Indiana Center for Coal Technology Research

Sulfur Dioxide Control Technologies In Electric Power Plants

CCTR Basic Facts File #5

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Roadmap Performance Target
Best technology Capability

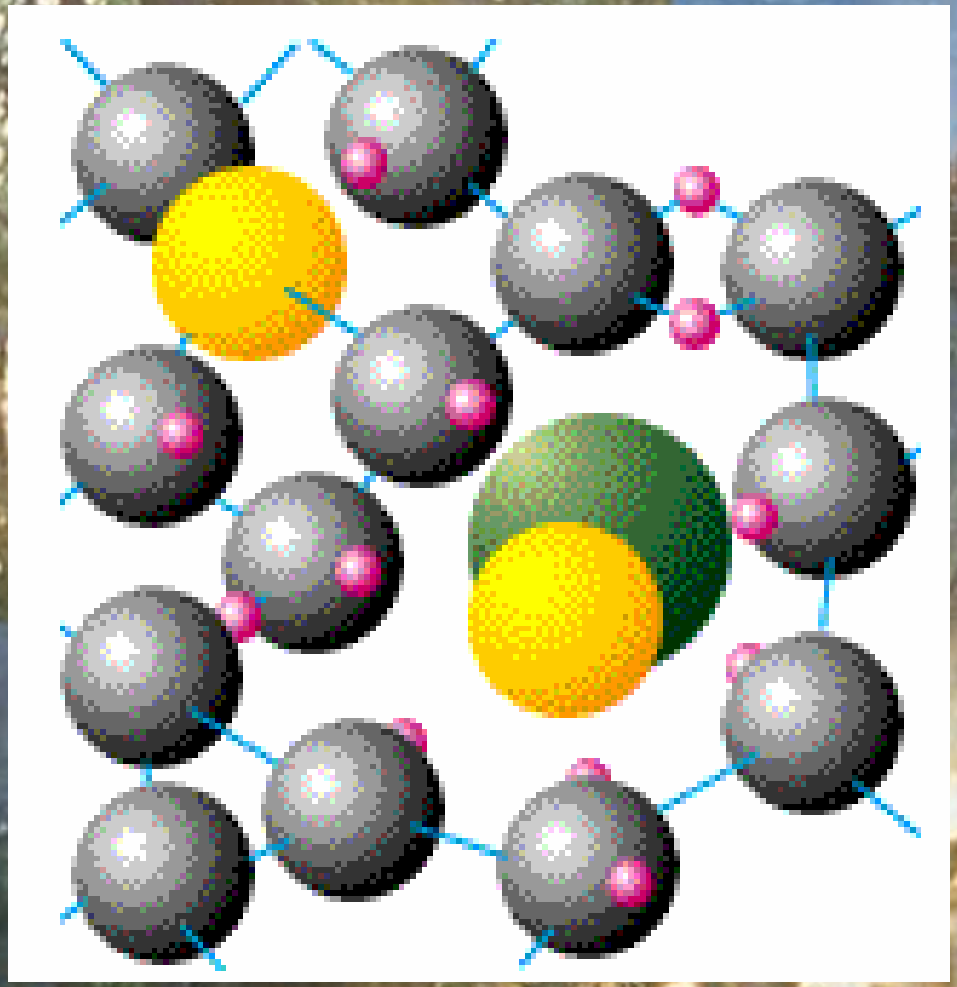
	Reference Plant*	2010	2020
Air Emissions	98% SO_2 removal	99%	>99%
	0.15 lb/10^6 Btu NOx	0.05 lb/10^6 Btu	<0.01 lb/10^6 Btu
	0.01 lb/10^6 Btu Particulate Matter	0.005 lb/10^6 Btu	0.002 lb/10^6 Btu
	Mercury (Hg)	90% removal	95% removal
By-Product Utilization	30%	50%	near 100%

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

Total control & elimination of SO_2 is on the roadmap for prevention of acid rain

Source: DOE, EPRI, CURC, http://www.netl.doe.gov/technologies/coalpower/ectp/ecpi/pubs/CCT_Roadmap.pdf

