Utility PM and Precursor Emissions and Multi Pollutant Control Options: Regulatory Landscape, Technologies, and Costs

Praveen Amar, Director, Science and Policy, NESCAUM

Rui Afonso, President, Energy and Environmental Strategies

NYSERDA Conference: Linking Science and Policy

Albany, New York

October 7-8, 2003

NESCAUM
Northeast States for Coordinated Air Use Management

What is NESCAUM?

- Northeast States for Coordinated Air Use Management
- Association of air quality divisions of state departments of environmental protection
- Provides Scientific, Technical and Policy Support
- Assists states in complying with Federal regulation and in developing regionally consistent strategies

Overview

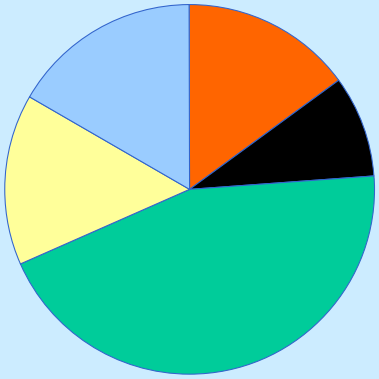
- Regulatory landscape: Federal and states in the Northeast
- Role of smart environmental regulation in driving technology innovation and application
- A look back at seasonal NOx controls
- Multi-p federal legislative proposals/Hg MACT/state initiatives

NESCAUM
Northeast States for Coordinated Air Use Management

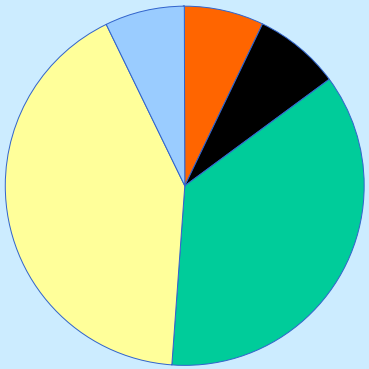
Sources of Fine Particles

- **SULFATE** from SO2 (Power Plants and Coal & Oil-fired Boilers)
- **NITRATE** from NOx (Cars, Trucks, Power Plants & Heavy Equipment)
- **CRUSTAL MATERIAL** (Roads, Construction & Field Dust)
- **ELEMENTAL CARBON** (Diesel Engines, Heavy Equipment, Highway Vehicles)
- **ORGANICS** (Wild Land Fires, Waste Burning, Heavy Equipment Engines, Cars & Trucks)

Typical Western City

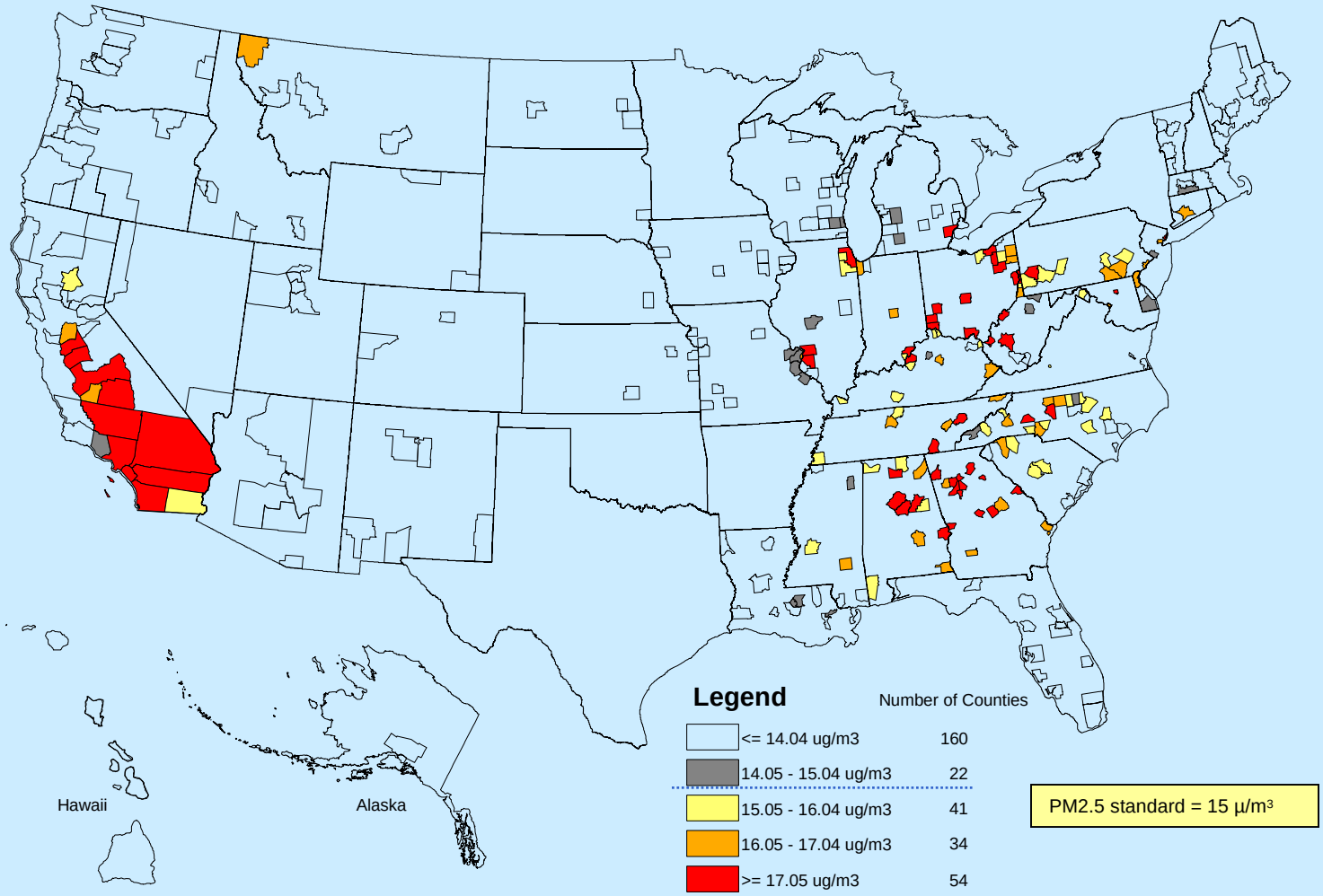


Typical Eastern City



NESCAUM
Northeast States for Coordinated Air Use Management

Current Attainment with the Fine Particle ($PM_{2.5}$) Standard (1999-2001)



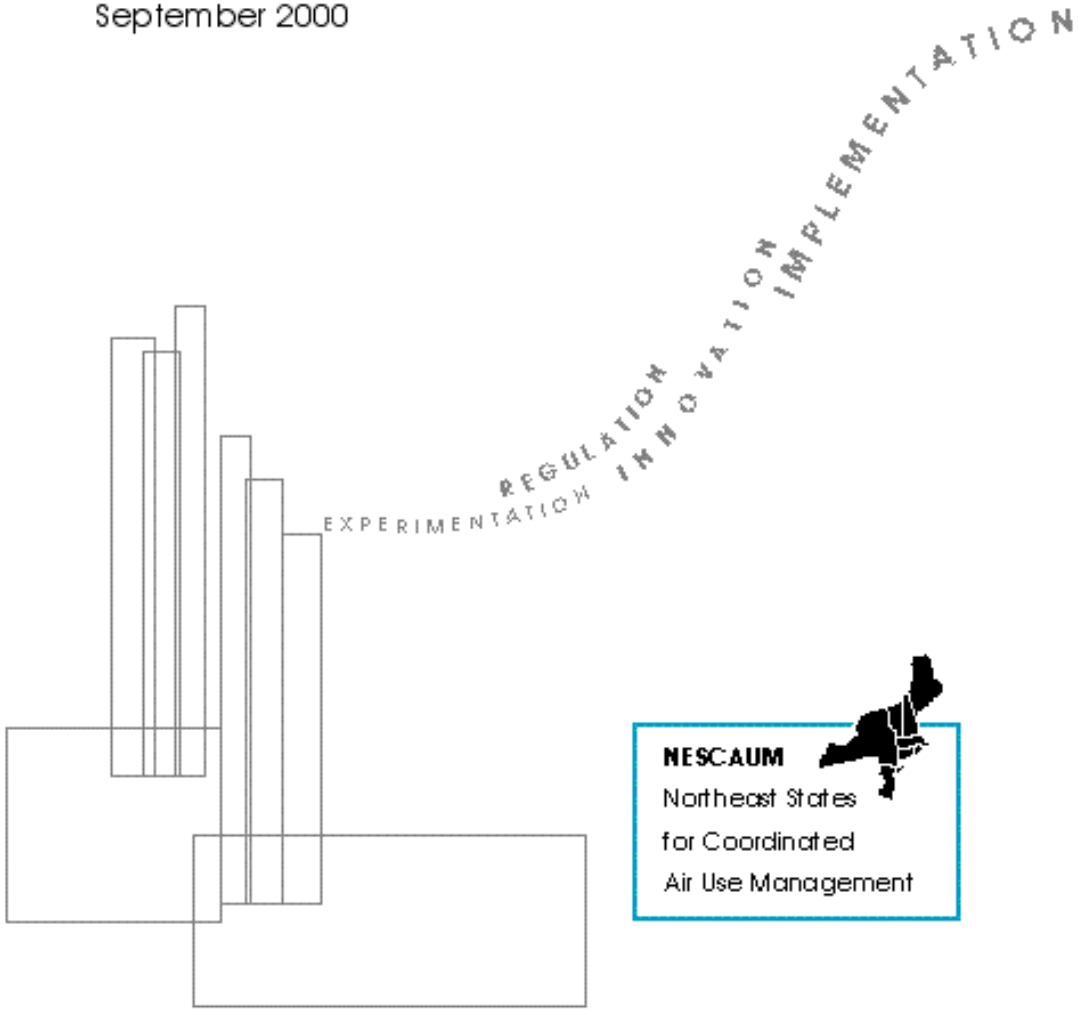
- **There are 129 counties nationwide (114 counties in the East) that are likely to exceed the annual fine particle standard of 15 µ/m³.**
- **65 million people (43 million people in the East) live in counties that would not meet this standard.**

