Increases in NO_x Emissions in Coal-Fired, SCR-Equipped Electric Generating Units

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New Jersey Department of Environmental Protection

NJ Clean Air Council
Princeton South Corporate Centre
Ewing, NJ
January 14, 2015

Increases in NO_x Emissions in Coal-Fired, SCR-Equipped Electric Generating Units

- Clean Air Act Amendments (1990)
  - NO_x RACT
  - OTC NO_x Budget Program (1999)
    - Northeast, Mid-Atlantic States
  - "NO_x SIP Call" NO_x Budget Program (2003-04)
    - 20 Eastern States
  - CAIR (2009)
  - CSAPR (2012…..)

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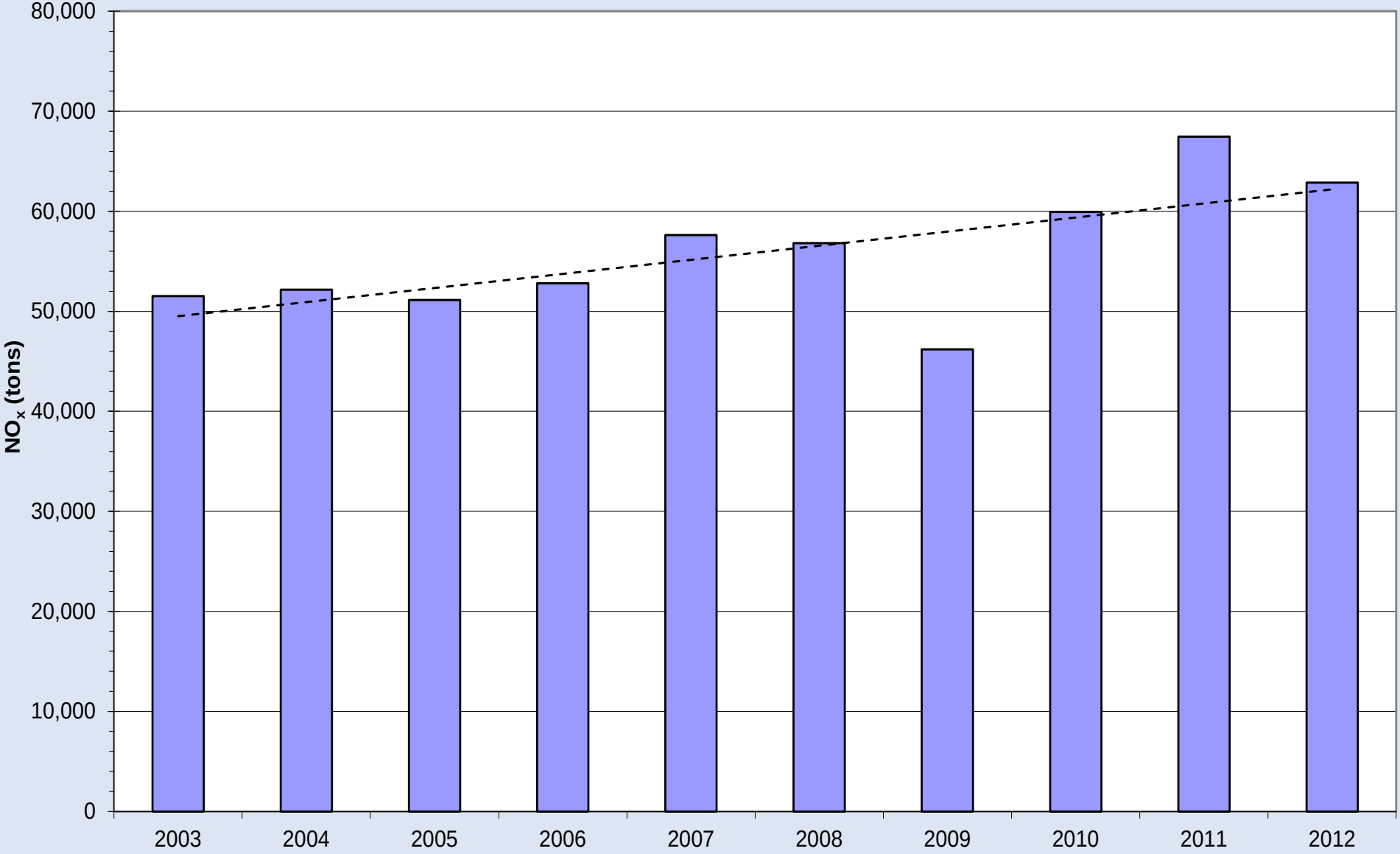
  - CSAPR (2015…..)

What has been Happening?

NJ Ozone Season NO_x Emissions

PA Ozone Season NO_x Emissions



What is NO_x?

- Oxides of Nitrogen

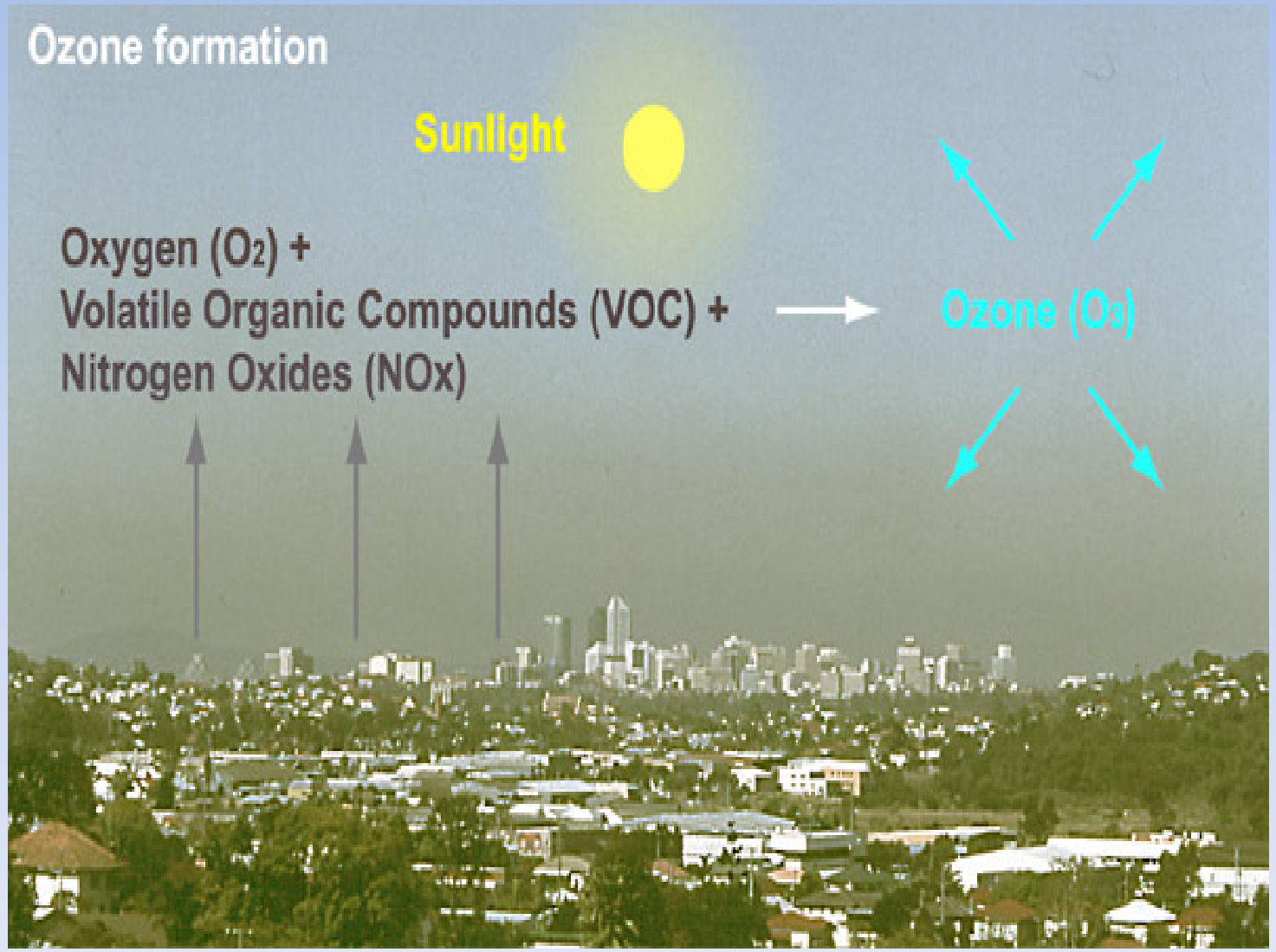
$$N_2 + O_2 \text{ --> } NO, NO_2$$

What is NO_x?

- Oxides of Nitrogen

$$N_2 + O_2 \rightarrow NO, NO_2$$

Why is NO_x a Concern?



What has been Happening?

- Hundreds of coal-fired EGUs have installed SCR

Selective Catalytic Reduction (SCR)

