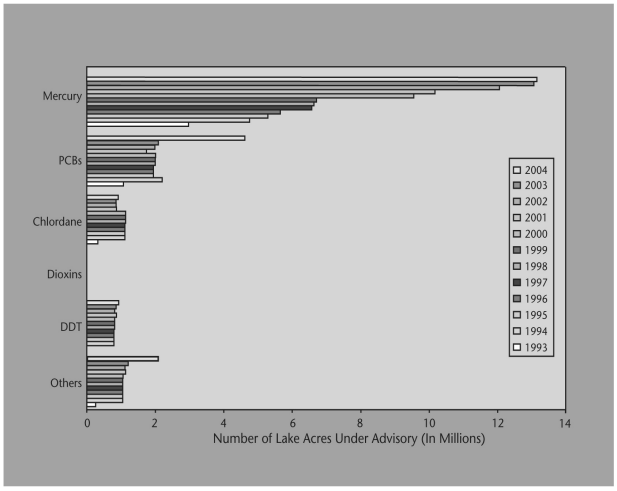
Fish Consumption Advisories for Mercury



NOTE: This map depicts the presence and type of fish advisories issued by the states for mercury as of December 2004. Because only selected waterbodies are monitored, this map does not reflect the full extent of chemical contamination of fish tissues in each state or province.

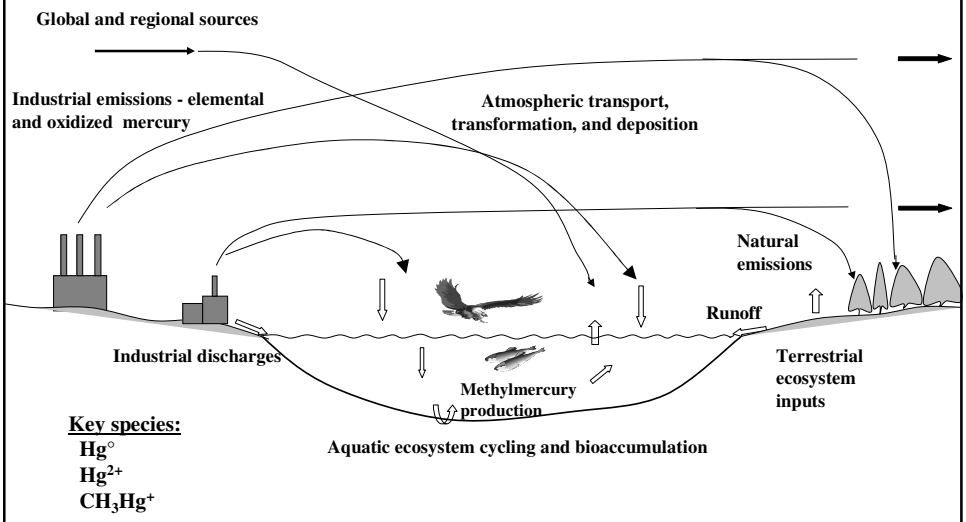
Source: U.S. EPA, National Listing of Fish and Wildlife Advisories, 2004