NESCAUM
Northeast States for Coordinated Air Use Management

Environmental Regulation and Technology Innovation:

Controlling Mercury Emissions from Coal-Fired Boilers

September 2000



NESCAUM
Northeast States
for Coordinated
Air Use Management

NESCAUM Report:
Environmental Regulation & Technology Innovation

- Evaluated historical relationships over 50 years between environmental regulatory drivers and development, implementation, and innovation in control technologies and strategies
- Three case studies: SO2 from power plants; NOx from power plants; & Automobiles (controls/fuels/engines)

NESCAUM
Northeast States for Coordinated Air Use Management

NESCAUM Report: Key Findings

- "Where strong regulatory drivers exist, substantial technological improvements & steady reductions in control costs follow."
- "Dynamic occurs even when control options were limited or untested at the time regulations were introduced."

NESCAUM
Northeast States for Coordinated Air Use Management

Acid Rain/SO_2

- First SO2 scrubber was installed at a power plant in London in 1930s
- First US installation in 1968
- Initially high capital & operational costs
- Weak environmental driver: 1990 CAAA; only 50% reduction required; 90 to 95% very doable and extremely cost-effective
- As of 2001, only 180 scrubbers for about 1,100 boilers (only 30 scrubbers after the 1990 CAAA !)

NESCAUM
Northeast States for Coordinated Air Use Management

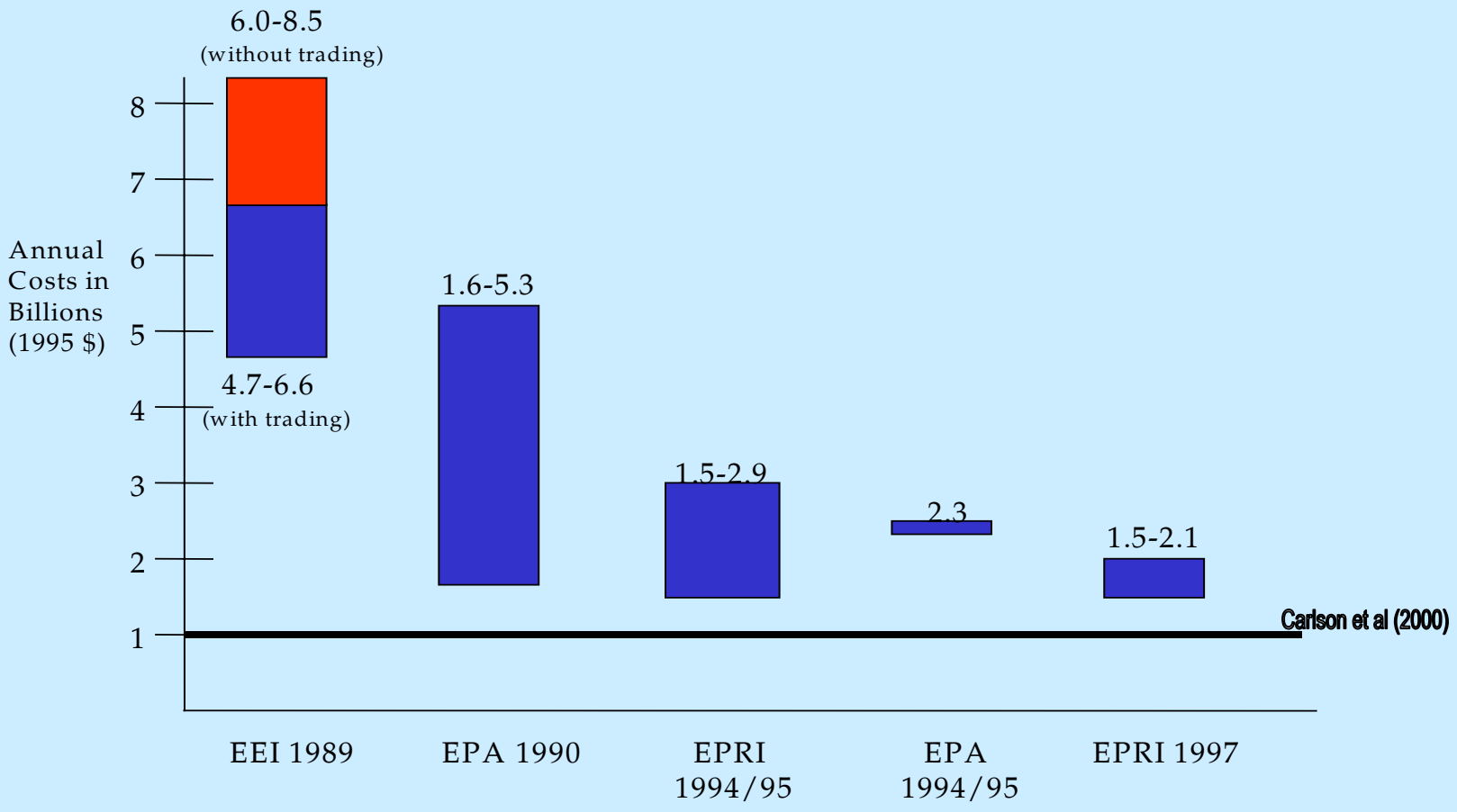
Coal Capacity (in MW) Equipped with Scrubbers (only 1/3 of the US coal-based MW capacity !)

Technology	United States	Abroad	World
Wet	82,092	114,800	196,892
Dry	14,081	10,654	24,735
Regenerable	2,798	2,394	5,192
Total FGD	**98,971**	**127,848**	**226,819**

Source: ORD, EPA

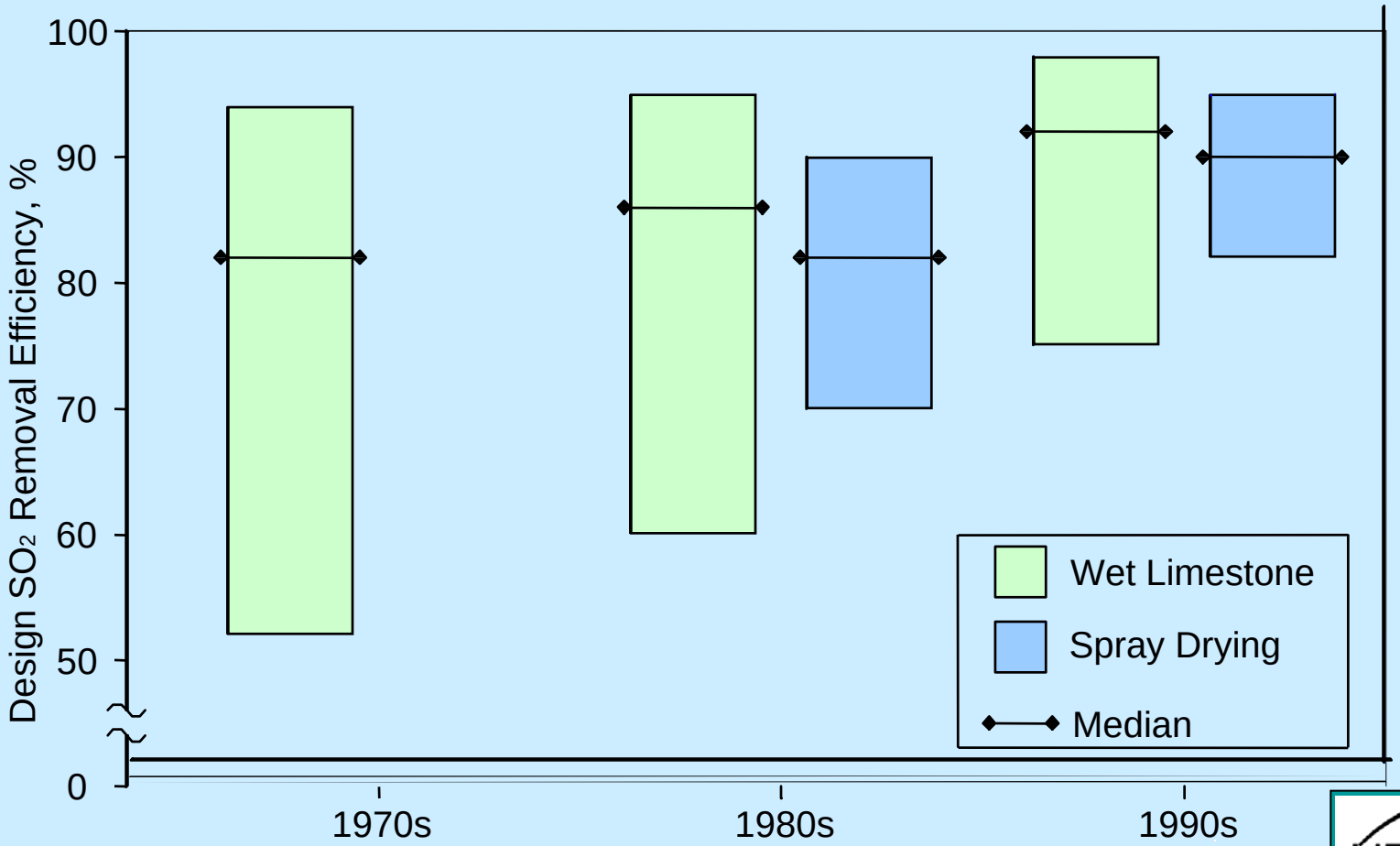
NESCAUM
Northeast States for Coordinated Air Use Management