$NO_x + NH_3 \rightarrow$ *catalyst* $\rightarrow N_2 + H_2O$

TiO_2, V_2O_5, WO_3,

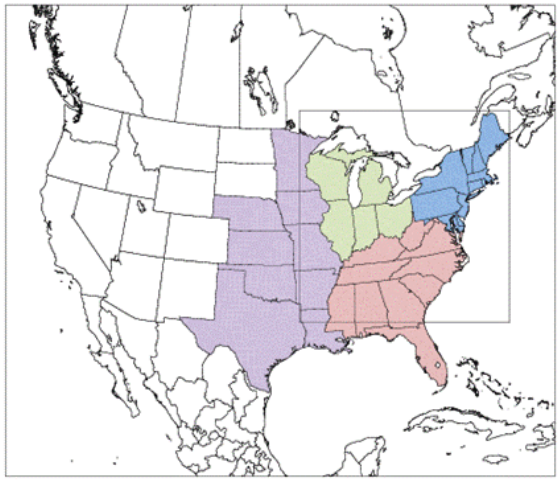
Pt, Pd, zeolites

350° - ~1,100 °F

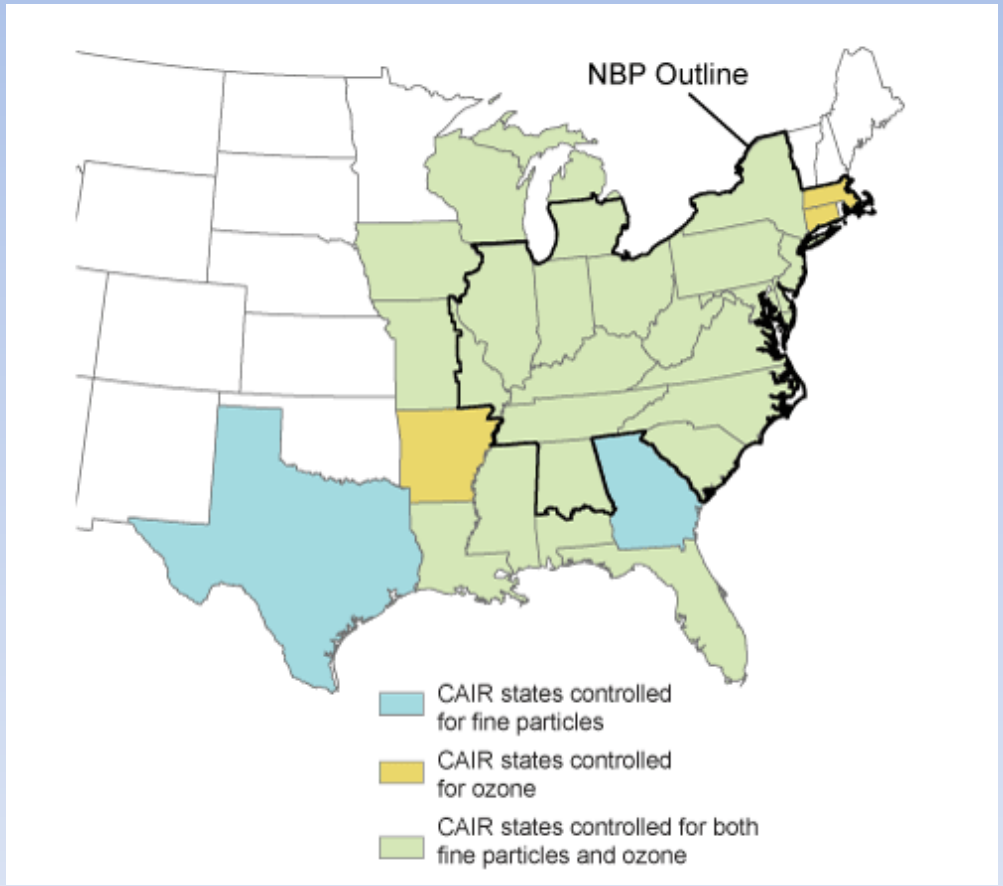
> 90% reduction

Coal-Fired EGUs in Eastern US

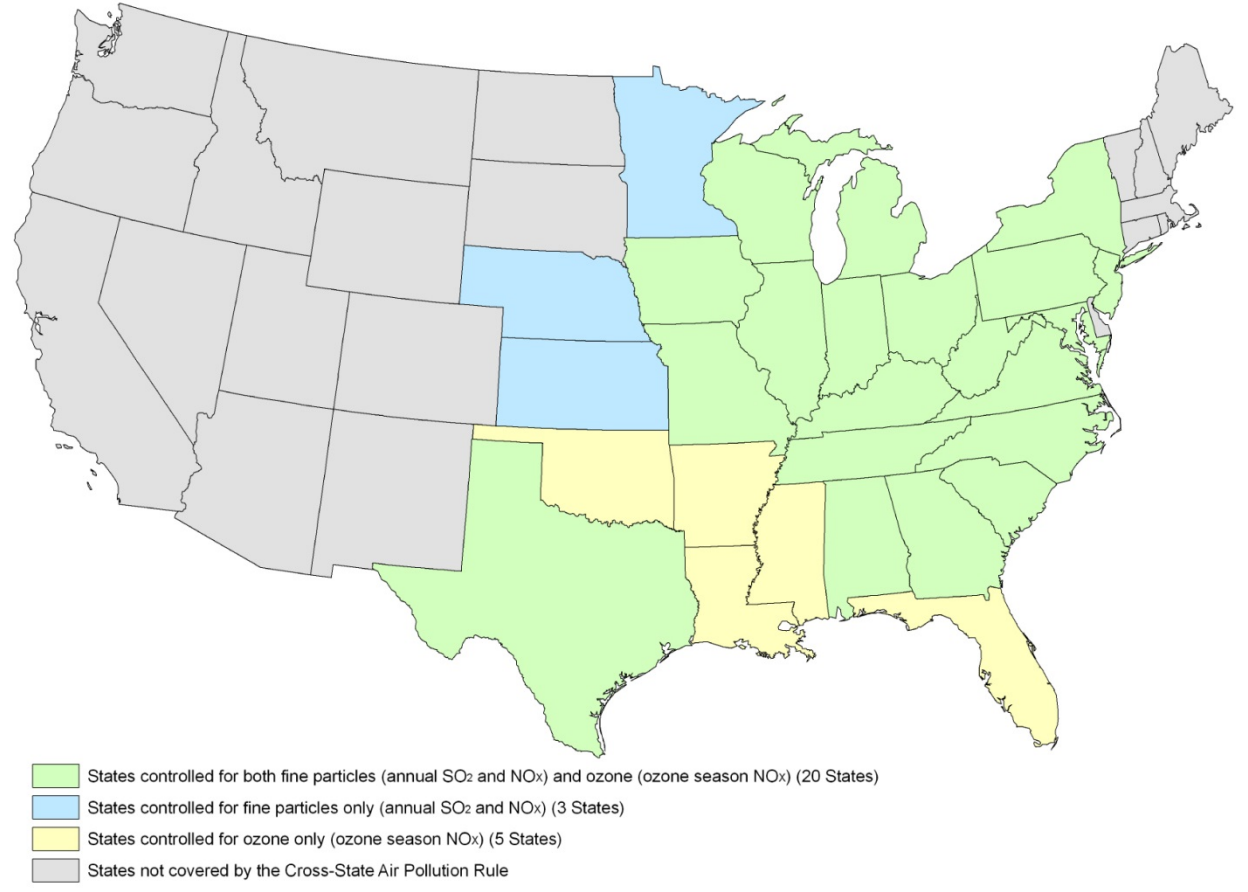
OTC Modeling Domain

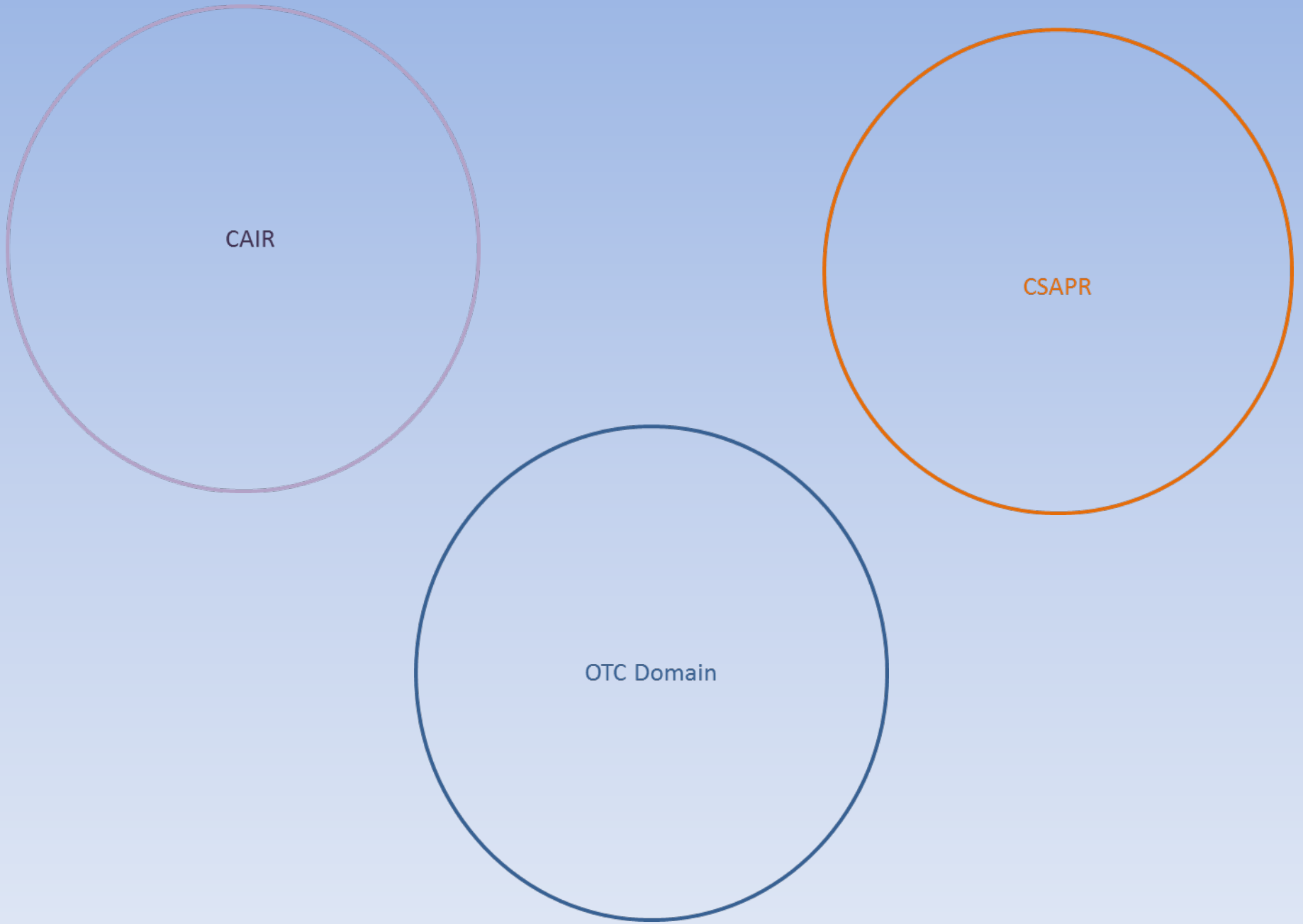


CAIR States

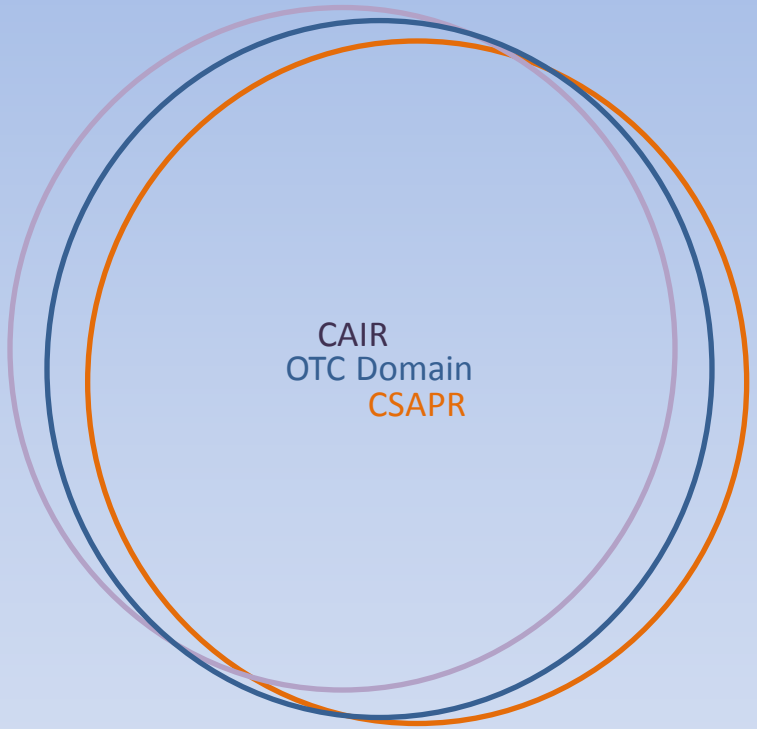

NBP Outline
CAIR states controlled for fine particles
CAIR states controlled for ozone
CAIR states controlled for both fine particles and ozone

CSAPR States




CAIR
CSAPR
OTC Domain

Eastern Half of US



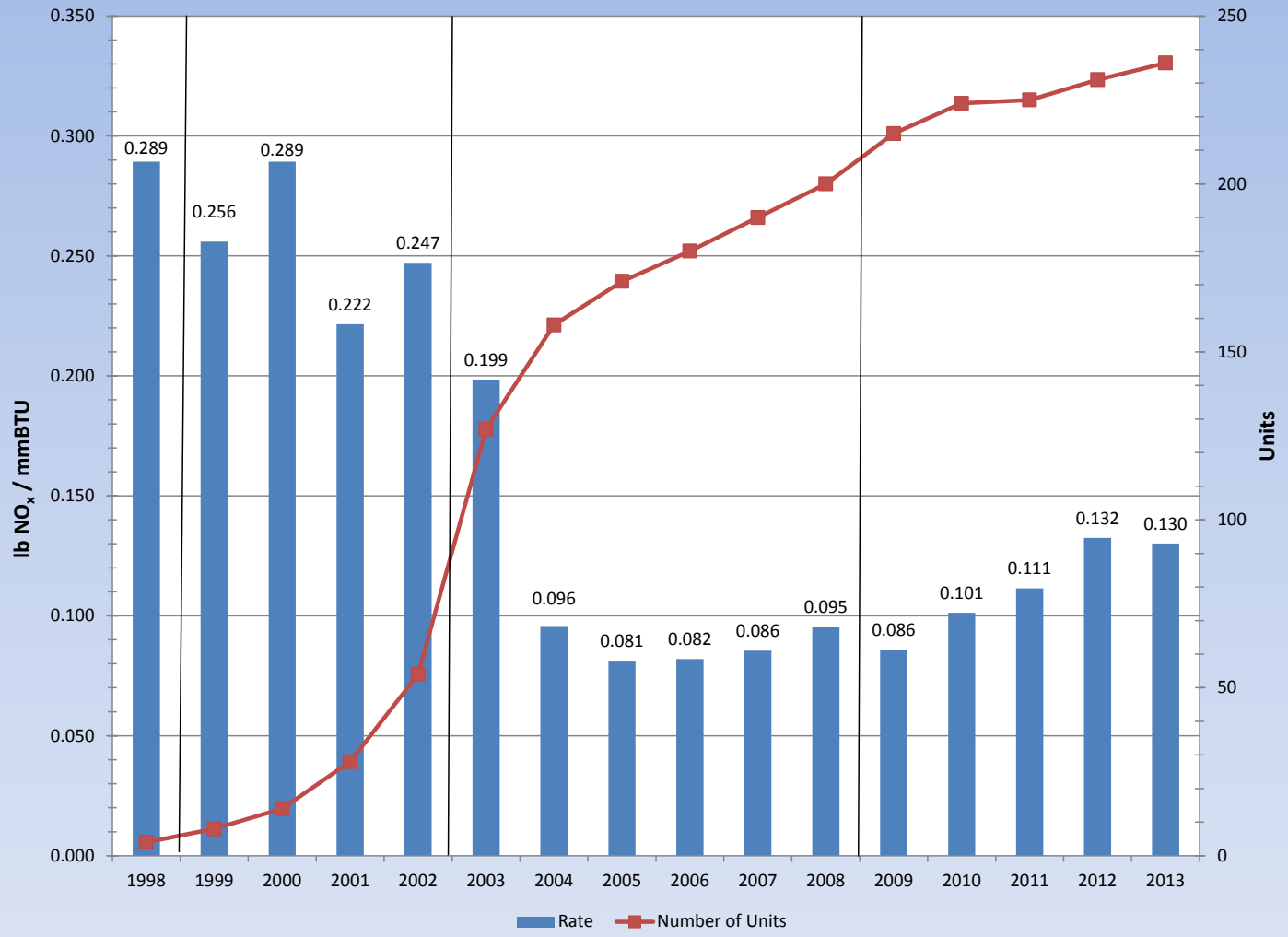
2014 Ozone Season Excess NO_x in Top 25 Emitters

- OTC Domain → 37,750 tons
- CAIR States → 36,626 tons
- CSAPR States → 32,403 tons

What has been Happening?

- Hundreds of coal boilers have installed SCR
- Emission rates fell dramatically 2003-09

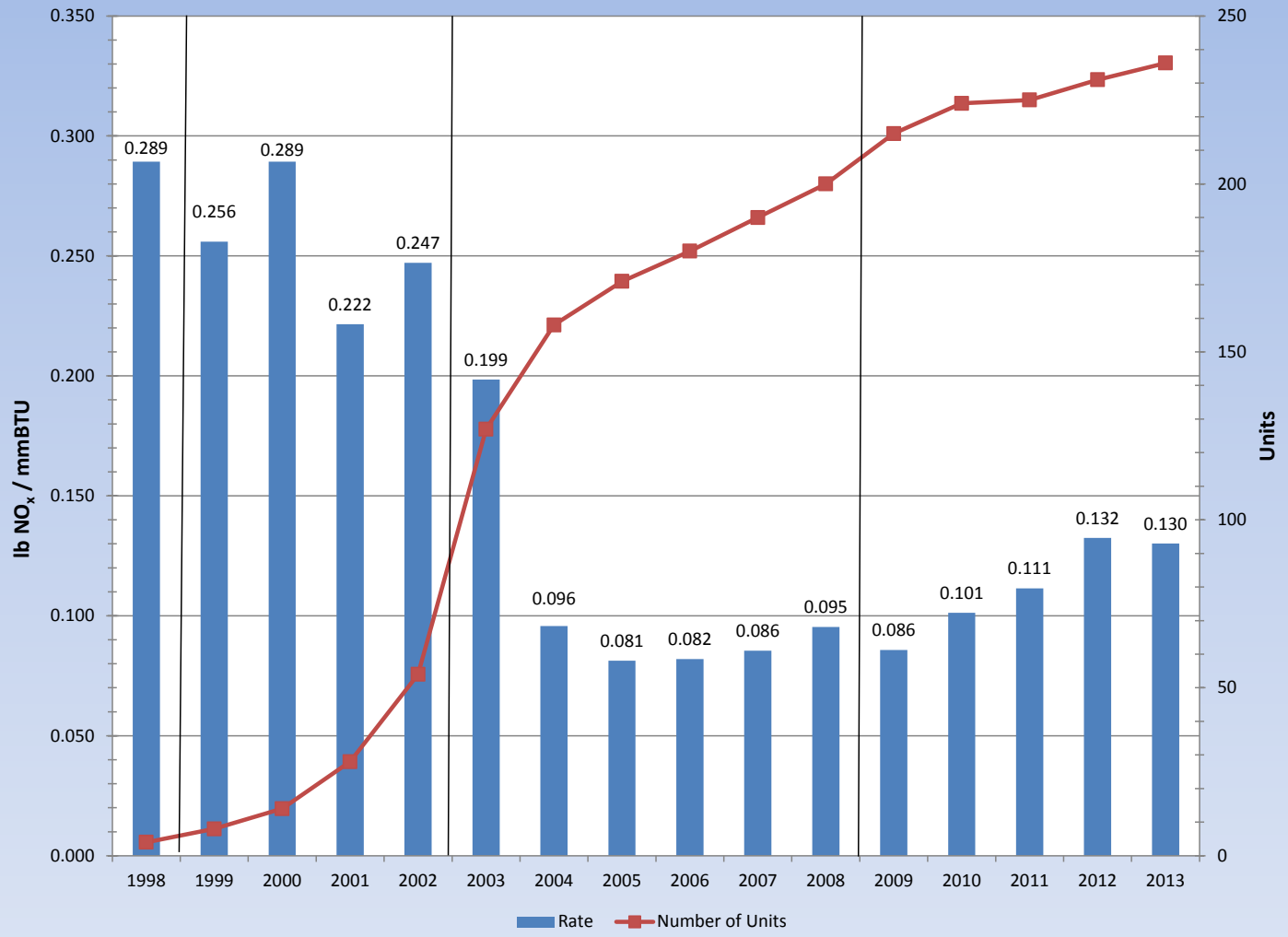
Ozone Season NO_x Emission Rates of SCR-Equipped Coal-Fired EGUs in Eastern US with Number of Units.



What has been Happening?