Number of Lake Acres Under Advisory for Various Pollutants – 2004

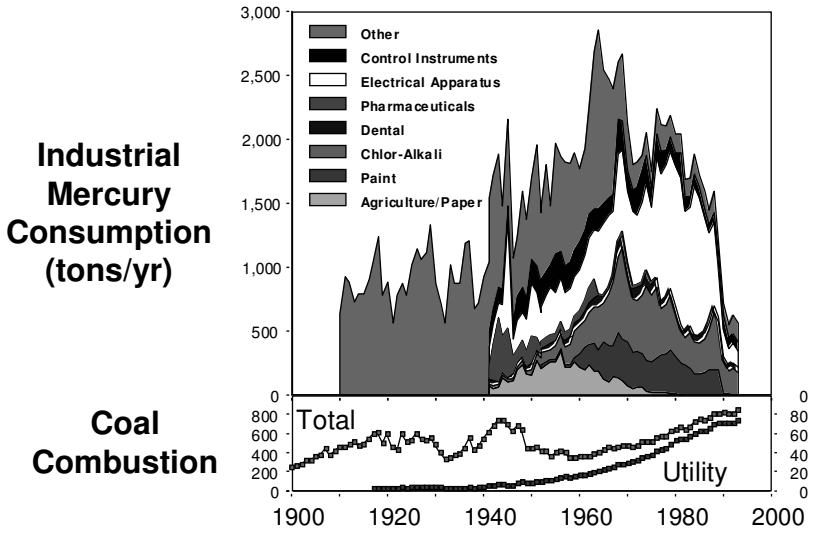


Source: U.S. EPA, National Listing of Fish and Wildlife Advisories, 2004

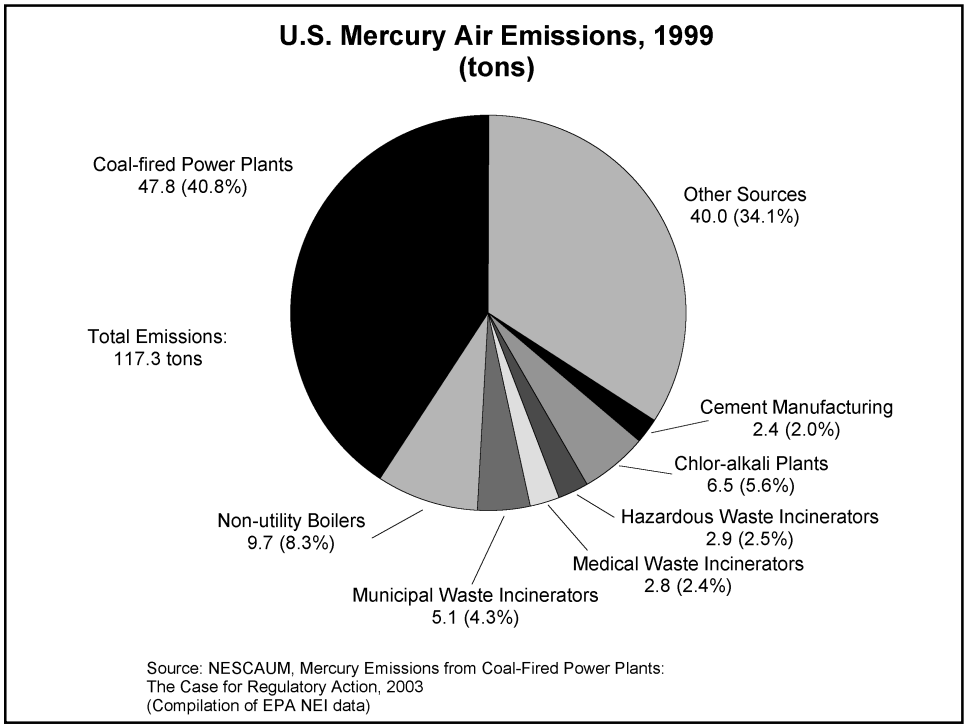
Schematic of Mercury Emissions and Transport in the Environment