History (1989 - 1997) of Cost Projections: Federal Acid Rain Program (Phase II)



NESCAUM
Northeast States for Coordinated Air Use Management

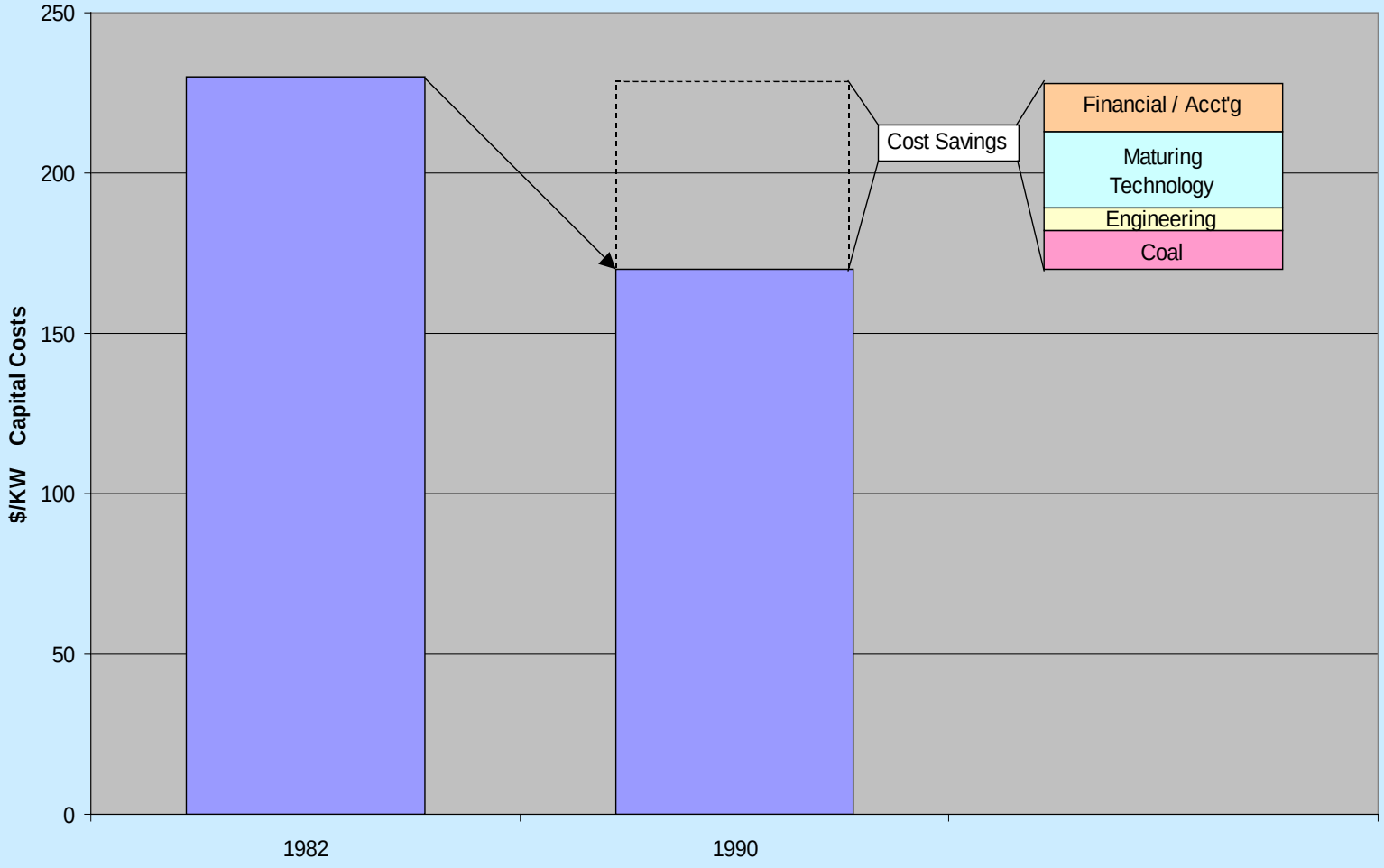
History of Improving FGD Performance



Source: ORD, EPA

NESCAUM
Northeast States for Coordinated Air Use Management

Acid Rain Scrubbers: Regulation Drives Cost Down by 25%



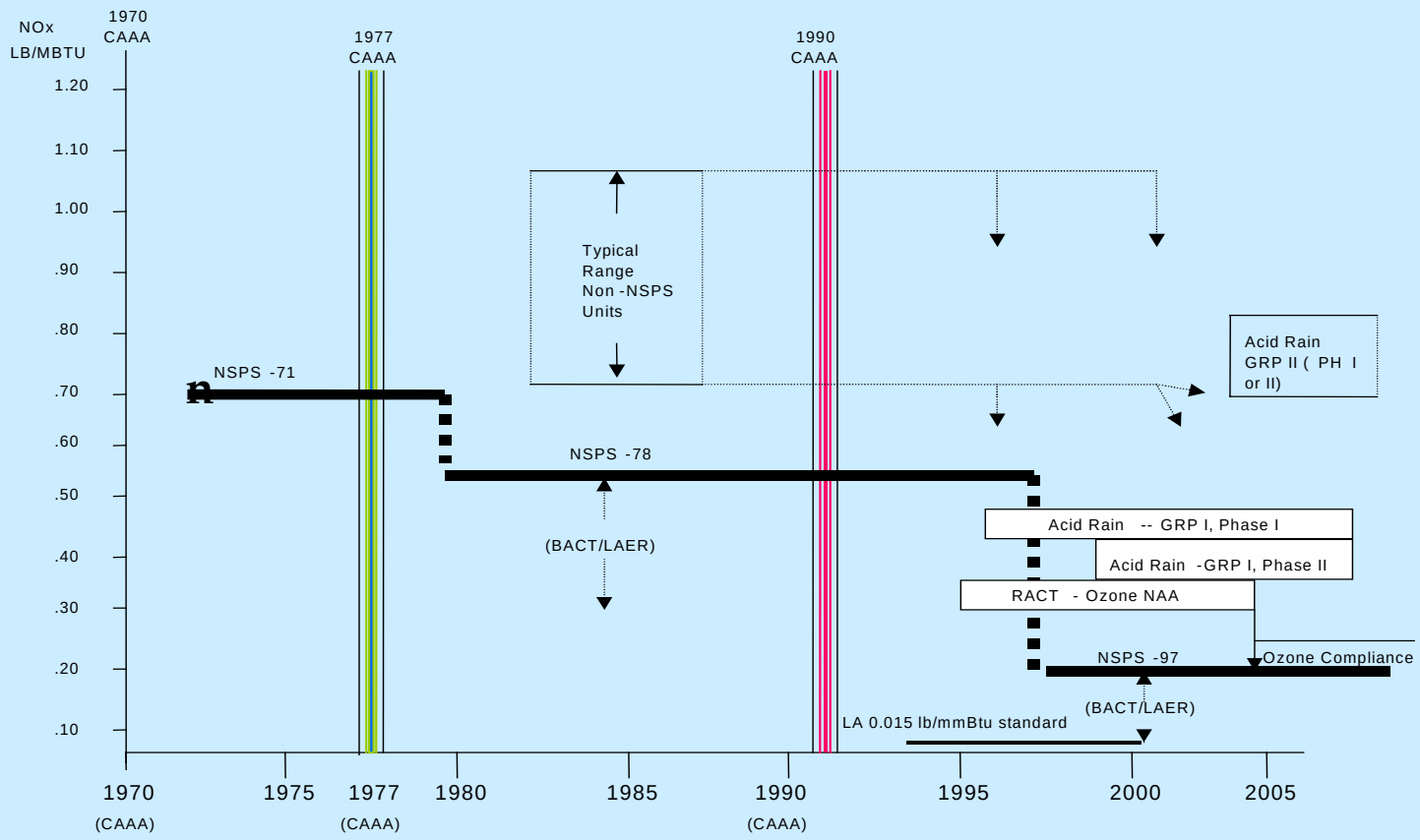
NESCAUM
Northeast States for Coordinated Air Use Management

NOx From Power Plants

- Technologies in use outside US (Germany and Japan) in late seventies and mid eighties
- Resistance in US (concern about costs and "NOx disbenefits")
- Weak regulatory drivers prior to 1990 CAAA

NESCAUM
Northeast States for Coordinated Air Use Management

The Relationship Between Regulations and Implementation of NO_x Control



NESCAUM
Northeast States for Coordinated Air Use Management

Cost of NOx Controls
Selective Catalytic Reduction

Study	Capital Costs ($/kW)	% Decrease	$ Per Ton	% Decrease
EPRI 1985	90-155	--	2,800 - 11,290	--
EPRI 1989	125	0	2,500 – 5,000	4 - 55
NESCAUM 1998	50-75	40-60	1,000 – 1,100	64 - 90

NESCAUM
Northeast States for Coordinated Air Use Management

Emerging Issue: Control Technologies for Hg, Other HAPs, Primary Fine PM, and Multi-p

Are we ready to learn from the past ?