- Hundred of coal boilers have installed SCR
- Emission rates fell dramatically 2003-09
- Emission Rates began increasing after 2009

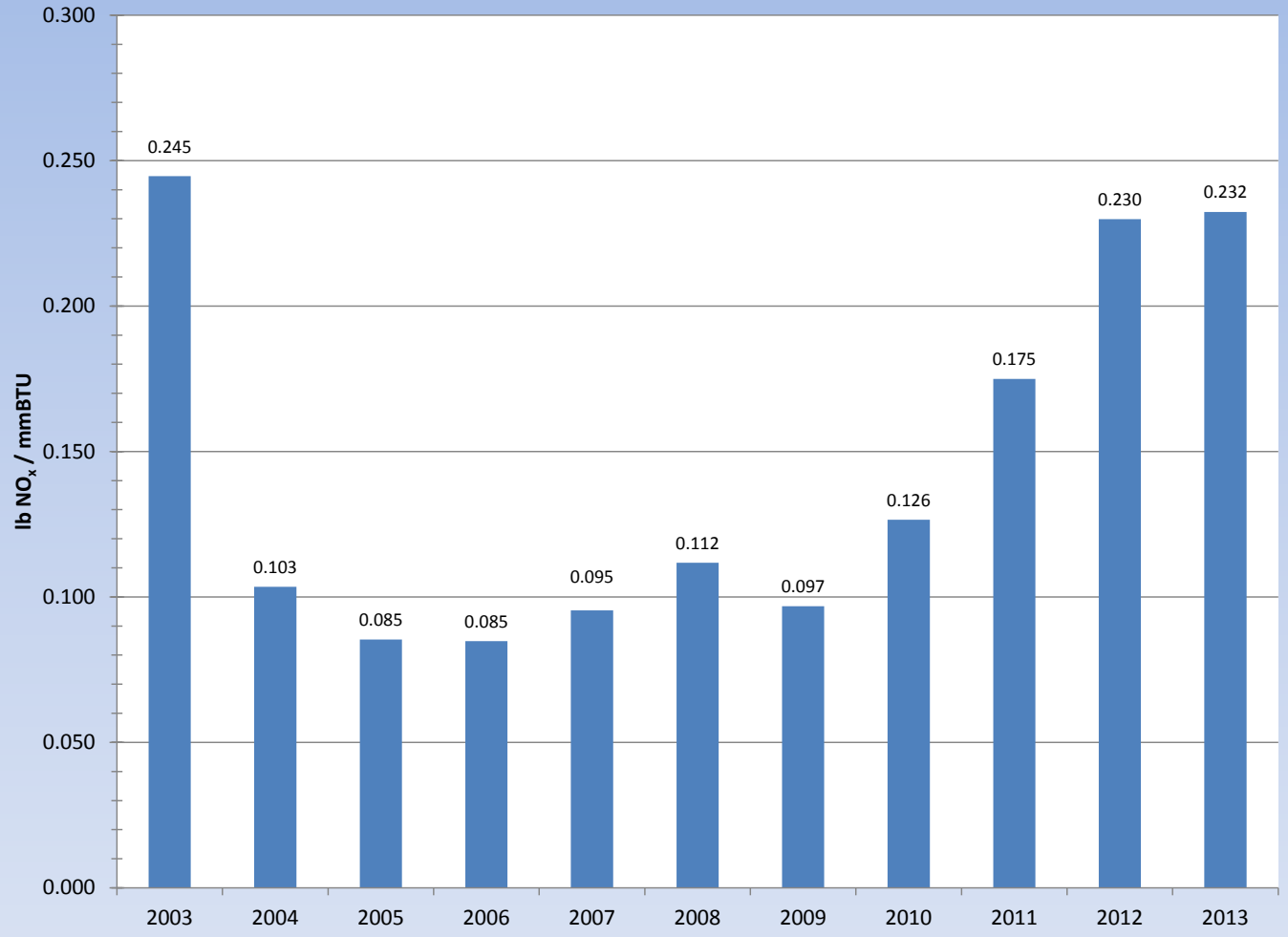
Ozone Season NO_x Emission Rates of SCR-Equipped Coal-Fired EGUs in Eastern US with Number of Units.



2013 Ozone Season

- Top 200 Boilers = 66% of NO_x
  - 198 Coal-fired EGUs
  - 79 SCR Equipped
    - Best Observed Rate (BOR), lb/mmBTU
      - ≈68%, 2013 Emission Rate > BOR
      - Ratio (79 Units): 1.0 – 9.2, Mean = 3.3

Ozone Season NO_x Emission Rates of Coal-Fired Units in OTC Modeling Domain with Reduced SCR Operations within the 2013 Top 200 Emitters.



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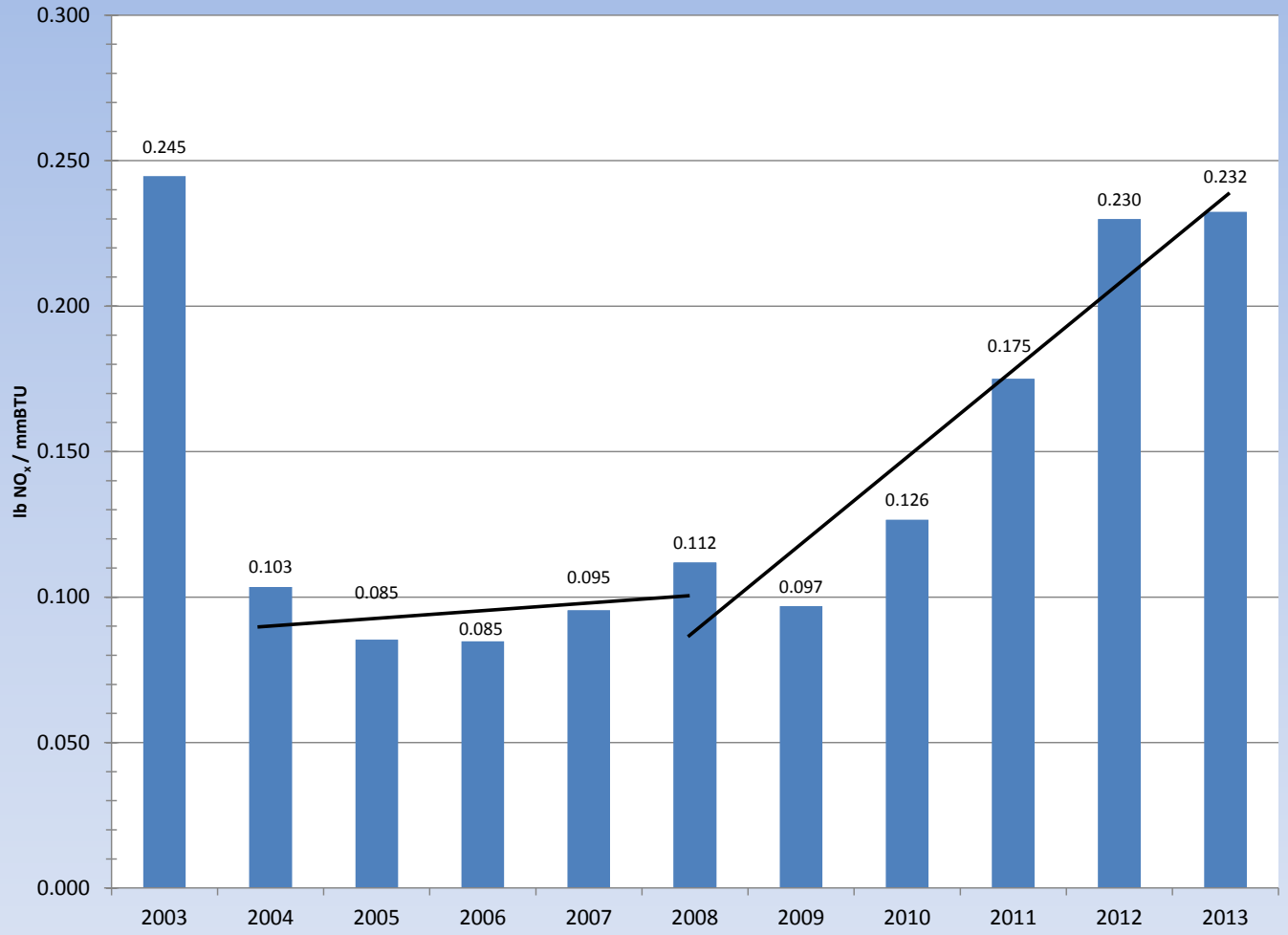
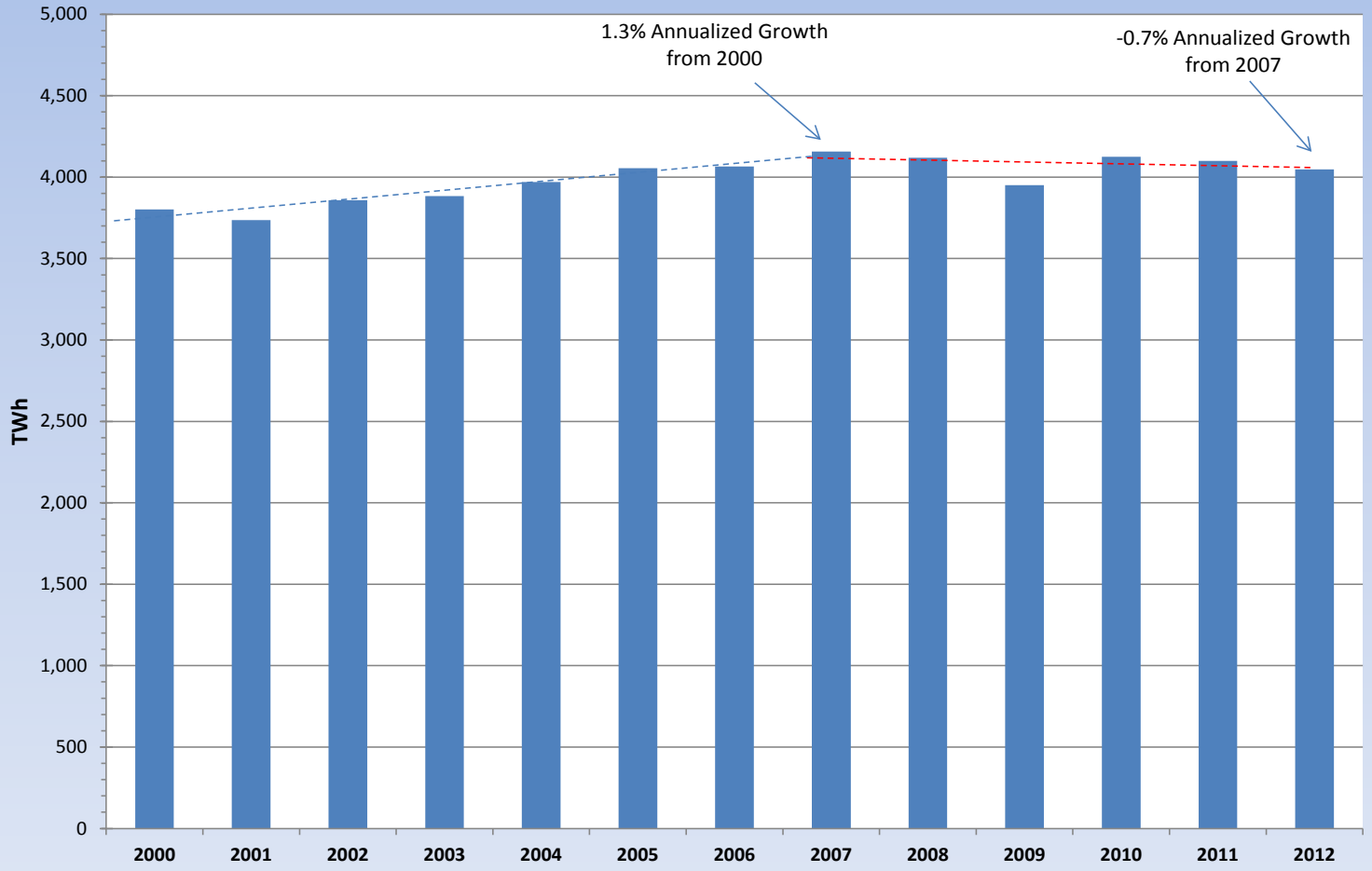


What Happened?

- Collapse of CAIR allowance costs
  - $4,600/ton January 2009, $51/ton October 2012
    - Oversupply of allowances
    - Market uncertainty
  - Less than forecast electric demand

Total US Annual Electrical Generation.



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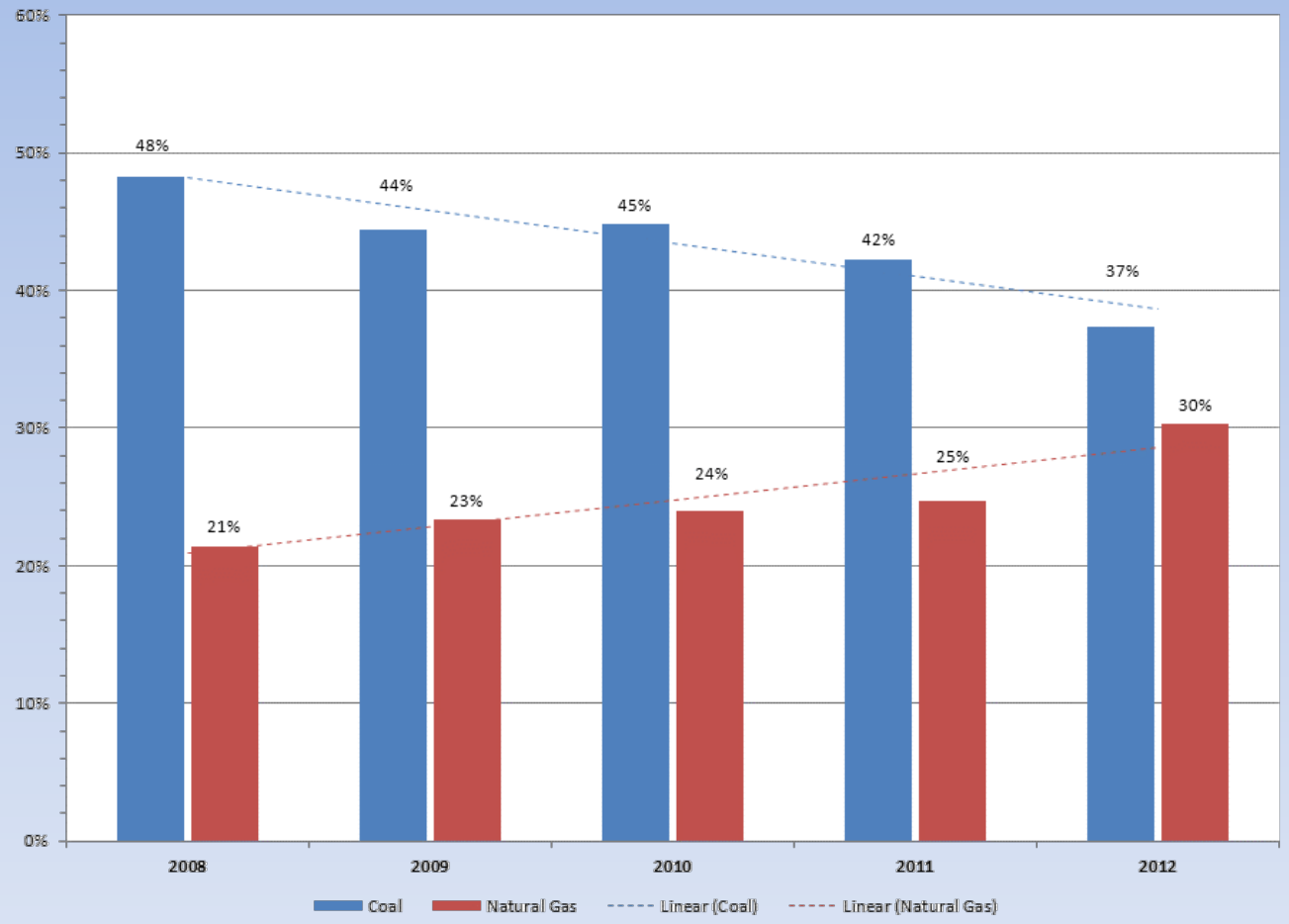
  - 2008-13 Top 200 NO_x emitters, GLOAD -1.7%
- Increased gas-fired generation