U.S. Mercury Use and Coal Combustion Emissions



Source: Figure from Minnesota Pollution Control Agency



Approaches to Reducing Mercury Emissions at Coal-Fired Power Plants

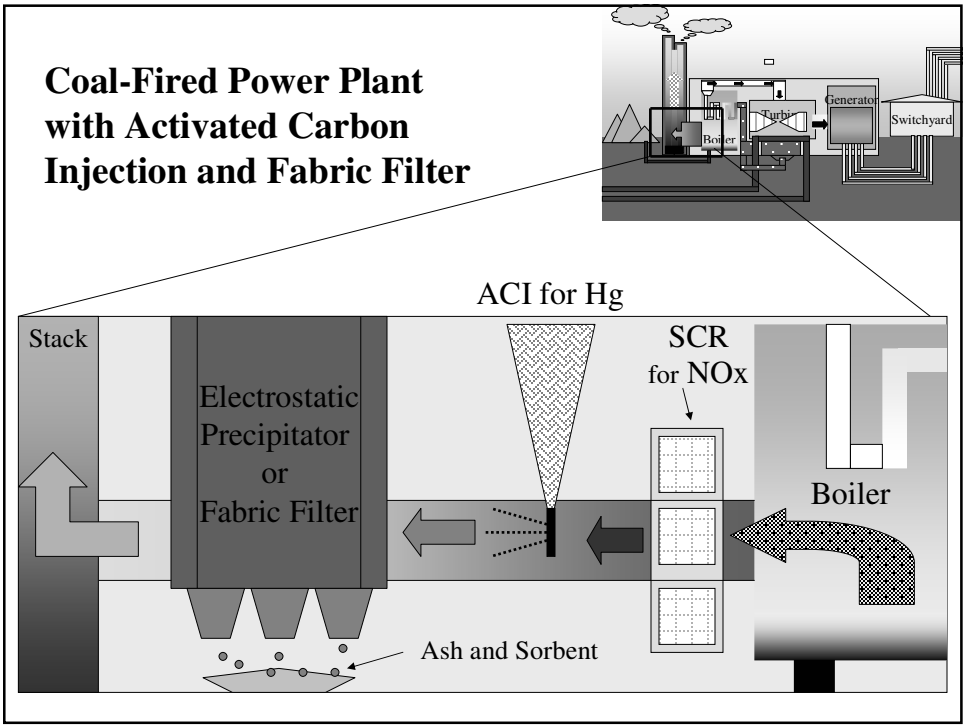
- Achieve reductions through co-benefits (of controls for other pollutants; incl. multipollutant approaches)
- Reduce mercury with existing controls for other pollutants (e.g. fabric filters)
- Reduce mercury with new targetted controls (e.g. activated carbon injection)
- Fuel switching (e.g., lower Hg coal, or natural gas)
- Improved efficiency, conservation measures (e.g. demand-side management)

Mercury Control at Coal-Fired Utilities with Existing Equipment (1999)

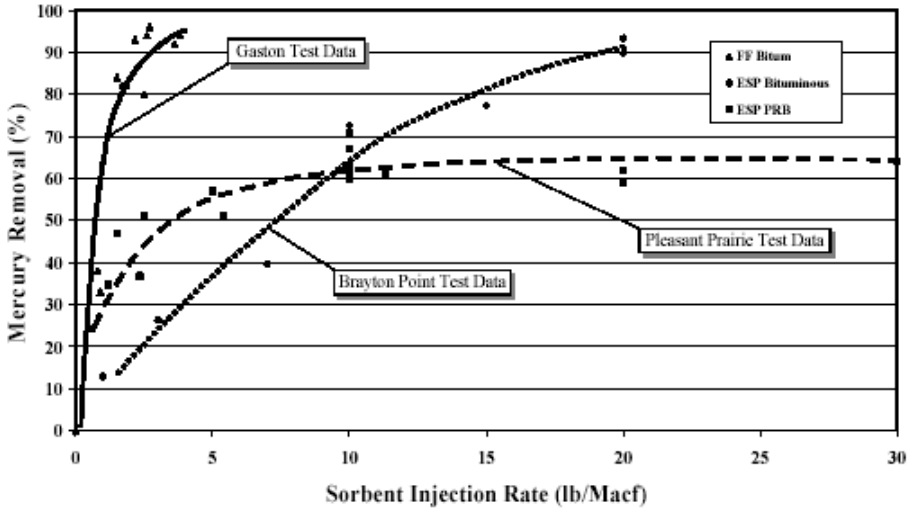
Technology	Avg. % Control by Coal Rank	
	Bituminous	Subbituminous
Cold-side ESP	36	3
Fabric filter	90	72
Spray dryer adsorber/ Fabric filter	98	24
Cold-side ESP/ Flue gas desulfurization	75	29

Source: Summary in Kilgroe et al., 2002 of EPA Information Collection Request data