NESCAUM
Northeast States for Coordinated Air Use Management

NESCAUM and MARAMA 1998 Status Report on NOx:

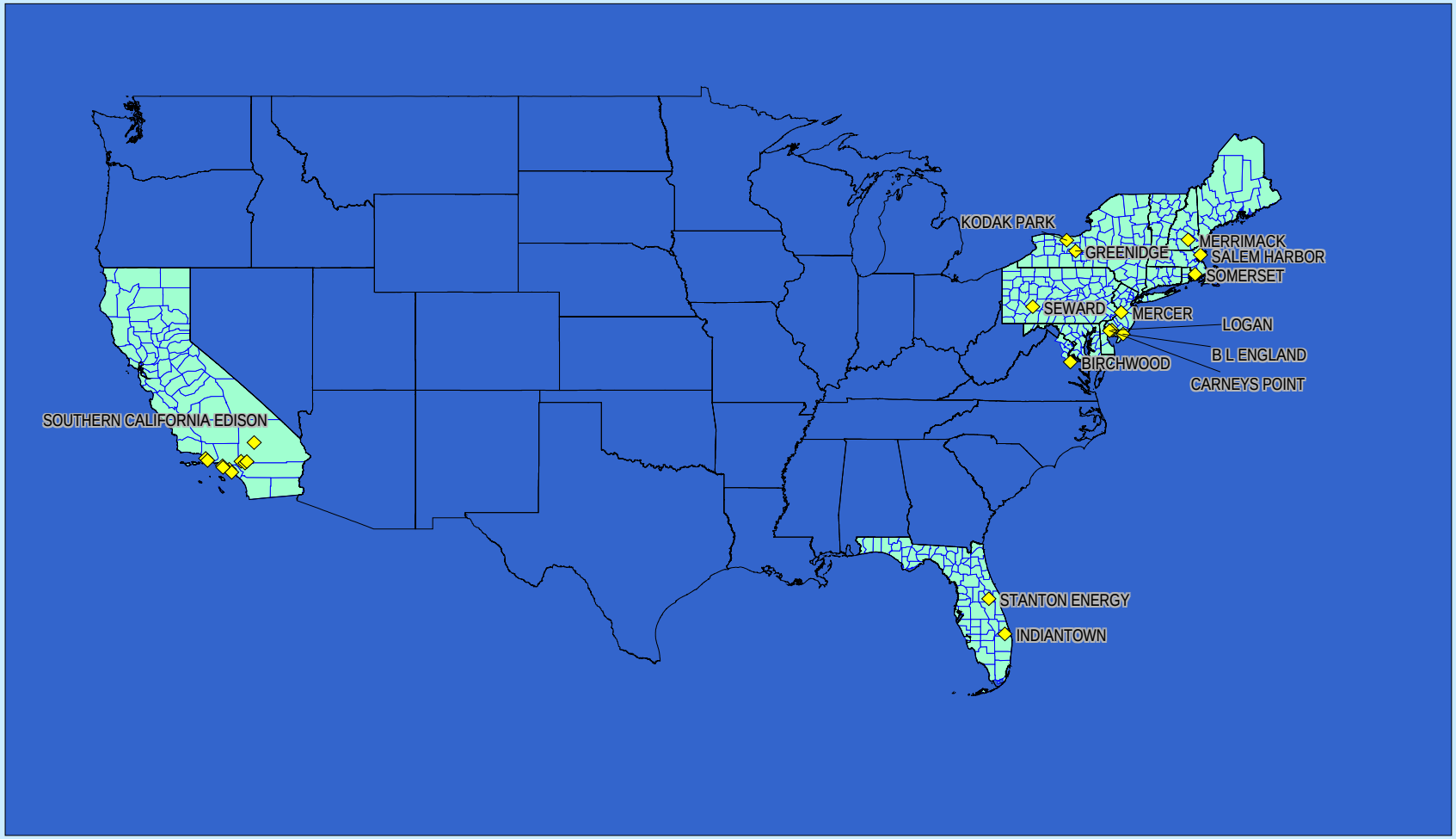
Control Technologies and Cost Effectiveness for Utility Boilers

A look back at a “bad” policy call on “ ozone-season only” NOx controls

NESCAUM Northeast States for Coordinated Air Use Management

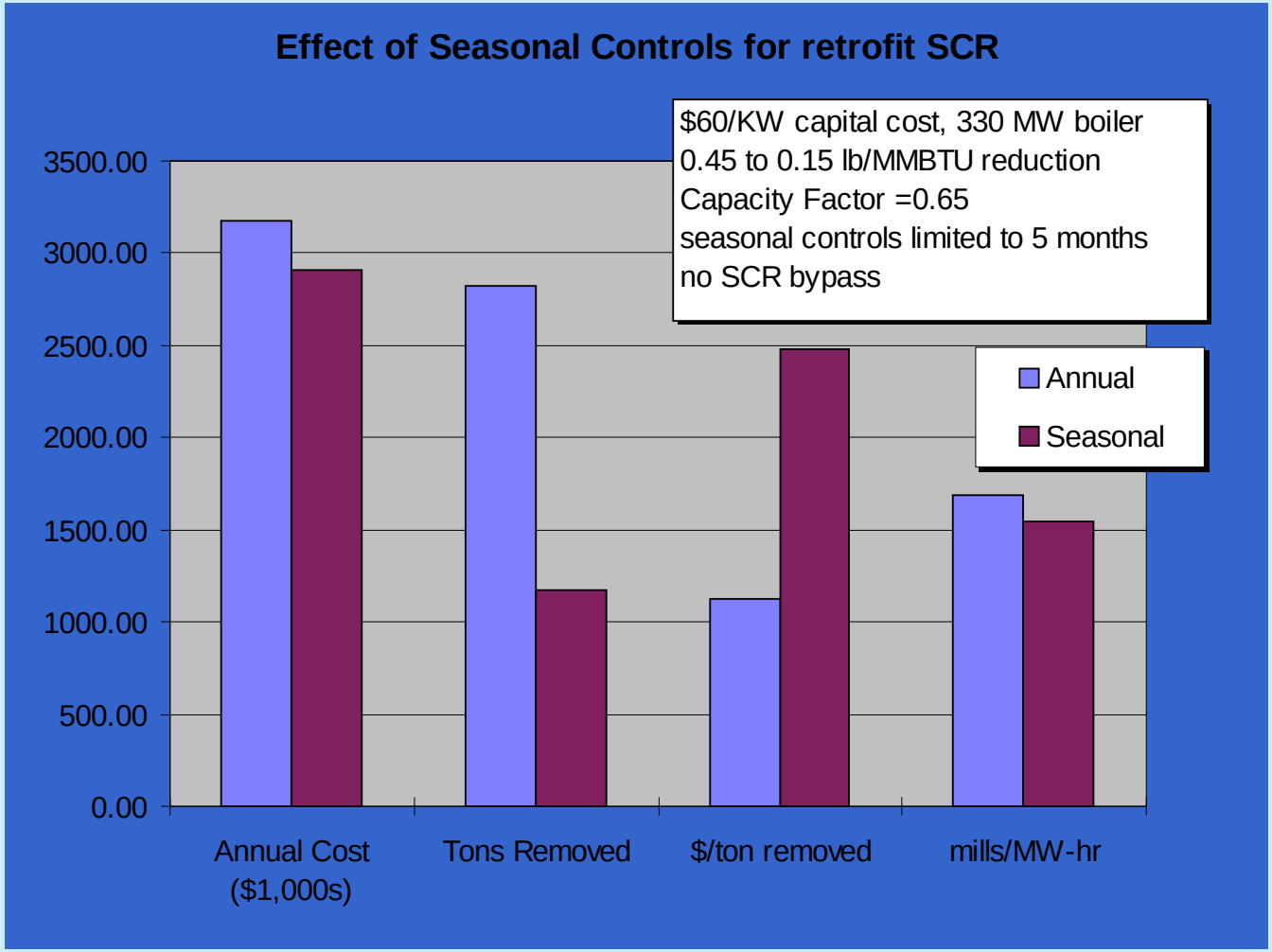
MARAMA Mid-Atlantic Regional Air Management Association

Case Study Locations



NESCAUM
Northeast States for Coordinated Air Use Management

SCR Group 1 Boilers -
Impact of Seasonal Controls



NESCAUM
Northeast States for Coordinated Air Use Management

SCR Cost Summary

Summary of Approximate Retrofit NOx Control Costs - SCR									
Technology	**Reduction**			**Cap. Cost**	**Capacity Factor**	**Annual Control**		**Seasonal Control**	
	From: lb/MMBTU	**To: lb/MMBTU**	**% Red'n**	**$/KW**	**%**	**$/ton**	**$/MWhr**	**$/ton**	**$/MWhr**
SCR Coal-Grp 1	0.45	0.15	67%	50-70	50-80	825-1,525	1.25-2.30	1,750-3,430	1.10-2.15
SCR Coal-Grp 1	0.45	0.07	85%	70-90	50-80	900-1,550	1.65-2.80	1,890-3,350	1.50-2.65
SCR Coal-Grp 2	1.50	0.35	75%	50-70	50-80	390-560	2.23-3.20	760-1,165	1.80-2.80
SCR Coal-Grp 2	1.50	0.15	90%	70-90	50-80	400-570	2.70-3.85	790-1,200	2.20-3.40
SCR Gas	*0.20*	*0.03*	*85%*	*~35*	*50-80**	*1,200-1,500*	*1.00-1.40*	*2,500-3,800*	*0.90-1.30*
SCR Gas	0.20	0.03	85%	~35	10-20	2,950-5,450	2.50-4.64	6,700-12,750	2.37-4.51

* ***In 1996 only 8 of the 123 oil/gas fired units (~4% of the total capacity) in the OTR had a Capacity Factor (CF) of 50% or more***

NESCAUM
Northeast States for Coordinated Air Use Management

Seasonal versus Annual Emission Reductions for Nitrogen Oxides

Analysis by

Resources for the Future

2001

NESCAUM
Northeast States for Coordinated Air Use Management

Question asked by RFF

- What is the most cost-effective way to achieve NO_x reductions with existing generating capital, given full set of NO_x related problems?