Increased gas-fired generation

Percentage of Total US Annual Electrical Generation by Fuel Type



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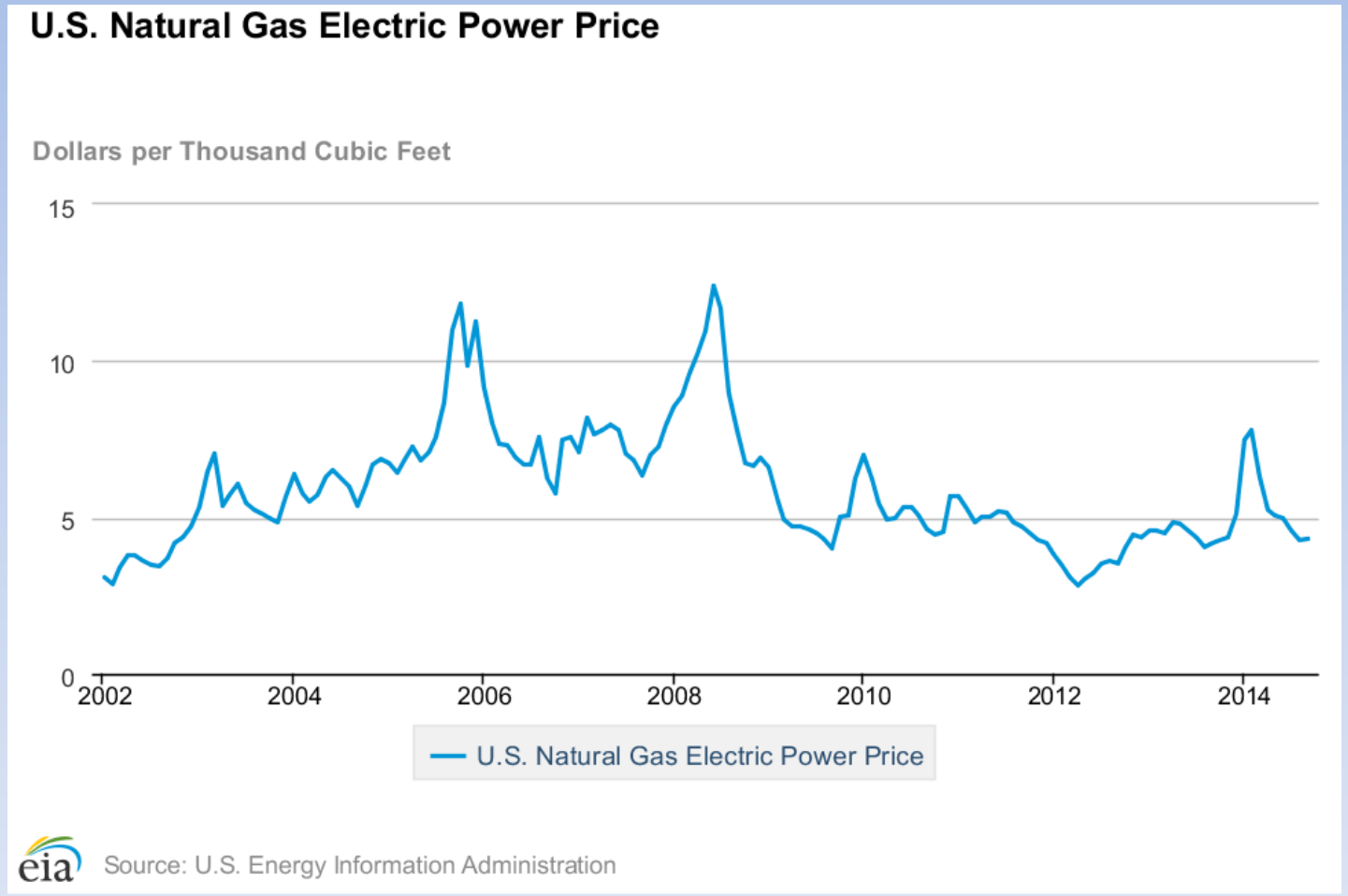
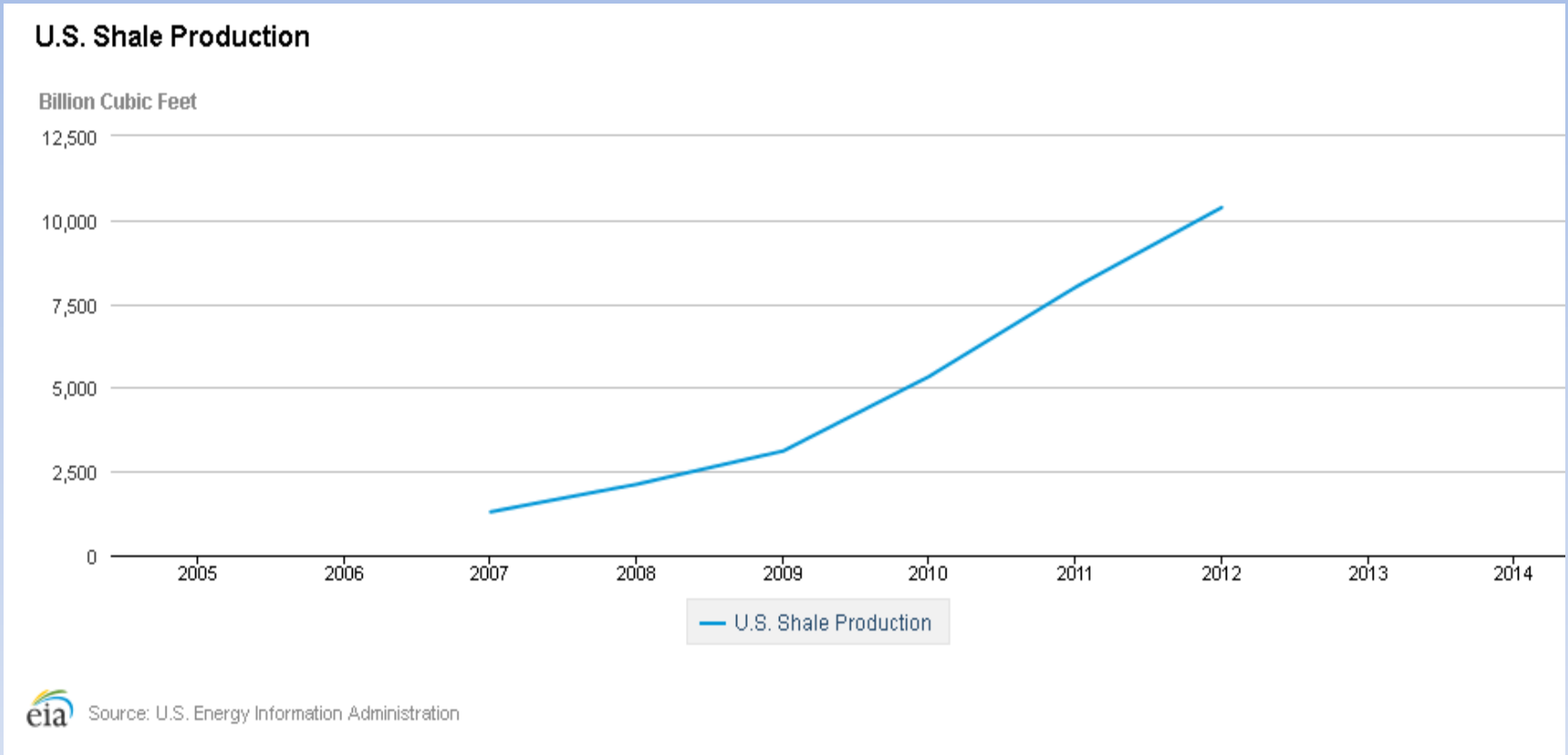
    - Market uncertainty
- Less than forecast electric demand
  - 2008-13 Top 200 NO_x emitters, GLOAD -1.7%
- Increased gas-fired generation
  - April 2012, Coal = Gas = 32%

Gas Got Cheap



What's Driving Gas Pricing?



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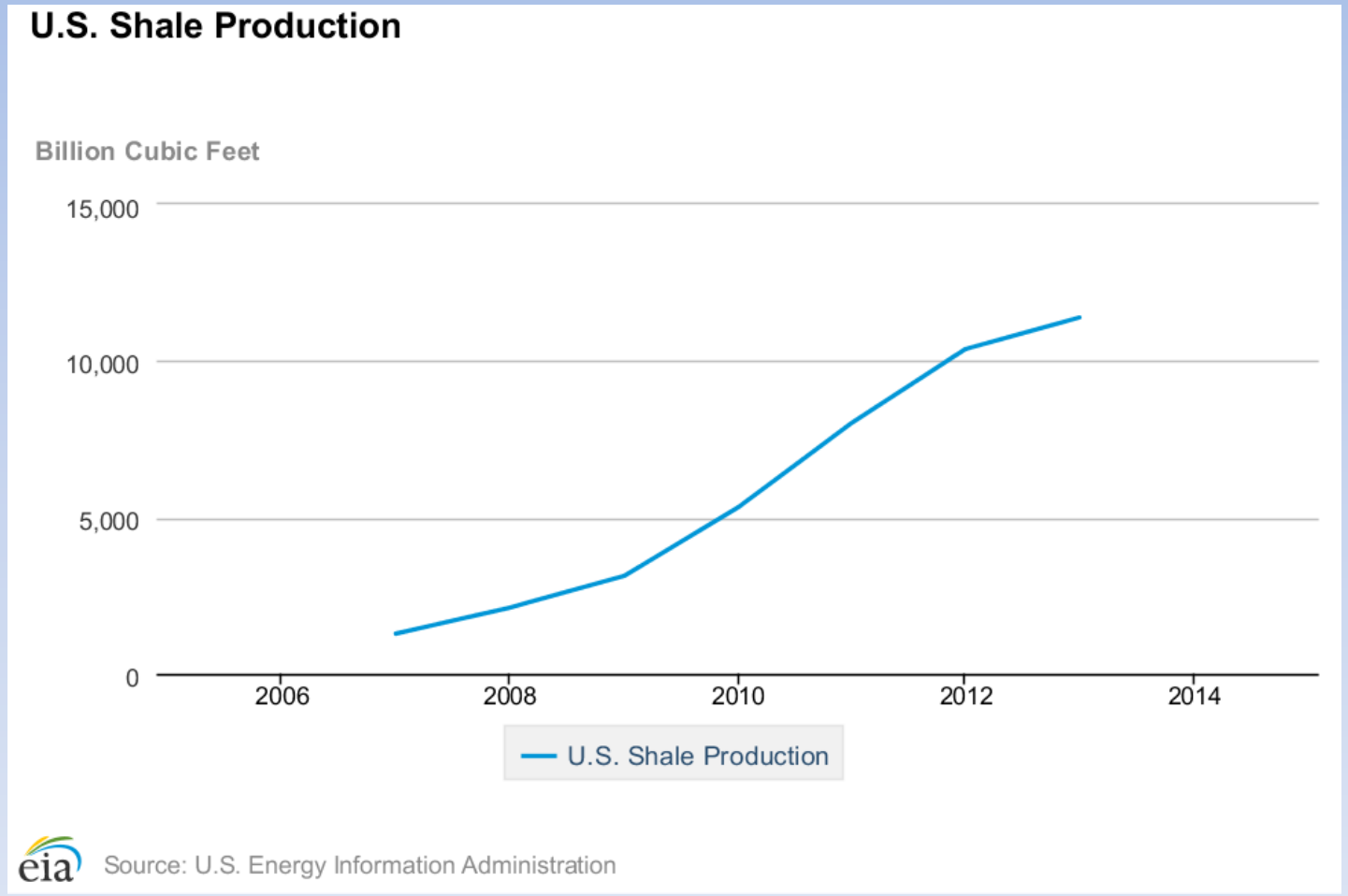
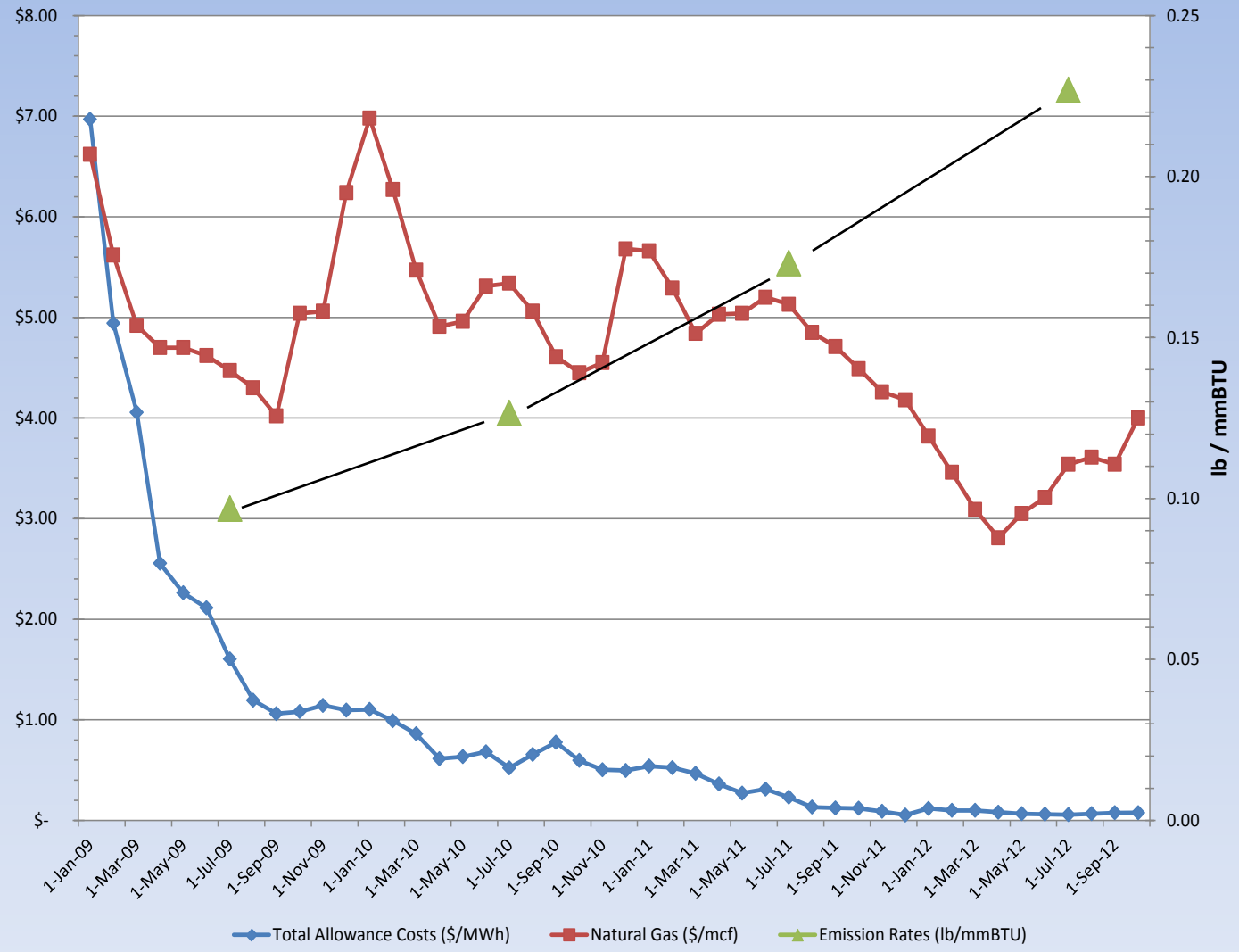
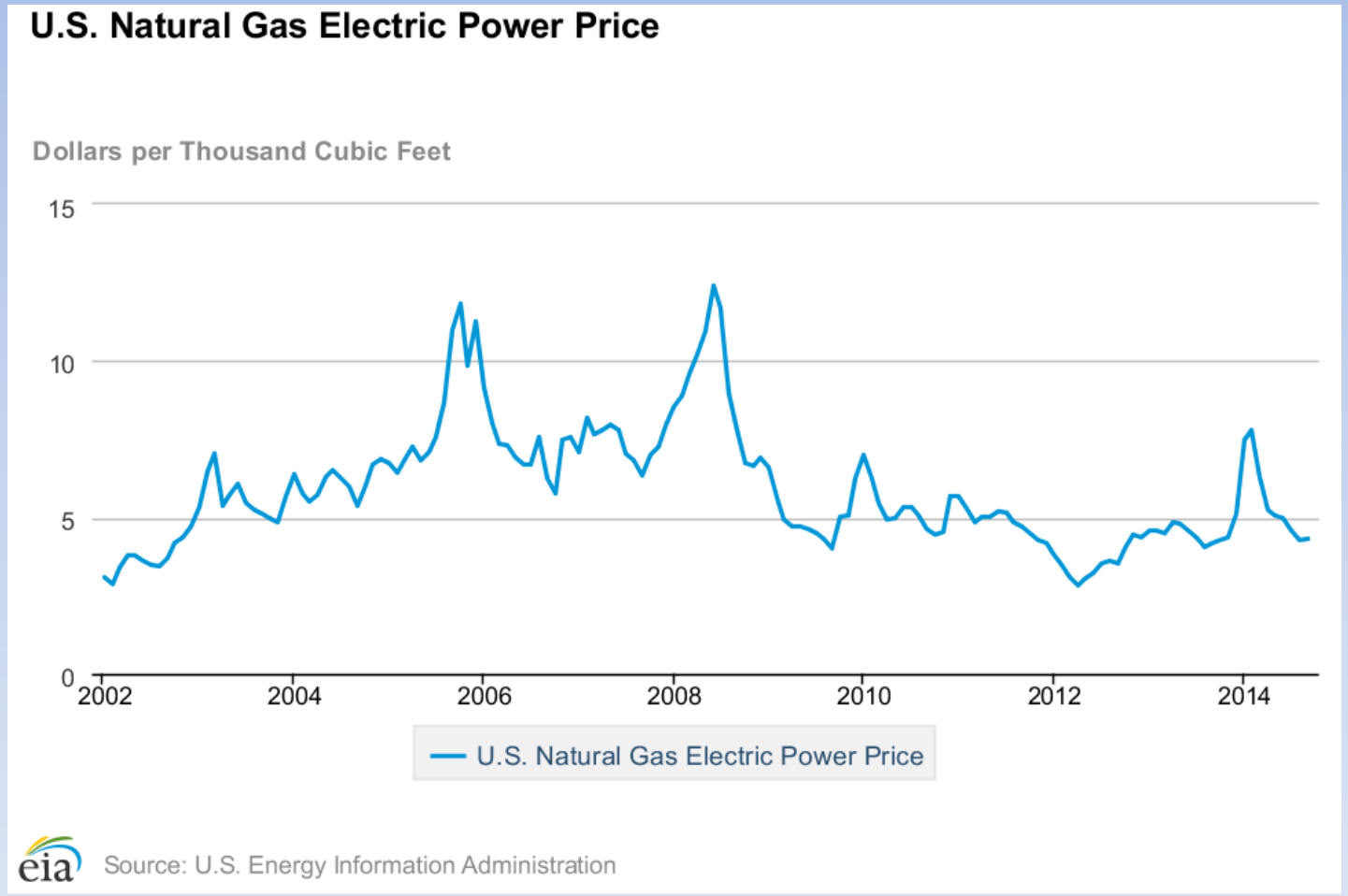