Coal-Fired Power Plant with Activated Carbon Injection and Fabric Filter

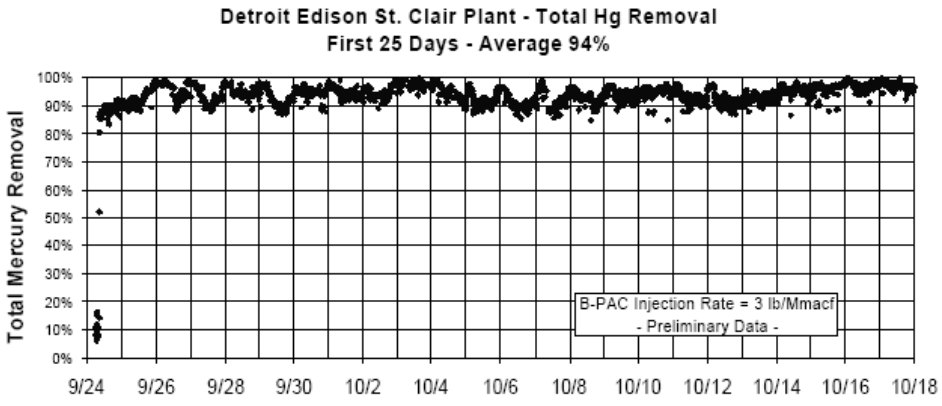


Field Test Results of Activated Carbon Injection for Mercury Control



From Feeley, T., 2003, A Review of DOE/NETL's Mercury Control Technology R&D Program for Coal-Fired Power Plants

Mercury Control at St. Clair Power Plant Using Brominated Powdered Activated Carbon Injection



From Nelson, S. 2004 (Sorbent Technologies, Inc.)

Status – NOx & Ozone

- Nationwide average 8-hour O_3 levels have declined by 21% since 1980, but rate of decline has decreased since 1990
- In 2003, more than 100 million people lived in the 209 counties with poor ozone air quality based on 8-hour standard
- NOx "SIP call" reducing emissions from power plants and industrial boilers
- Other sectors (esp. transportation) are also important NOx sources

Status - Sulfur Dioxide/Particulates

- Nationwide, acid rain provision of CAA have resulted in reduced emissions of 10.6 million tons (38 percent) from 1990 levels
- Wet sulfate deposition has decreased 39 percent in northeastern U.S. and 17 percent in southeastern U.S. from ≈ 1990 levels
- But...
  - Progress has been uneven – 42 % of plants operating in 1990 and 2001 increased SO_2 emissions over period
  - Emissions from 41 larger plants have been associated with up to 5,600 premature deaths, 111,000 asthma attacks, and 930,000 work loss days annually (Abt & Associates, 2002)

Air Quality Response to August 2003 Blackout

- Airborne measurements over central Pennsylvania during blackout revealed decreases in several air pollutants due to shutdown of upwind power plants:
  - SO_2: > 90% reduction
  - O_3: approx. 50% reduction
  - Light scattering by particles: approx. 70% reduction
- Translated into reduction in low-level O_3 of approximately 38 ppbv and improvement of visibility by > 40 km.

Clean Air Interstate Rule (CAIR)

- Promulgated by EPA on March 10, 2005, covering 28 eastern states and D.C.
- Uses cap and trade approach to reduce SO_2 and NOx emissions
- States have option to:
  - Meet state emissions budgets, with power plants participating in EPA-administered cap and trade program; or
  - Meet state emissions budgets through measures of state's choosing
- Projected reductions (from 2003 baseline) include:
  - By 2015, 57% reduction in power plant SO2
  - By 2015, 61% reduction in power plant NOx
- Projected benefits include:
  - $100 billion in annual health benefits by 2025
  - $2 billion in annual visibility benefits in eastern parks
  - Reductions in acidified surface waters in Eastern U.S.

Status – Mercury

- Mercury contamination of environment remains persistent problem, threatening human health (e.g., up to an estimated 600,000 newborns annually in U.S.) and wildlife
- Emission limits have been promulgated over past decade for numerous sources (e.g. incinerators, industrial boilers, chlor-alkali plants)
- Significant amount of current research ongoing on various control/reduction approaches, including coal cleaning, lower cost sorbents for flue gas, and multipollutant options
- Existing and emerging technologies indicate several options for cost-effective approaches, including for higher control effectiveness (i.e. 90% or higher)

Clean Air Mercury Rule (CAMR)