NESCAUM
Northeast States for Coordinated Air Use Management

Main Findings of RFF Study

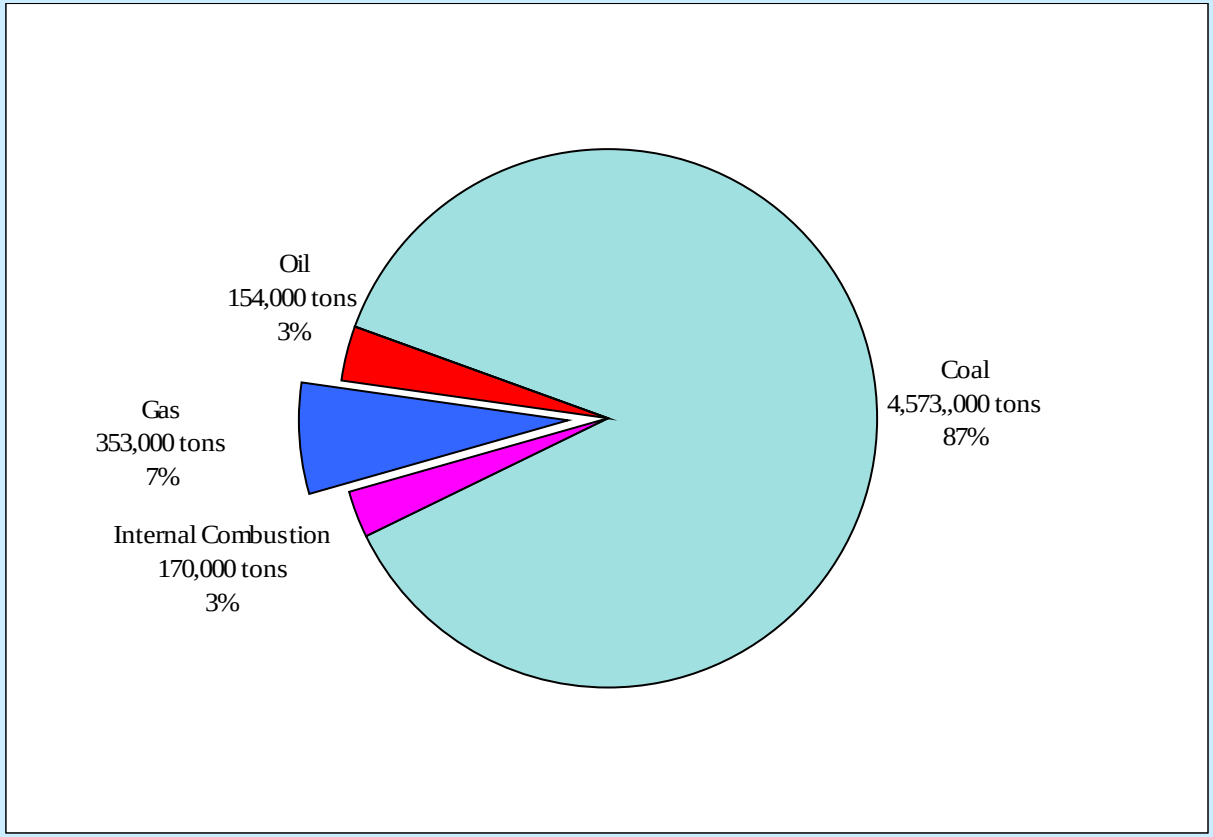
- Annual policy yields $450 million to $770 million per year in additional net benefits.
- Finding is robust to omitted benefits.
- Annual policy has small effect on politically sensitive measure of electricity price.

NESCAUM
Northeast States for Coordinated Air Use Management

Existing NOx Regulations

NESCAUM
Northeast States for Coordinated Air Use Management

Utility Sources of NOx



Title IV NOx Program, Phase I

- Affected sources nationwide, starting January 1, 1996
- Emission limits for Group 1 boilers
  - Dry bottom, wall-fired: 0.50 lb/10^6 Btu
  - Tangentially fired: 0.45 lb/10^6 Btu
  - Basis: low NO_x burners
- NOx reduction: 340,000 tons/yr

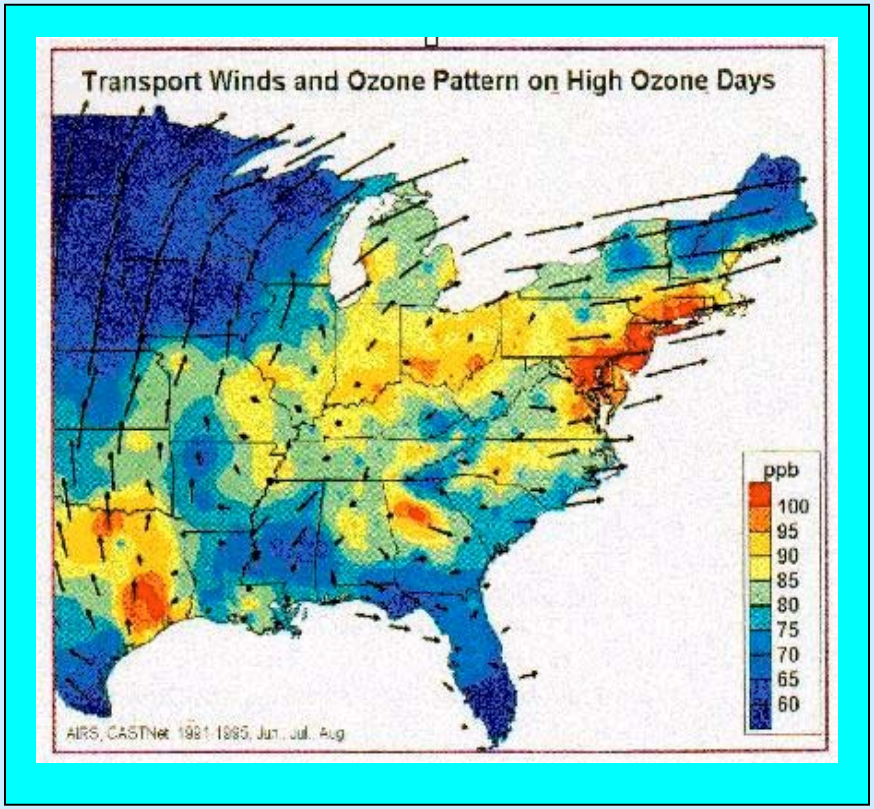
Title IV NOx Program, Phase II

- Affected sources nationwide, starting January 1, 2000
- Revised limits for Group 1 boilers
  - Dry bottom, wall-fired: 0.46 lb/10^6 Btu
  - Tangentially fired: 0.40 lb/10^6 Btu
  - Basis: low NO_x burners
- Emission limits for Group 2 boilers
  - Cyclone (>155 MWe): 0.86 lb/10^6 Btu
  - Cell burner: 0.68 lb/10^6 Btu
  - Wet bottom (>65 MWe): 0.84 lb/10^6 Btu
  - Vertically fired: 0.80 lb/10^6 Btu
  - Basis: Comb. Controls, SCR, NGR
- NOx reduction: About 2 million tons/yr