Total Monthly Average Ozone Season Allowance Costs at 3.0 lb NO_x / MWh, Monthly Average Natural Gas Electrical Generation Costs, "53 SCR Boiler" Average Ozone Season Emission Rates.



Gas Got *Very* Competitive



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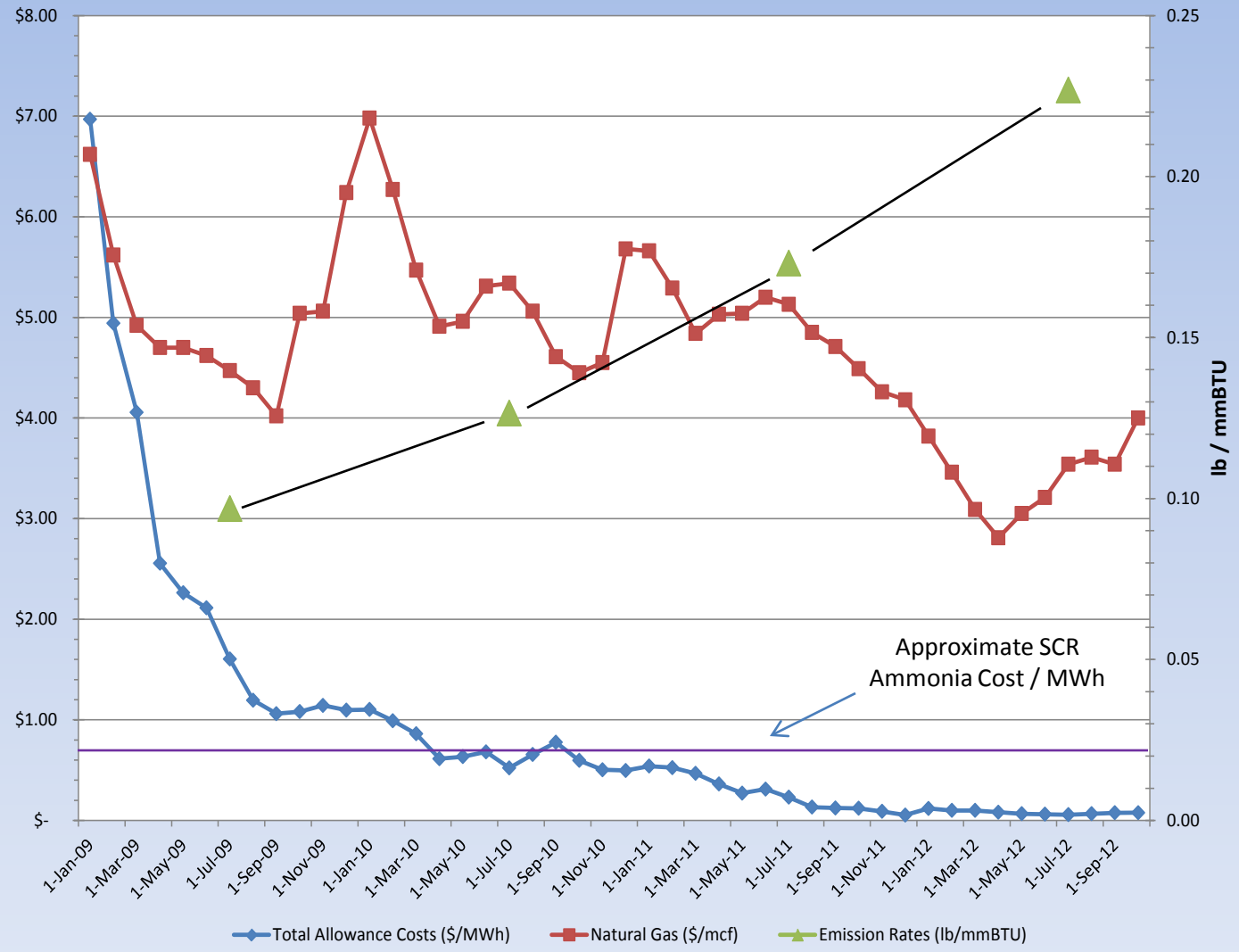


CAIR-region States with Representative Low and High Average NO_x Emission Rates, (lb/mmBTU), of SCR-Equipped Coal-Fired EGUs in the 2013 Ozone Season.

Low	Alabama	Arkansas	Georgia	Maryland
	0.077	0.068	0.061	0.074
High	Missouri	New Hampshire	New York	Pennsylvania
	0.376	0.274	0.323	0.247

Average 2013 Ozone Season NO_x Emission Rates, (lb/mmBTU), of SCR-Equipped Coal-Fired EGUs in Western States that are not in the CAIR Cap and Trade Program.

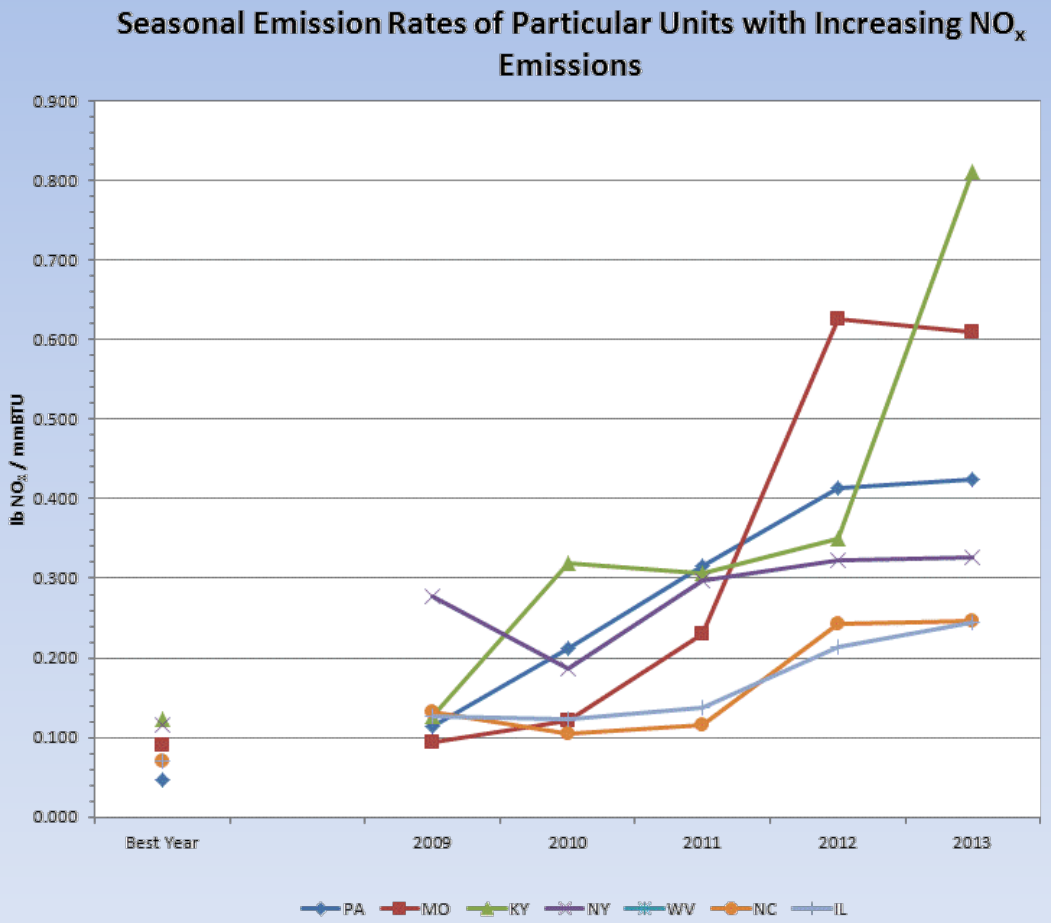
Arizona	Colorado	Kansas	Montana	Nevada	Texas	Wyoming
0.076	0.067	0.087	0.079	0.064	0.056	0.057