Sulfur in Coals



Although coal is primarily a mixture of carbon (*black*) & hydrogen (*red*) atoms, sulfur atoms (*yellow*) are also trapped in coal, primarily in two forms. In one form, the sulfur is a separate particle often linked with iron (*green*, pyritic sulfur) with no connection to the carbon atoms, as in the center of the drawing (fools gold). In the second form, sulfur is chemically bound to the carbon atoms (organic sulfur), such as in the upper left

Source: http://www.fossil.energy.gov/education/energylessons/coal/coal_act2.html

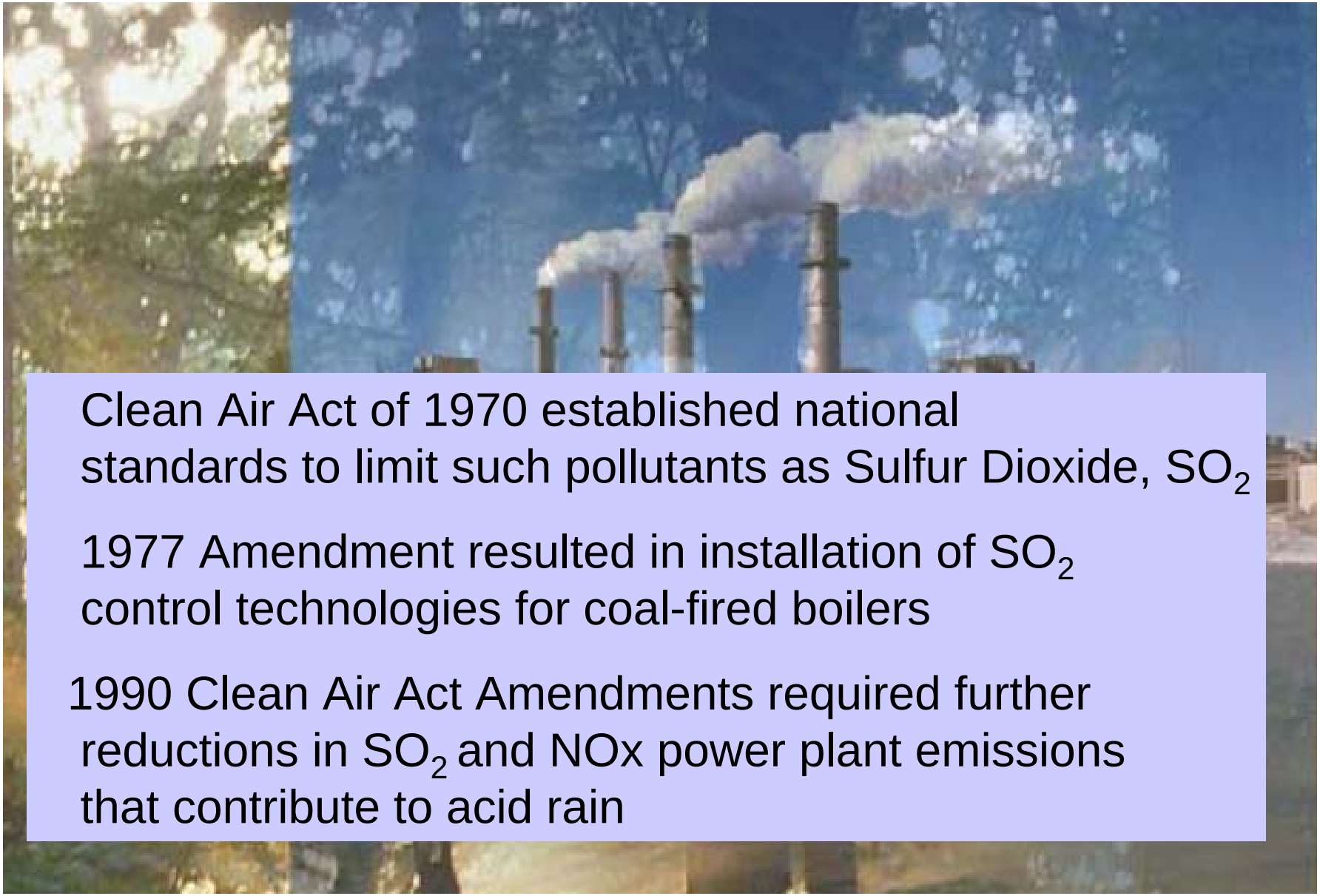
Amount of Sulfur in Coals

Supply State	Sulfur (% weight)	Heat Content (Btu/lb)
Indiana	2.136	11,101
Illinois	2.445	10,860
Kentucky	1.034	12,289
Ohio	3.157	11,703
Pennsylvania	2.011	12,927
Virginia	0.728	13,905
West Virginia	1.934	12.654
Wyoming	0.239	8,829