NESCAUM
Northeast States for Coordinated Air Use Management

NOx SIP Call

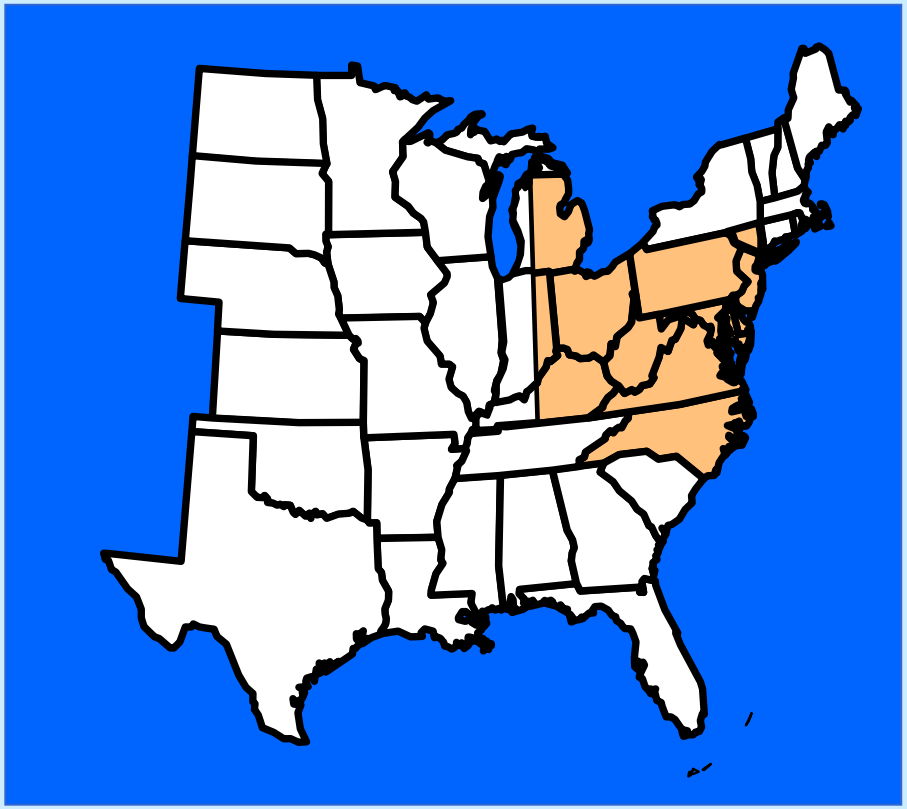
- NO_x budgets for 19 States & DC, starting May 2003-4
- Assumes reductions primarily from large sources in a cap and trade program
  - EGUs (average rate): 0.15 lb/10^6 Btu
  - Non-EGU: 60% control level
- Basis: A variety of NO_x controls
- NOx reduction: 1 million tons by 2007



NESCAUM
Northeast States for Coordinated Air Use Management

Section 126 Rules

- NO_x budgets for 12 States & DC, starting May 31, 2004
- Assumes reductions from large boilers/turbines in a cap and trade program
  - EGUs (average rate): 0.15 lb/10^6 Btu
  - Non-EGU: 60% decrease
- Basis: A variety of NO_x controls
- Requirements do not apply if area has approved NOx SIP Call rules in place



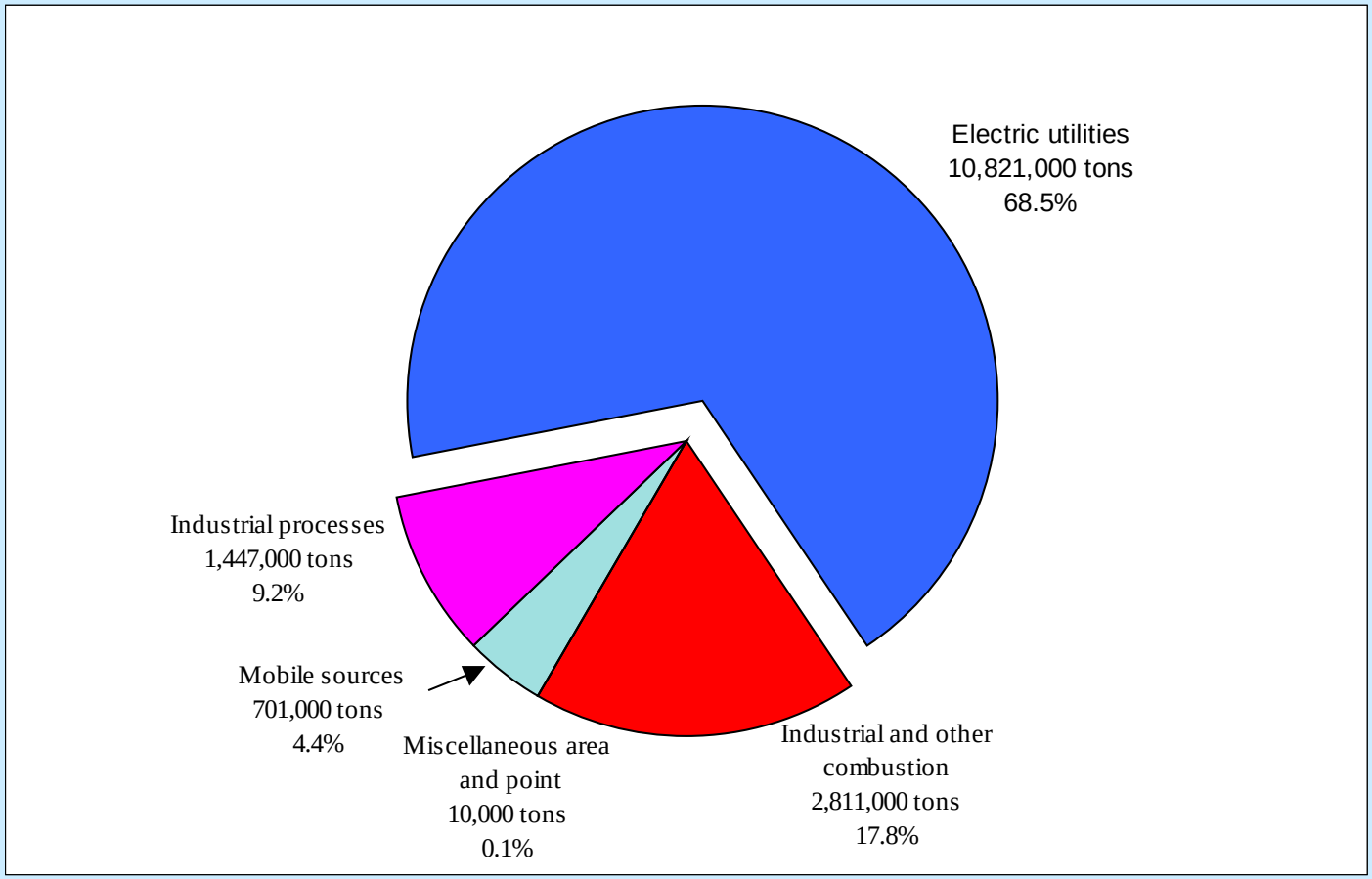
NESCAUM
Northeast States for Coordinated Air Use Management

Existing SO2 Regulations

- **Title IV of the Clean Air Act Amendments of 1990 required SO_2 reductions to address acid rain (deposition)**
- **SO2 reduction via a cap-and-trade program**
  - **Phase I, 1995-2000: 445 units,**
  - **Phase II, 2000- : >2000 units,**

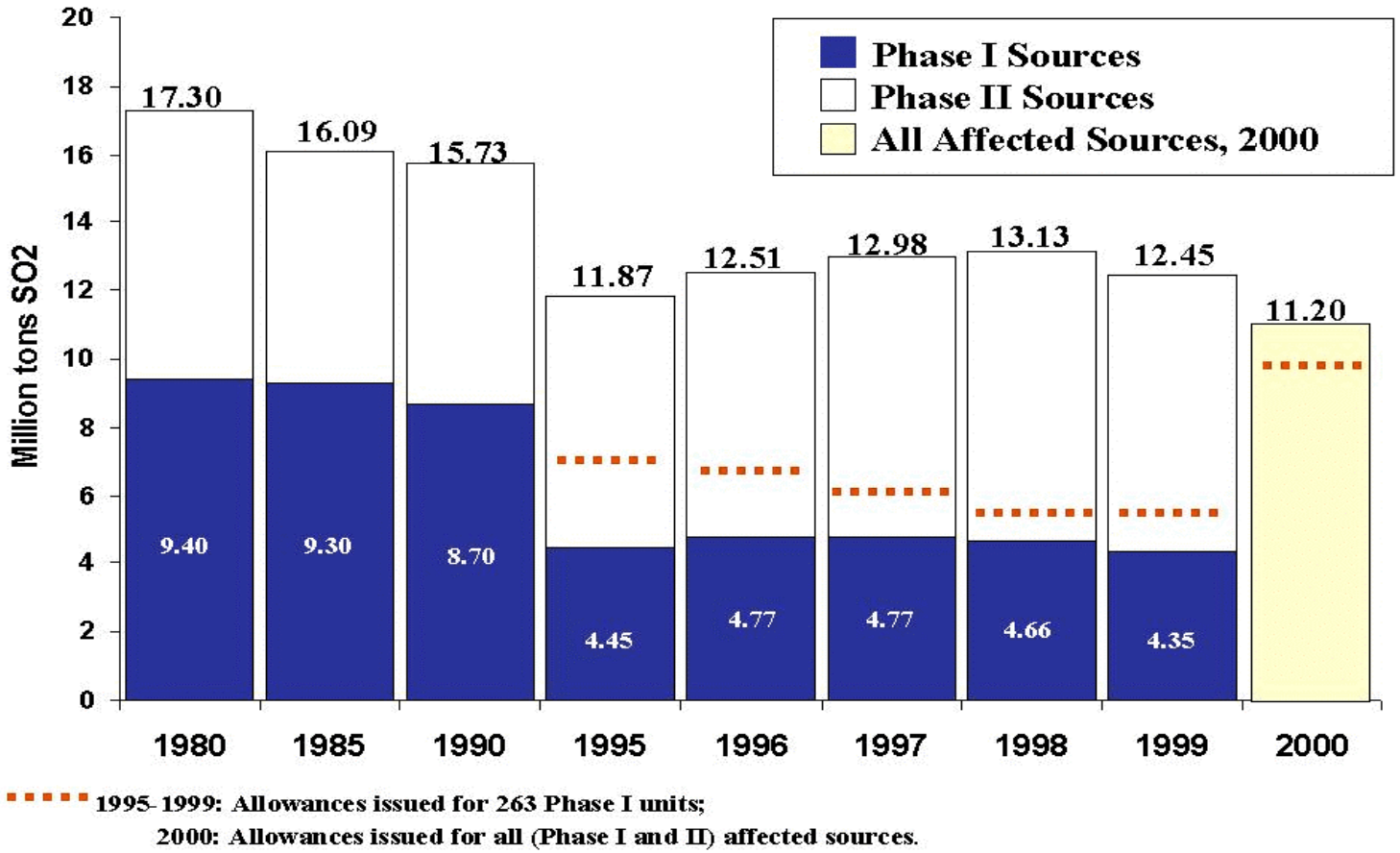
NESCAUM
Northeast States for Coordinated Air Use Management