Reduced, "Sub-Optimal" SCR Operation

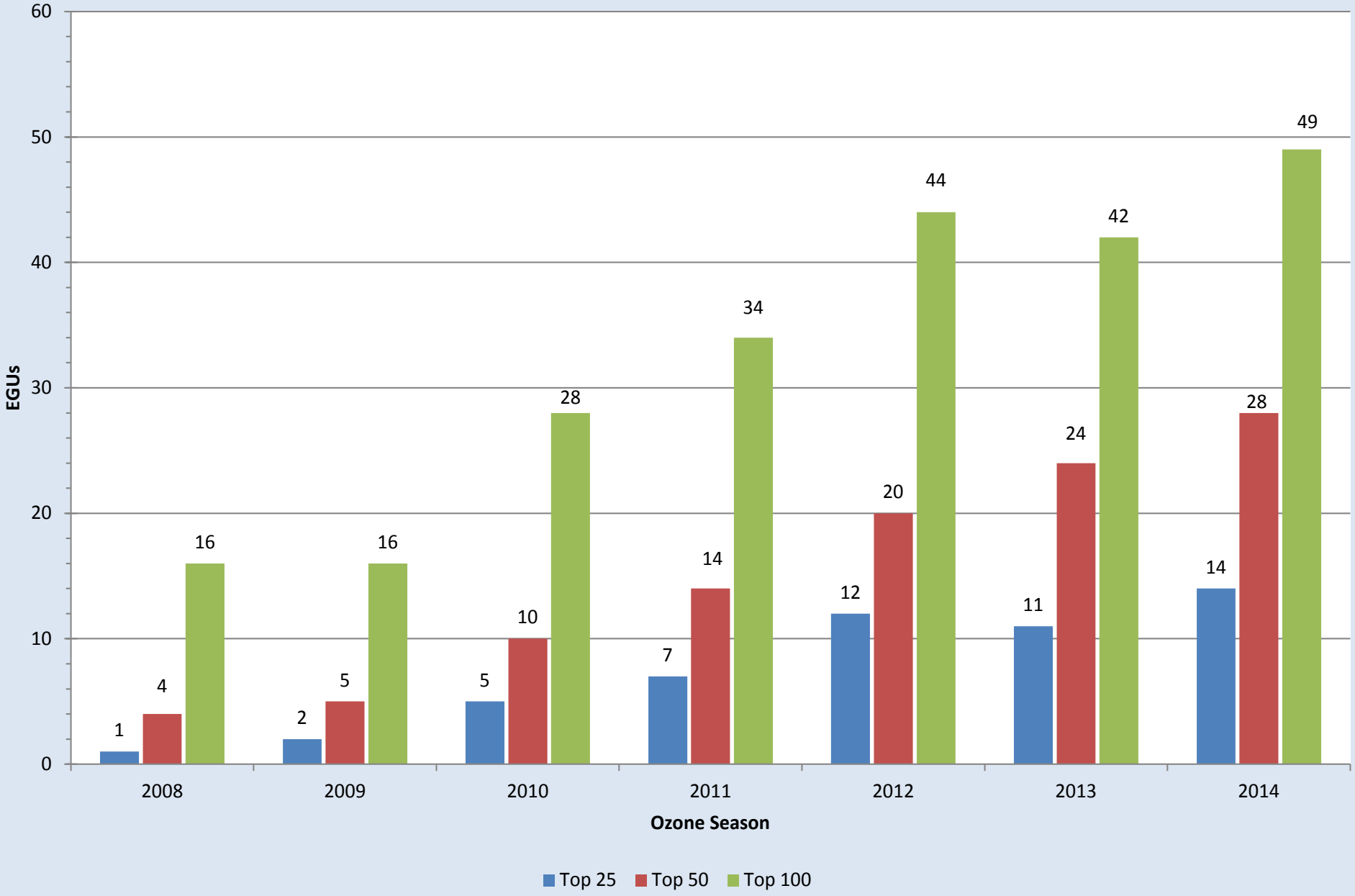
NO_x Emission Rates, lb/mmBTU

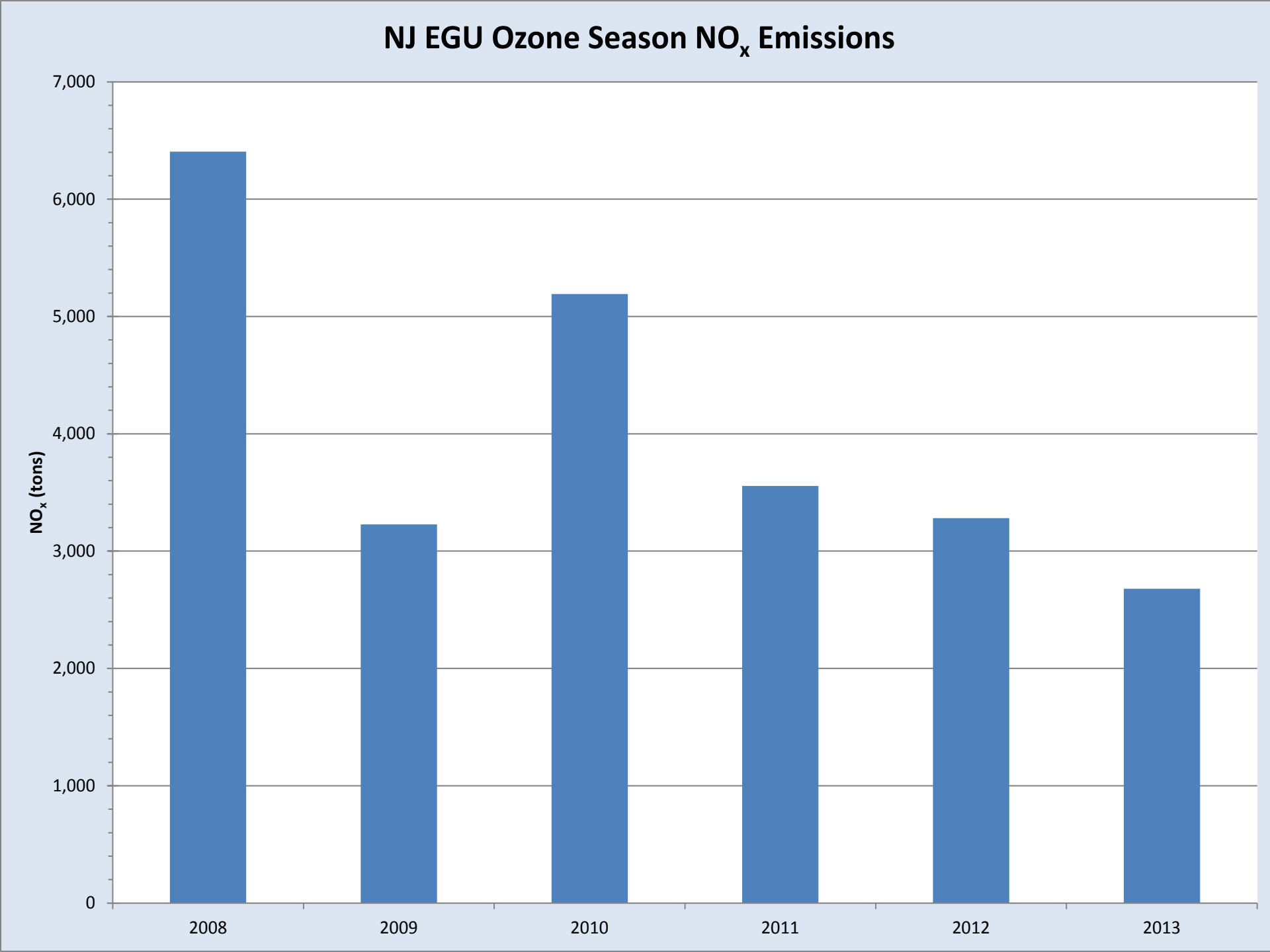
Plant Location	Best Year	2009	2010	2011	2012	2013
PA	0.044 (2003)	0.113	0.212	0.316	0.414	0.424
MO	0.090 (2009)	0.090	0.108	0.230	0.627	0.609
KY	0.123 (2006)	0.127	0.320	0.307	0.349	0.812
WV	0.071 (2004)	0.080	0.260	0.206	0.304	0.300
NC	0.070 (2004)	0.132	0.104	0.116	0.243	0.247
IL	0.071 (2004)	0.127	0.124	0.137	0.214	0.245

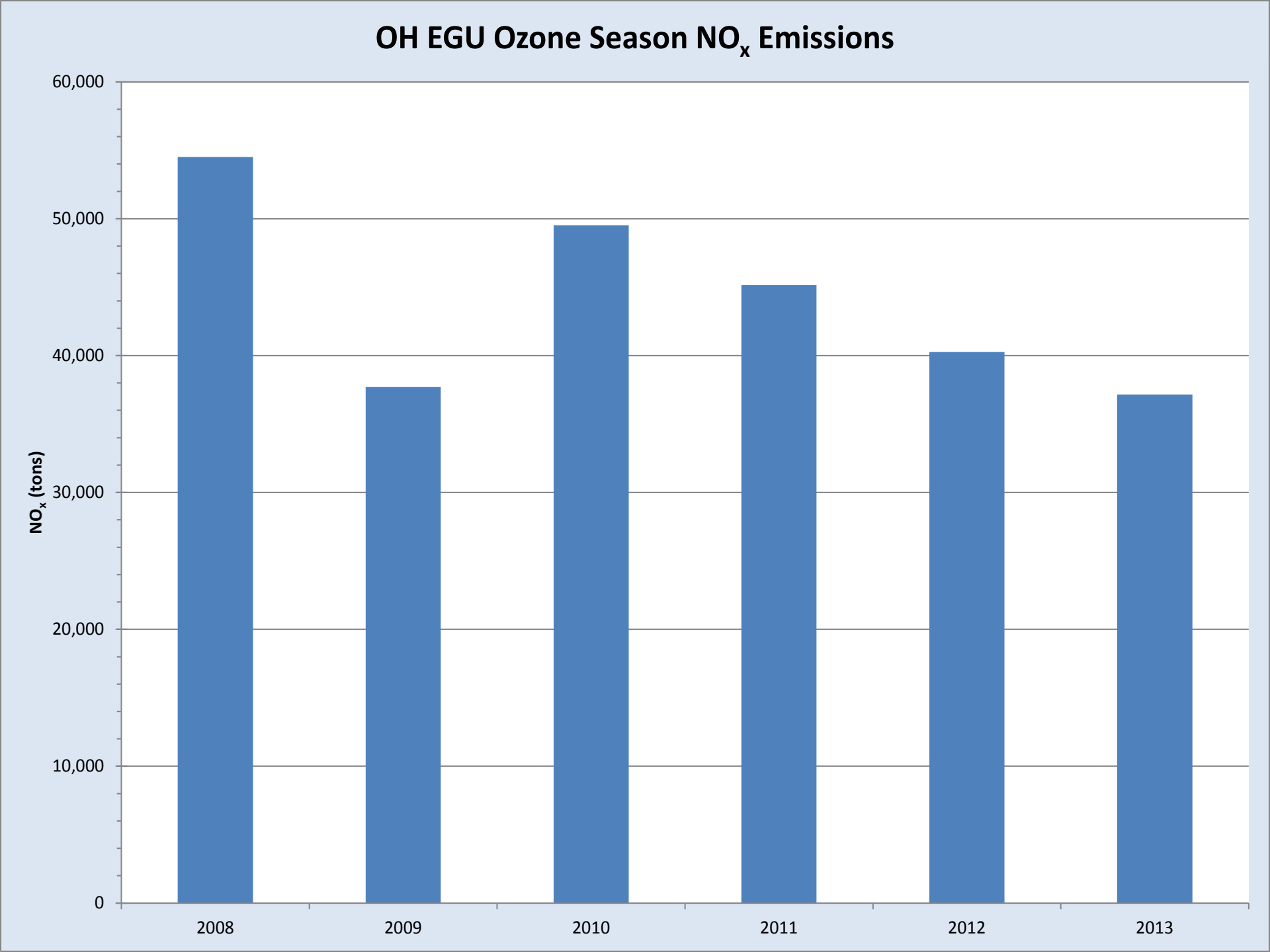
Reduced, "Sub-Optimal" SCR Operation?

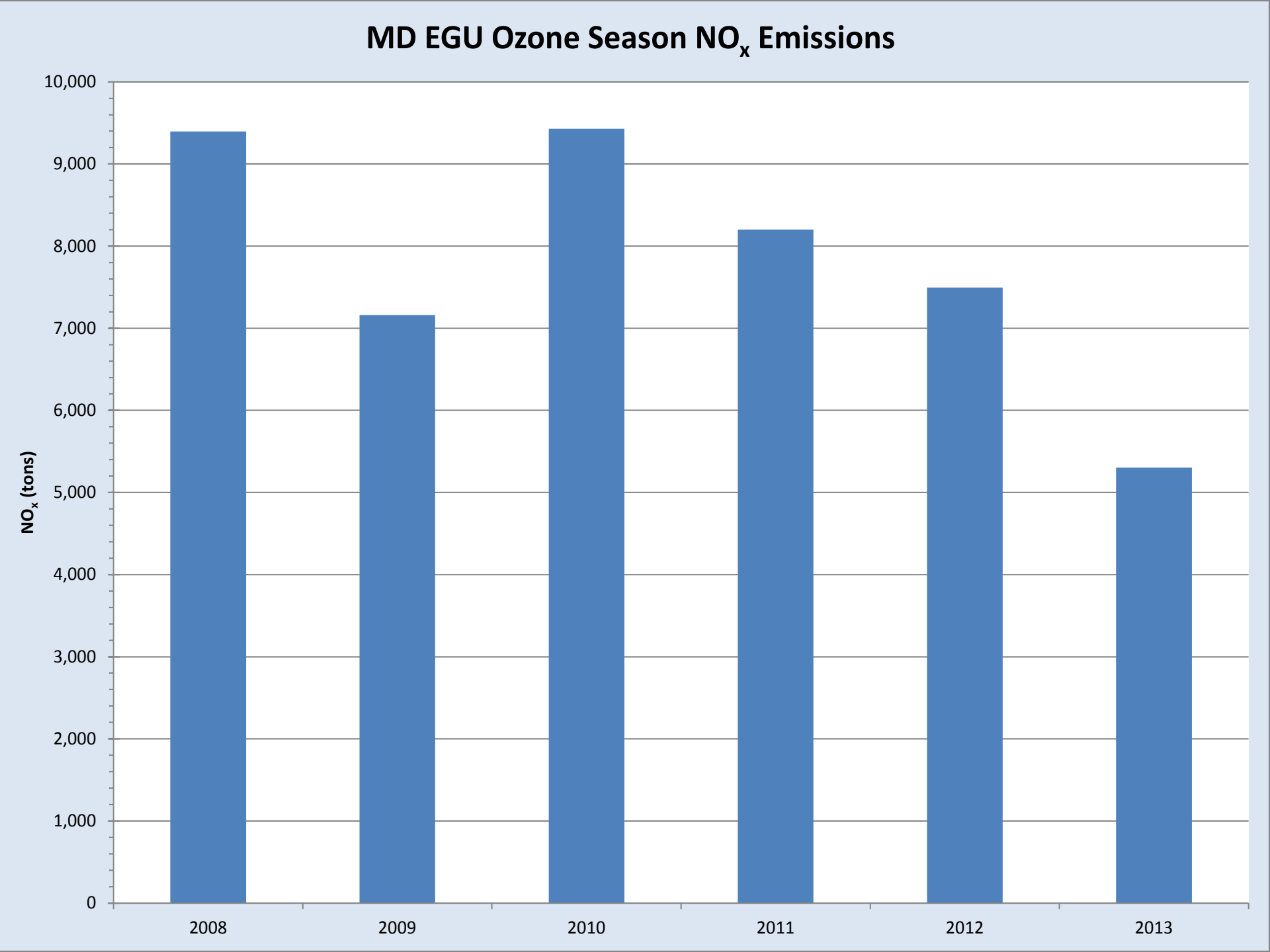


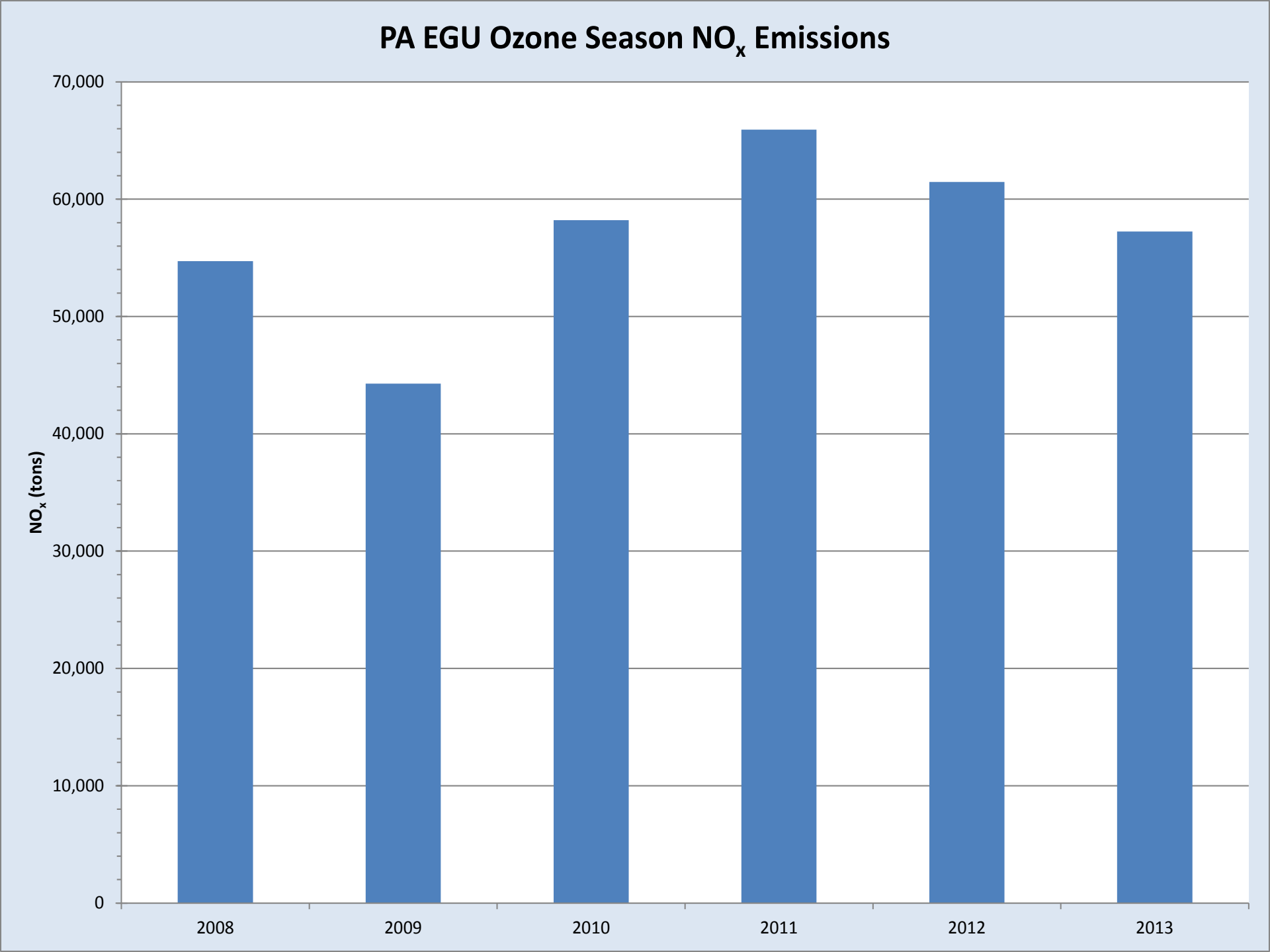
Numbers of SCR-Equipped EGUs in Top 25, 50, and 100 NO_x Emitters in CAIR States