Indiana average sulfur content = 2.1% by weight

Source: “Expanding the Utilization of Indiana Coals”, http://discoverypark.purdue.edu/wps/portal/Energy/CCTR_Research

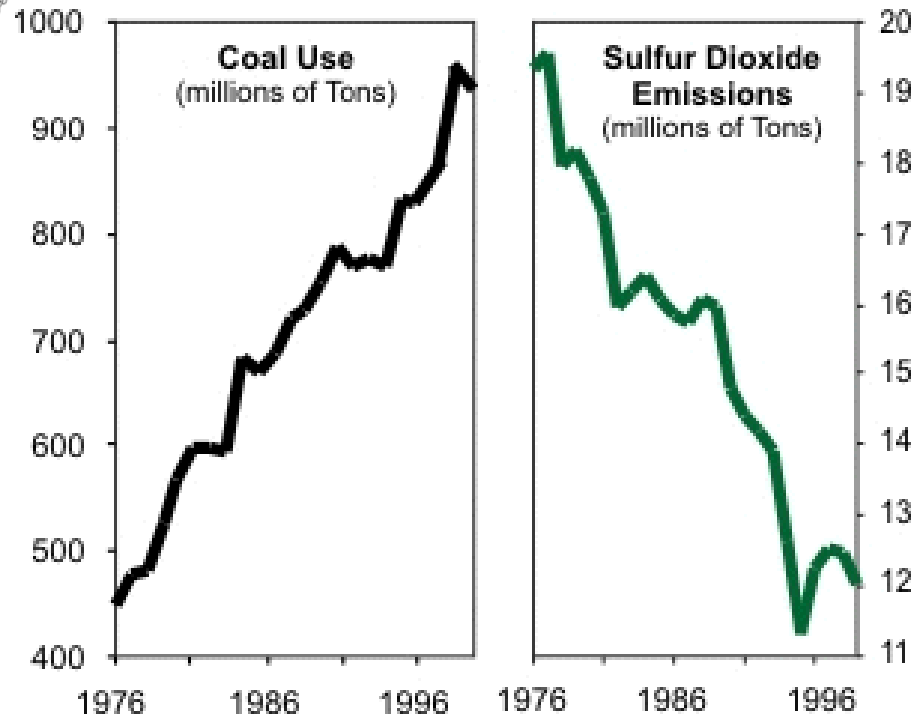
Emission Control Strategies for Power Plants



Clean Air Act of 1970 established national standards to limit such pollutants as Sulfur Dioxide, SO_2

1977 Amendment resulted in installation of SO_2 control technologies for coal-fired boilers

1990 Clean Air Act Amendments required further reductions in SO_2 and NOx power plant emissions that contribute to acid rain