Sources of SO2



NESCAUM
Northeast States for
Coordinated Air Use
Management

Title IV SO2 Program



NESCAUM
Northeast States for Coordinated Air Use Management

Clean Air Act Section 112 Rule for Hg and other HAPs

- **"Best of the best" for new sources**
- **Average of the top performing 12 percent for existing sources defines the floor emission limit**
- **Allows for determining the floor based on subcategories (based on what ?)**
- **Emissions standard applicable to each source**
- **Section 112 does not allow trading between facilities to meet the standard**

NESCAUM
Northeast States for Coordinated Air Use Management

Sources of Mercury

- Top five anthropogenic sources (1999)
  - **Utility coal - 48 tons (40%)**
  - Industrial boilers - 12 tons (10%)
  - HWI - 6.6 tons (5.5%)
  - Chlorine production - 6.5 tons (5.4%)
  - MWC - 5 tons (4.0%): **THE GREAT SUCCESS STORY**

NESCAUM
Northeast States for Coordinated Air Use Management

Mercury MACT Plans/ Schedule

- **Under settlement agreement, proposal of MACT rule on or before December 15, 2003 UNLESS multipollutant legislation enacted before then that amends CAA and eliminates MACT requirement**
- **Promulgation on or before December 15, 2004**
- **Litigation expected**
- **Compliance by December 15, 2007 (extensions?)**

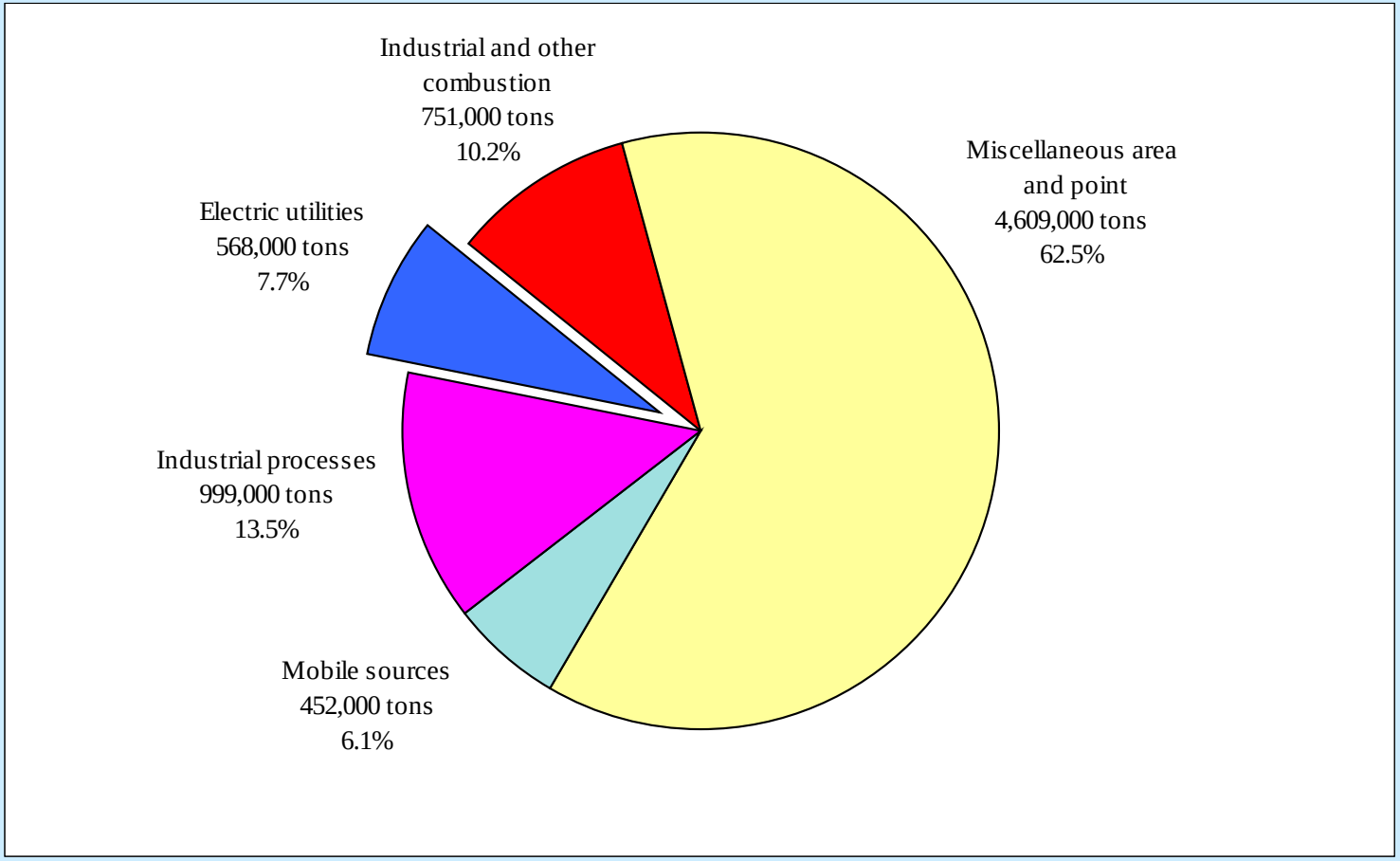
NESCAUM
Northeast States for Coordinated Air Use Management

Fine PM (and Hg/HAPs) Control

- An emerging issue: Most (84%) of the US coal utility infrastructure has ESPs; only 14% , the more efficient baghouses
- Though both do well (99%+) for total PM mass, baghouses do much better (99%+) than ESPs (80 to 95%) for fine PM mass
- Has serious implications for control of hazardous air pollutants (HAPs) including mercury; cost of retrofitting existing infrastructure with baghouses? $20-$40/KW?

NESCAUM
Northeast States for Coordinated Air Use Management

$PM_{2.5}$ Sources



PM Regulatory Schedules

8-hr Ozone Standards

2003 States recommend nonattainment designations

- EPA makes nonattainment designations

2005-09 New NOx Rule/NAAQS Review

2007-08 States develop/submit SIPs

2007-08 EPA approves SIPs

2007-19 Attainment deadlines vary

Regional Haze Program

2007-08 States submit regional haze SIPs

2008-09 EPA approves SIPs

2013-18 Plants must install BART or comply with backstop trading program

$PM_{2.5}$ Standards (fine particles)

2003 States recommend nonattainment designations

2004-05 EPA makes nonattainment designations, complete NAAQS review

2005 EPA Issues SOx/NOx transport rule

2004-08 States develop/submit SIPs

2008-09 EPA approves SIPs

2010-14 Attainment deadlines

Mobile Source Program

2003 Non-road diesel proposal

2003-- Other non-road categories

2004 Tier 2 becomes effective

- HD diesel rules effective

NESCAUM
Northeast States for Coordinated Air Use Management

Clean Air Act is a Complex Set of Requirements Covering the Power Sector

NSR Permits for new sources & modifications that increase emissions

Ozone

- OTC NO_x Trading
- 1-hr Serious Area Attainment Date
- NO_x SIPs Due
- Section 126 NO_x Controls [1]
- Designate areas for 8-hr Ozone NAAQS
- NO_x SIP Call Red-uc-tions
- 1-hr Severe Area Attainment Date
- Marg-inal 8-hr Ozone NAAQS Attain-ment Date
- 8-hr Ozone Attain-ment Demon-stration SIPs due
- Assess Effectiveness of Regional Ozone Strategies
- Possible Regional NO_x Reductions ? (SIP call II) [2]
- Moderate 8-hr Ozone NAAQS Attainment Date
- Serious 8-hr Ozone NAAQS attainment Date

99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18

- Phase II Acid Rain Compliance
- Mercury Determination
- Proposed Utility MACT
- Designate Areas for Fine PM NAAQS
- Final Utility MACT
- Interstate Transport Rule to Address SO_2/ NO_x Emissions for Fine PM NAAQS and Regional Haze
- New Fine PM NAAQS Implementation Plans
- Regional Haze SIPs due
- Compliance with Utility MACT
- Latest attainment date for Fine PM NAAQS [3]
- Compliance for BART Sources
- Compliance for BART sources under the Trading Program
- Second Regional Haze SIPs due

Acid Rain, $PM_{2.5}$, Haze, Toxics

Note: Dotted lines indicate a range of possible dates.

[1] The D.C. Circuit Court has delayed the May 1, 2003 EGU compliance date for the section 126 final rule

[2] Further action on ozone would be considered based on the 2007 assessment.