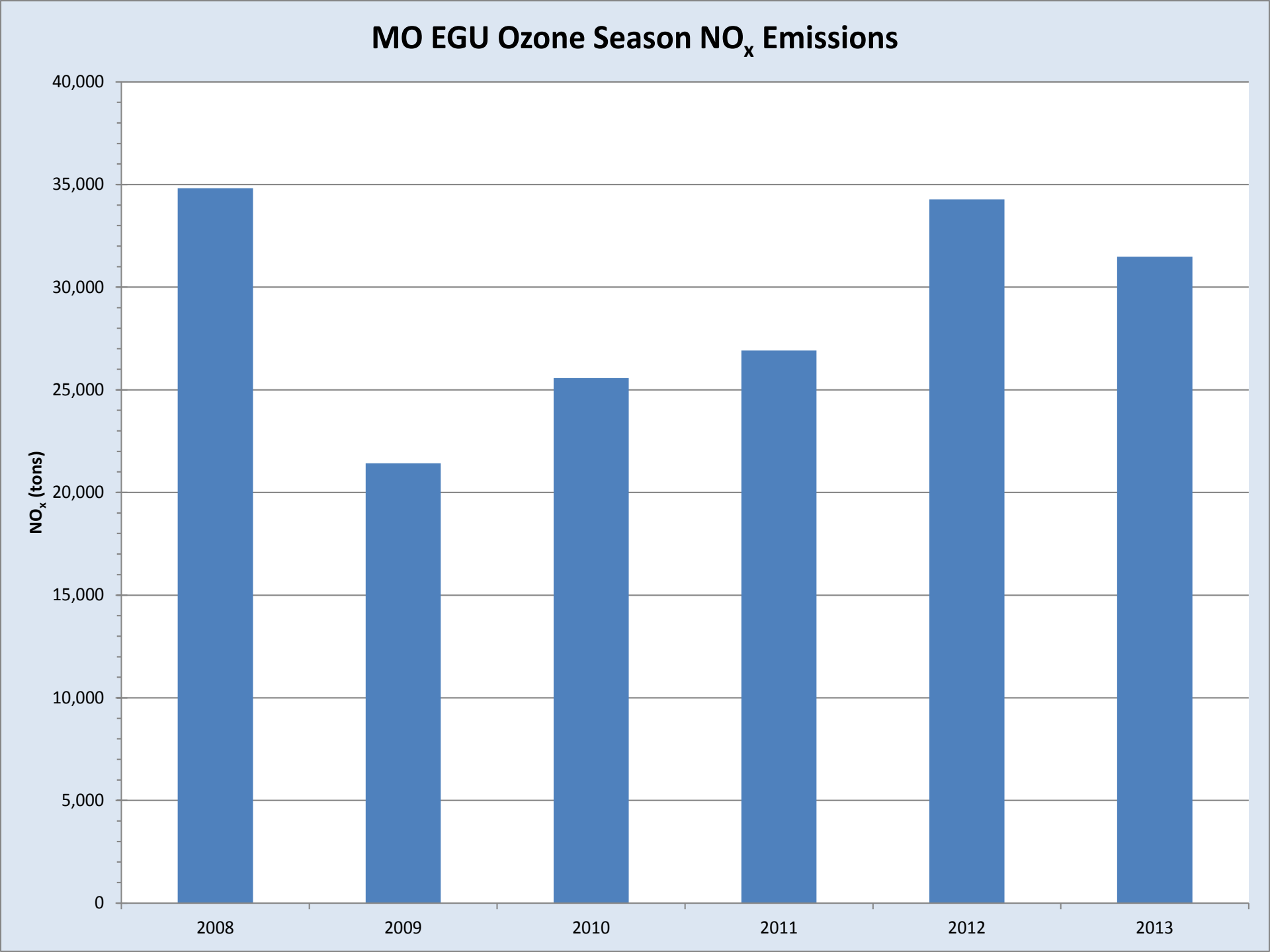


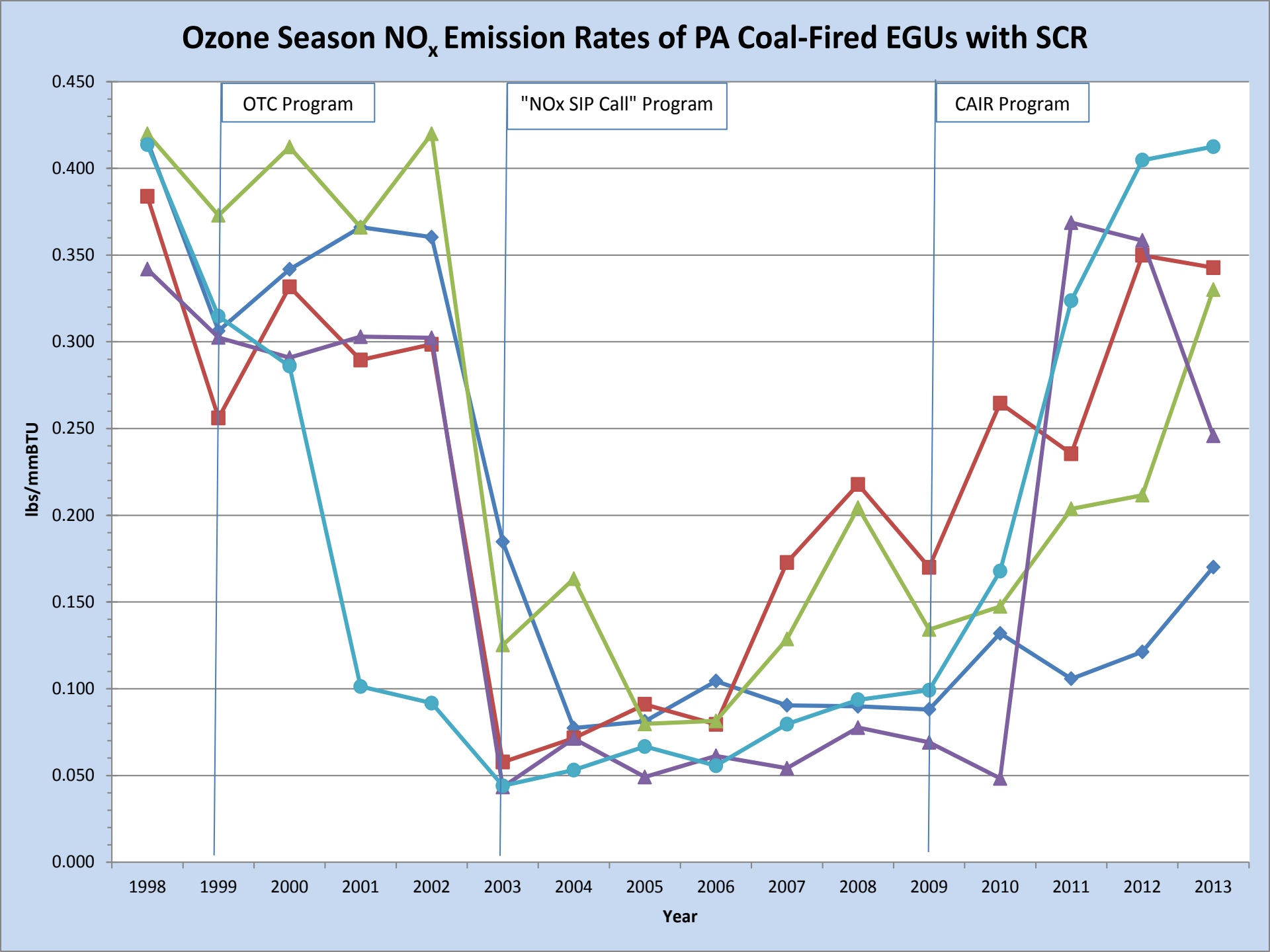

NJ EGU Ozone Season NOx Emissions
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
NOx (tons)
2008
2009
2010
2011
2012
2013

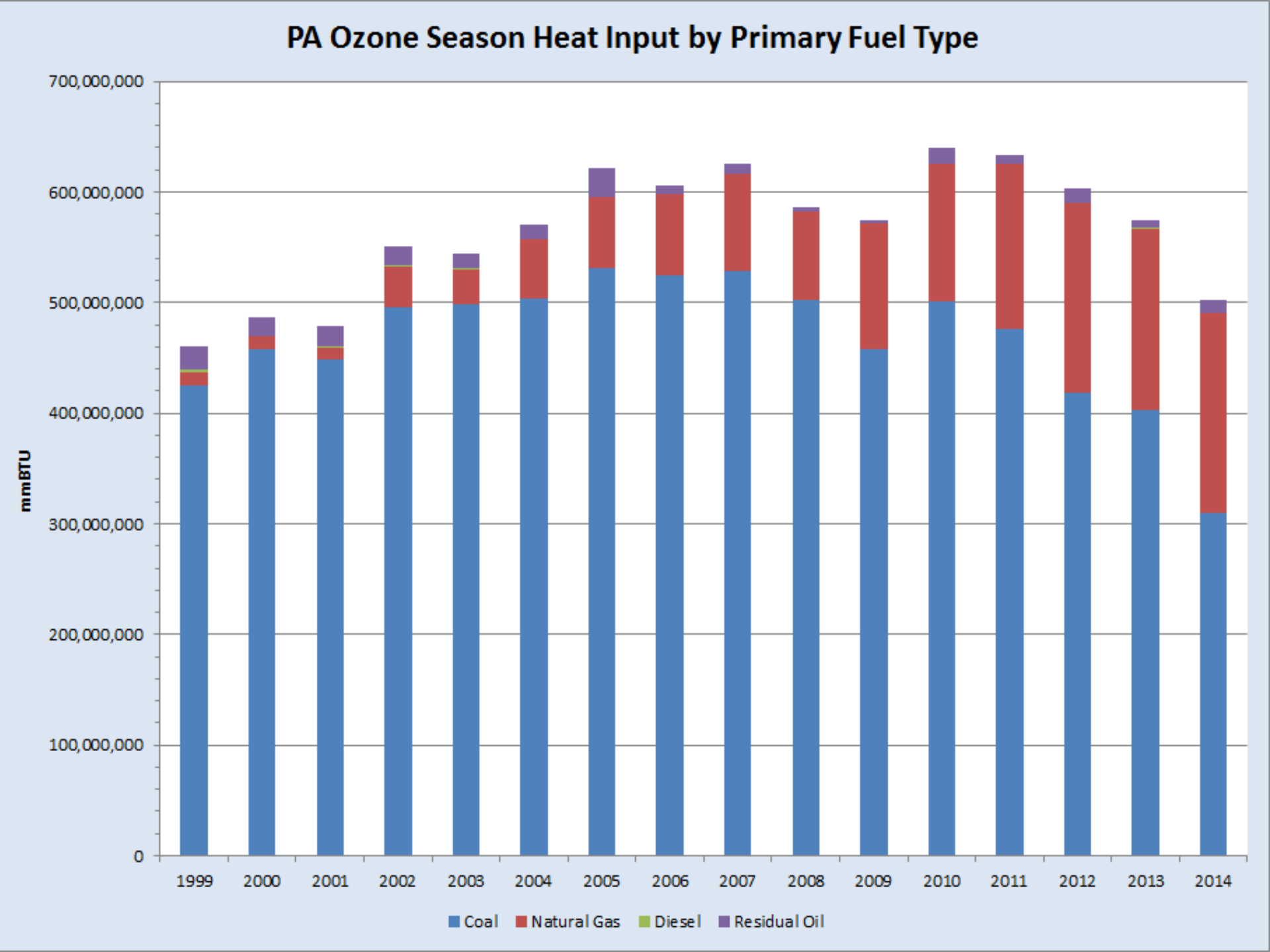

OH EGU Ozone Season NOx Emissions
60,000
50,000
40,000
30,000
20,000
10,000
0
NOx (tons)
2008
2009
2010
2011
2012
2013