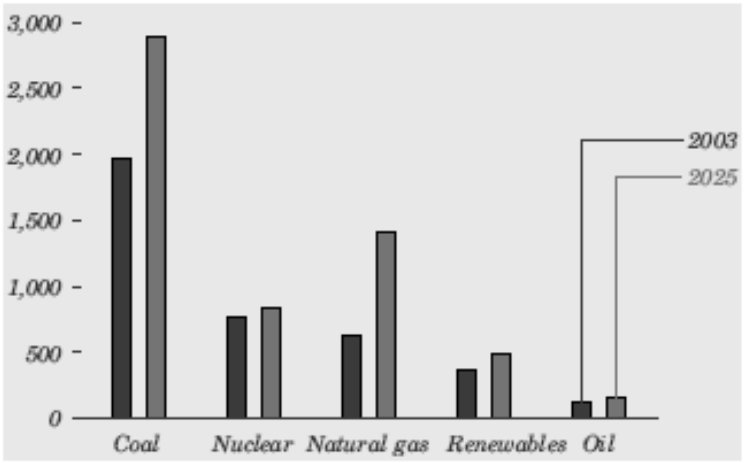
- Promulgated by EPA on March 15, 2005 to address mercury emissions from coal-fired power plants
- Uses cap and trade approach, with two phases:
  - 38 ton cap by 2010
  - 15 ton cap (approx. 69% reduction by 2018)
- States must meet statewide emissions budgets, and can participate in EPA cap and trade program
- First time EPA has regulated a hazardous air pollutant using a cap and trade approach, rather than via Maximum Achievable Control Technology provision
- Rule is under legal challenge by approx. one dozen states, environmental groups

Mercury Regulation – Other Issues

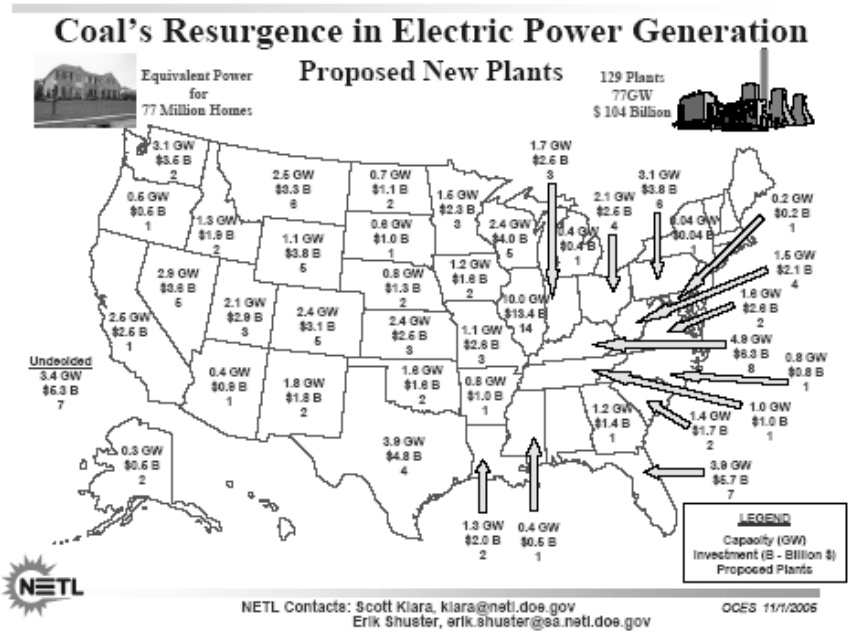
- Recent studies have estimated impact of power plant mercury pollution:
  - Northeast States for Coordinated Air Use Management (NESCAUM) report estimated annual benefits in reducing Hg could be up to $288 million for decreased impairments in children, and up to $4.9 billion for decreased cardiovascular disease in adults (higher uncertainty)
  - Other research estimated annual children's health costs (due to decreased IQ, earning potential) of power plant Hg pollution at (midrange) $1.3 billion (Trasande et al., 2005)
- Associations of state and local air pollution control officials this week released model rule more stringent than CAMR, that states can adopt

Current Projections Indicate Increased Coal-Fired Electricity Generation in U.S.

Figure 69. Electricity generation by fuel, 2003 and 2025 (billion kilowatthours)



Source: DOE, Energy Information Administration, Annual Energy Outlook 2005



Source: DOE, NETL, Tracking New Coal-Fired Power Plants, Nov. 7, 2005

Ongoing Issues/Future Possibilities

- Coal will remain major fuel source for electric power for decades
- While new/recent rules will lead to emissions reductions, increased generation will slow progress, and environmental/human health impacts will remain for years
- Other coal-based approaches offer cleaner options (e.g. integrated coal gasification combined cycle)
- Non-fossil fuel-based generation and other measures (renewables, efficiency, conservation) can lead to environmental benefits on front and emissions ends