[3] The SIP-submittal and attainment dates are keyed off the date of designation; for example, if PM or ozone are designated in 2004, the first attainment date is 2009

EPA is required to update the new source performance standards (NSPS) for boilers and turbines every 8 years

In developing the timeline of current CAA requirements, it was necessary for EPA to make assumptions about rulemakings that have not been completed or, in some case, not even started. EPA's rulemakings will be conducted through the usual notice-and-comment process, and the conclusions may vary from these assumptions.

NESCAUM
Northeast States for Coordinated Air Use Management

Overview of the Proposals

	NOx Cap	SO_2 Cap	CO_2 Cap	Hg Cap	Emission Trading	NSR & Other Regulatory Reform	Allocation Methodology
Clean Power Act (S. 366) Main Sponsor: Jeffords	1.51 MT by 2009	2.25 MT by 2009; with 0.28 MT in west (WRAP + MT, WA, CA) and 1.98 MT in eastern region.	2.05 BT by 2009 (roughly 1990 levels) plus flexibility mechanisms.	5 T by 2009	Trading allowed for NOx, SO_2 and CO_2. No trading for mercury.	Retains NSR. Contains "birthday" provision: 40 years after commencing operation, each facility subject to BACT.	Declining share of total cap (starting at 10%) allocated to EGUs based on output basis. All other allowances auctioned with $$ going to consumers, electricity-intensive industries, renewables & EE & carbon sequestration.
Clean Air Planning Act (S. 843) Main Sponsors: Carper, Chaffee, Gregg	1.87 MT by 2009 1.7 MT by 2013	4.5 MT by 2009 3.5 MT by 2013 2.25 MT by 2016	Stabilize at 2006 levels (approx. 2.57 BT) plus flexibility measures in 2009. 2001 levels (approx. 2.47 BT) plus specified flexibility measures in 2013.	24 T by 2009 10 T by 2013 50 & 70% reduction required at each plant in 2009 & 2013, respect-tively.	Cap-and-trade for NOx, SO_2, CO_2 and mercury, w. facility-specific mercury requiremen ts as noted.	NSR restricted to new units (incl. replacement of existing boiler) and to activities that result in increase in maximum hourly rate of emissions of air pollutants regulated under NSR, as measured in lbs/MWh. BACT to be defined biennially. All plants constructed before August 1971 to meet performance standards of 4.5 lb/MWh for SO_2 and 2.5 lbs/MWh for NOx. Definition of LAER changed to include economic considerations and limited to twice the cost of BACT. Federally mandated offset requirements for new units eliminated. States required to identify & remedy adverse local impacts.	For NOx, Hg and CO_2, allocation is output-based using average annual net generation from most recent 3-year period. For SO_2, allocation is based on existing Acid Rain Program, with some modifications.
Clear Skies Act (S. 485; H.R. 999) Sponsors: Inhofe & Voinovich in Senate; Barton & Tauzin in House.	2.1 MT cap in 2008. 1.7 MT cap in 2018	4.5 MT cap in 2010 3.0 MT cap in 2018	Does not include CO_2. Administration has advocated voluntary program for reducing GHG intensity of economy.	26 T cap in 2010. 15 T cap in 2018.	Trading allowed for NOx, SO_2 and mercury.	New or modified sources exempt from NSR and BART so long as they meet new national emissions limits or (1) achieve PM controls of 0.03 lb/mmBtu within 8 years and (2) use good combustion practices to minimize CO. In addition, bill would (1) restrict federal action on Section 126 petitions w. respect to power plants until after 2012 and subject to new cost-benefit require-ments; (2) remove EPA authority to regulate non-Hg HAPs; (3) restrict visibility protections to sources located within 50 km of Class I area; (4) remove offset requirements (provided no inter-ference w. attainment); (5) create new "transitional" designation for areas that can model attainment under future EGU reductions plus local measures. Effective attainment deadlines delayed until as late as 2020 for these areas.	Input-based allocations with auctions for a portion of the allowances each year. Portion of total budget that is auctioned starts at 1% and increases very gradually over time.

NESCAUM
Northeast States for Coordinated Air Use Management

Three Key Questions to ask of each multi-p initiative

- Is it comprehensive?
- Is it sufficient to address the significant public and environmental challenges we face?
- Does it strengthen our clean-air efforts not only at the national level, but also at the local/state/regional levels?

NESCAUM
Northeast States for Coordinated Air Use Management

Other equally important questions to ask of each multi-p initiative

- Does it recognize and incorporate the historic and well-proven relationship between environmental regulatory drivers and technology innovation?
- Does it recognize that current cost estimates are almost always much higher than actual future costs? And then buy the right amount of environmental protection we can afford *now*.

NESCAUM
Northeast States for Coordinated Air Use Management

Sulfur Dioxide - SO_2

What's on the table:

- 3.5-4.5 million ton *interim* cap
- 2.25-3.0 million ton *final* cap
- Dates: 2009-2018

What's at stake:

- PM_{fine} attainment, acid rain recovery, regional haze progress, SO_2 NAAQS attainment (in some areas), public health.

'Status quo' alternative:

- Rely on PM attainment needs, future 126 petitions, cont'd acid rain concerns and regional haze SIPs to drive further reductions.

Other considerations:

- Interaction of existing CAA programs with current Title IV cap of 8.9 million tons.

NESCAUM
Northeast States for Coordinated Air Use Management

Nitrogen Oxides - NO_x

What's on the table:

- 1.87-2.1 million ton *interim* cap
- 1.51-1.7 million ton *final* cap
- Dates: 2009-2018

What's at stake:

- Water quality & nitrogen deposition, acid rain recovery, PM_{fine} attainment, ozone attainment (to the extent tighter caps provide additional summertime reductions), public health.

'Status quo' alternative:

- Rely on water quality/acid rain concerns and PM/regional haze SIPs to drive annual controls. Rely on all of the above, plus ozone attainment needs to drive add'tl overall cuts.

Other considerations:

- 1st phase reductions in all proposals essentially annualize NOx SIP call, hence little further ozone attainment benefit in eastern states. Question about inclusion of industrial boilers now in SIP call.

NESCAUM
Northeast States for Coordinated Air Use Management

Mercury

What's on the table:

- 24-26 ton *interim* cap
- 5-15 ton *final* cap
- Dates: 2009-2018
- Full trading (CSI), no trading (Jeffords), minimum plant-by-plant requirement (Carper)

What's at stake:

- Public health concerns (esp. for fetus and young children); impacts on wildlife.

'Status quo' alternative:

- Rely on mercury MACT process to yield rulemaking by end of 2004 and implementation of plant-specific control requirements by end of 2007.

Other considerations:

- Current Clean Air Act requires controls at level of "Maximum Achievable Control Technology"

NESCAUM
Northeast States for Coordinated Air Use Management

Carbon Dioxide – CO_2

<u>What's on the table</u>:

- **No action (CSI)**
- **2006 levels by 2009 and 2001 levels by 2013 (Carper)**
- **1990 levels by 2009 (Jeffords)**

NESCAUM
Northeast States for Coordinated Air Use Management

States Initiatives/Legislation/Regulation

- New York
  - SO2 and NOx (reg. approved March 2003)
  - SO2: 50% below Title IV (phase II), statewide cap
  - NOx: Year round statewide cap (based on 0.15 lbs/MMBtu)
  - Governor's Task Force on carbon
  - No action on Hg yet

NESCAUM
Northeast States for Coordinated Air Use Management

States Initiatives/Legislation/Regulation

- Massachusetts:
  - NOx, SO2, C, and Hg (facility specific reductions)
  - Output based standards (1.5 lbs/MWhr for NOx by 2004/2006; 3.0 lbs/MWhr for SO2 by 2006/2008); 1800 lbs/MWhr for CO2 by 2006/2008
  - Hg: regulation proposed September 19, 2003

NESCAUM
Northeast States for Coordinated Air Use Management

State Initiatives/Legislation/Regulation

- Connecticut:
  - NOx, SO2 (reg. passed in 2000) and Hg
  - Statewide annual NOx cap (based on 0.15 lbs/MMBtu)
  - Two-phase approach; 0.3% S or 0.33 lbs/MMBtu by 2003 in Phase II
  - June 2003 state leg. to control Hg by 90% by 2008
  - Developing CO2 plan to meet NEG/ECP goals

NESCAUM
Northeast States for Coordinated Air Use Management

State Initiatives/Legislation/Regulation

- New Hampshire:
  - NH's Clean Power Act (2002) for NOx, SO2, CO2, and "future" Hg
  - 90% reduction from 1990 emissions for NOx
  - 87% reductions from 1999 emissions for SO2
  - Return to 1990 levels for CO2 by 2006
  - Cap for Hg to be proposed by 3/2004

NESCAUM
Northeast States for Coordinated Air Use Management

The Northeast is Moving Forward in Controlling Mercury

- On September 19, 2003, Massachusetts announced its proposed regulations for power plants (http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm#regs)
- Public hearings in November 2003
- In simple terms: 85% removal by 2006; 95% removal by 2012 (reduction of over 130 pounds per year)

NESCAUM
Northeast States for Coordinated Air Use Management

Northeast States Mercury Initiatives

- Connecticut passed state legislation in June 2003 requiring 90% reduction in power plant mercury emissions by 2008
- New Hampshire's "Clean Power Act" of 2002 requires a statewide cap on mercury emissions (recommendation on cap expected by March 2004)

NESCAUM
Northeast States for Coordinated Air Use Management