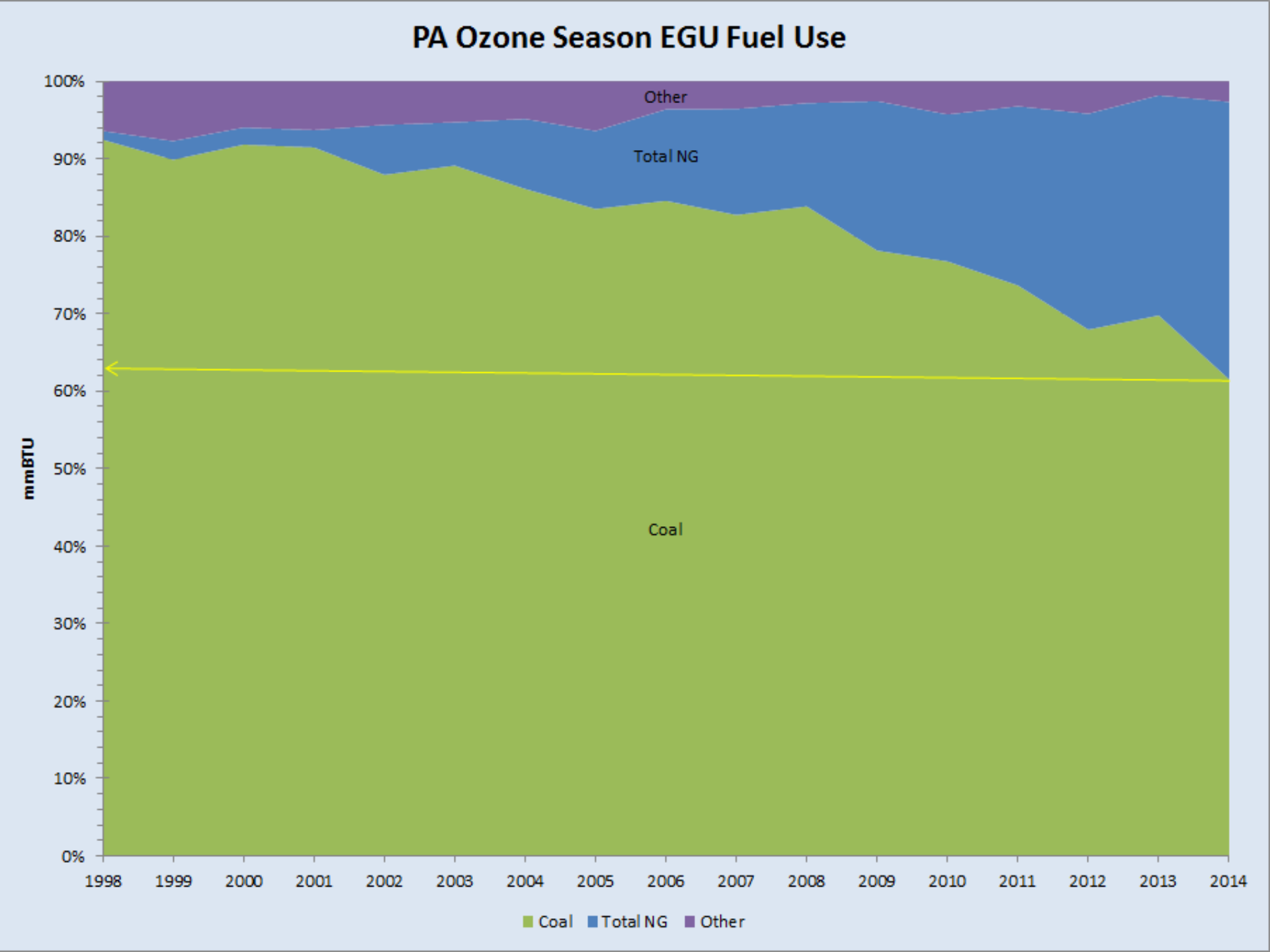

MD EGU Ozone Season NOx Emissions
NOx (tons)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2008
2009
2010
2011
2012
2013

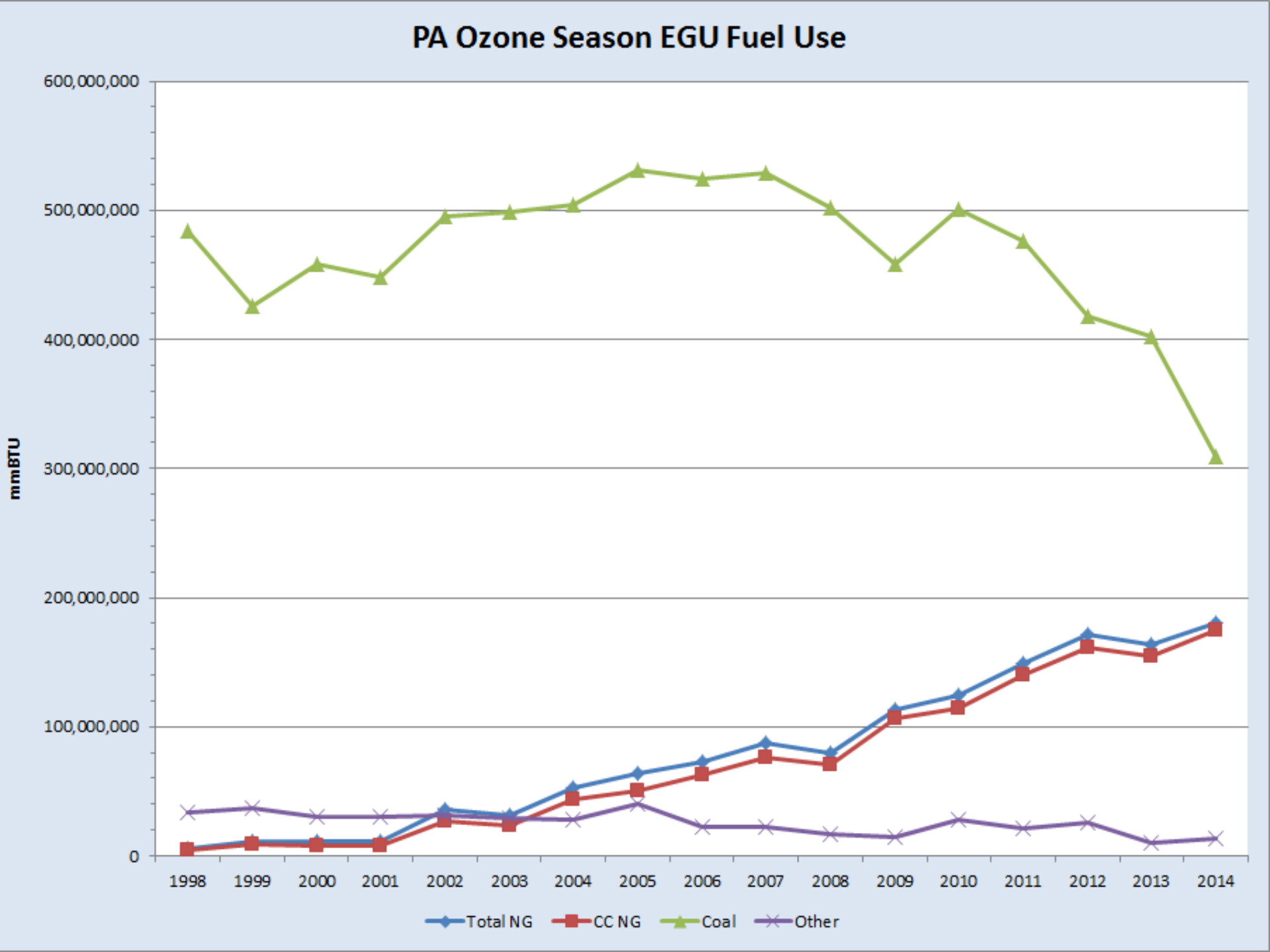

PA EGU Ozone Season NOx Emissions
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
NOx (tons)
2008
2009
2010
2011
2012
2013

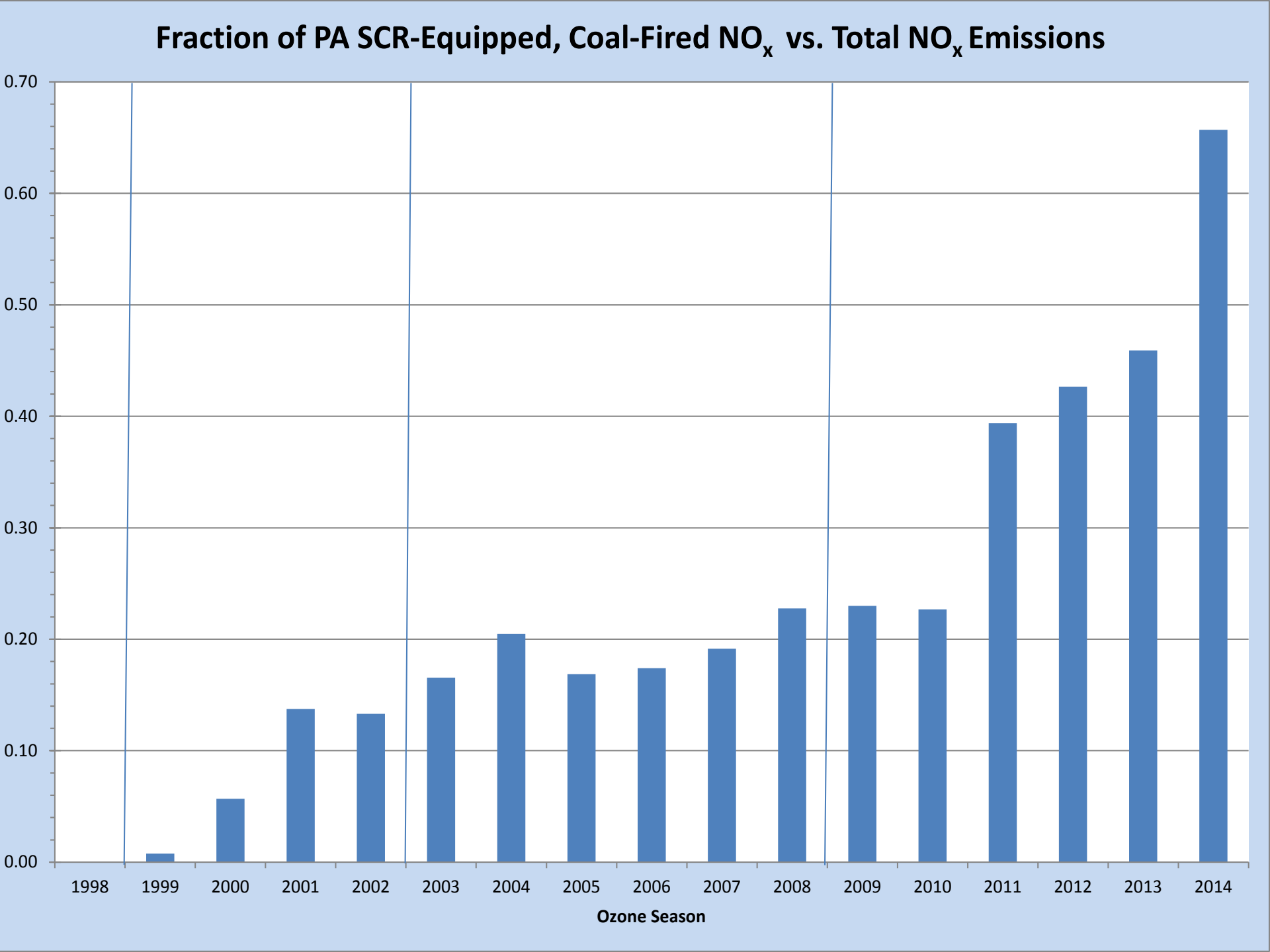

MO EGU Ozone Season NOx Emissions
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
NOx (tons)
2008
2009
2010
2011
2012
2013


Ozone Season NOx Emission Rates of PA Coal-Fired EGUs with SCR
OTC Program
"NOx SIP Call" Program
CAIR Program
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
lbs/mmBTU
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year

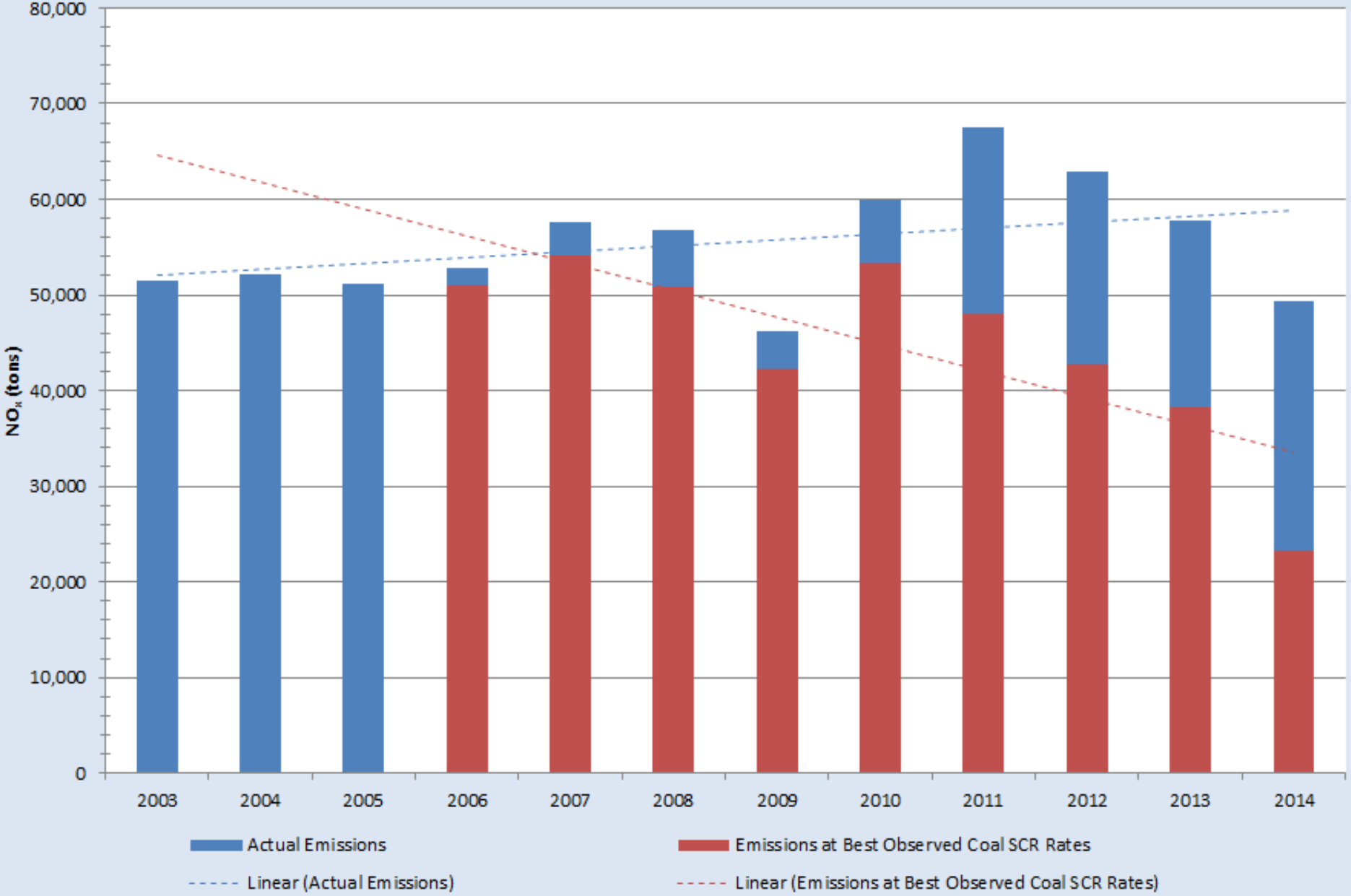

PA Ozone Season Heat Input by Primary Fuel Type
700,000,000
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
0
mmBTU
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Coal
Natural Gas
Diesel
Residual Oil


PA Ozone Season EGU Fuel Use
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
mmBTU
Other
Total NG
Coal
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Coal
Total NG
Other


PA Ozone Season EGU Fuel Use
mmBTU
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Total NG
CC NG
Coal
Other


Fraction of PA SCR-Equipped, Coal-Fired NOx vs. Total NOx Emissions
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Ozone Season

Actual Pennsylvania Statewide Ozone Season EGU NO_x Emissions as Compared with Emissions at Optimal Rates of SCR-Equipped Coal Plants



Total Excess NO_x Emissions (tons) from Coal-Fired SCR-Equipped EGUs in 2013 Top 200 Emitters in Eastern US

2010	2011	2012	2013	2014
27,600	41,100	59,000	61,500	66,700

Total = 255,900 tons

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