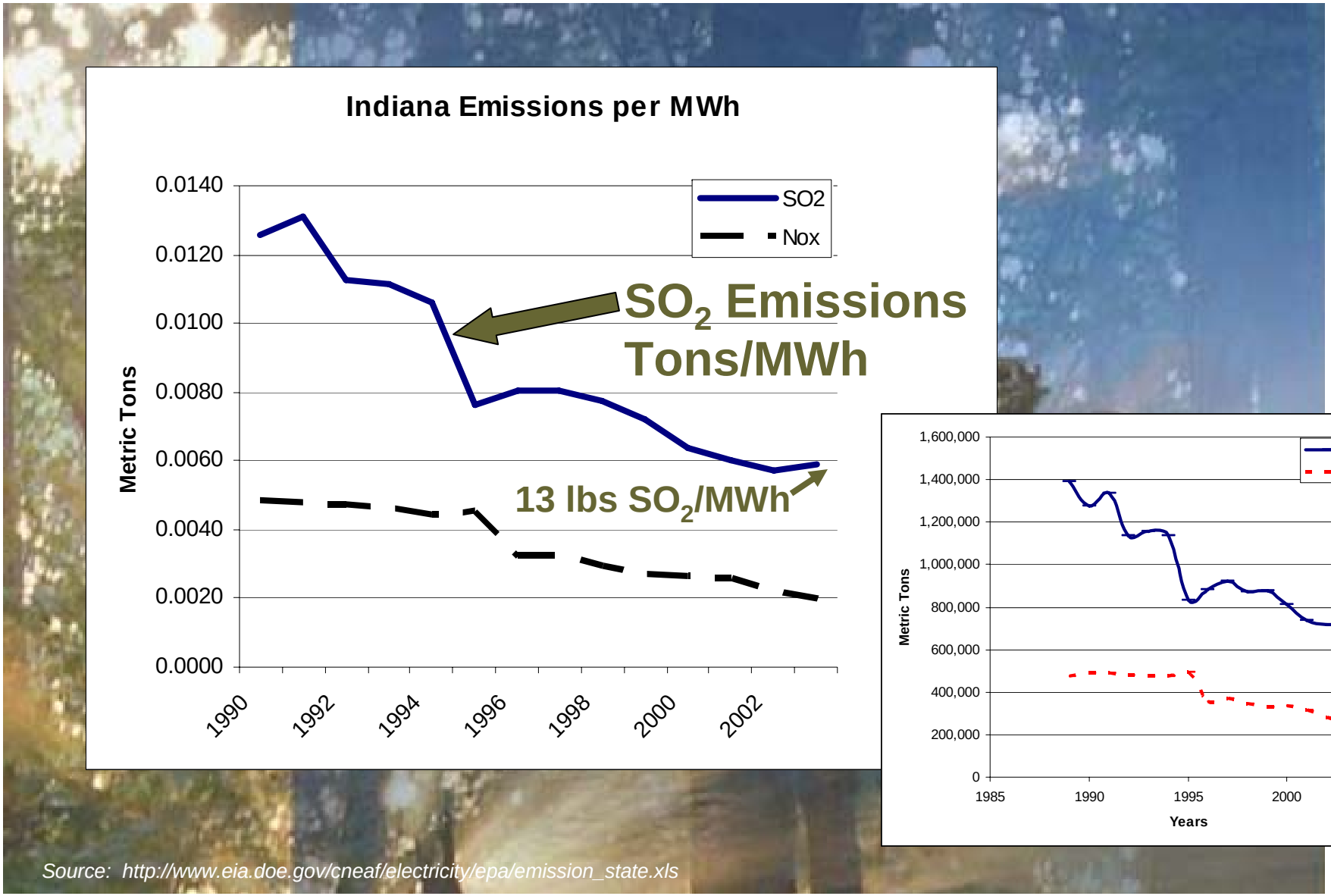


Coal Use & Reductions in SO_2 Emissions from Power Plants

Coal is being burned more cleanly today than ever before. Air pollution from coal is decreasing, while coal use is increasing. Coal-fired power plants in the U.S. have reduced their SO_2 (Sulfur Dioxide) emission rate (lbs SO_2/Ton coal burned) by 71% from 1976 to 1999

Source: http://www.coaleducation.org/Ky_Coal_Facts/environment/air_quality.htm

Indiana Coal-Fired Generation & Emissions



Source: http://www.eia.doe.gov/cneaf/electricity/epa/emission_state.xls

	SO_2 emissions (Tons)	SO_2 RANK
IL	437,593	
IN	**878,196**	**3rd**
KY	585,141	**5th**
OH	1,232,450	**1st**
PA	951,373	**2nd**
TX	577,122	
WV	598,053	**4th**

SO_2 Emissions from Utilities by State in 2000 (Tons)

2004 Indiana SO_2 emissions from utilities = 797,000 Tons

Sources: *http://www.eia.doe.gov/cneaf/electricity/st_profiles/sep2004.pdf*
EPA eGRID2002 Version 2.01 State File,
http://www.epa.gov/cleanenergy/egrid/index.htm

Methods of Controlling SO_2 From Coal-Fired Power Plants

Methods include:

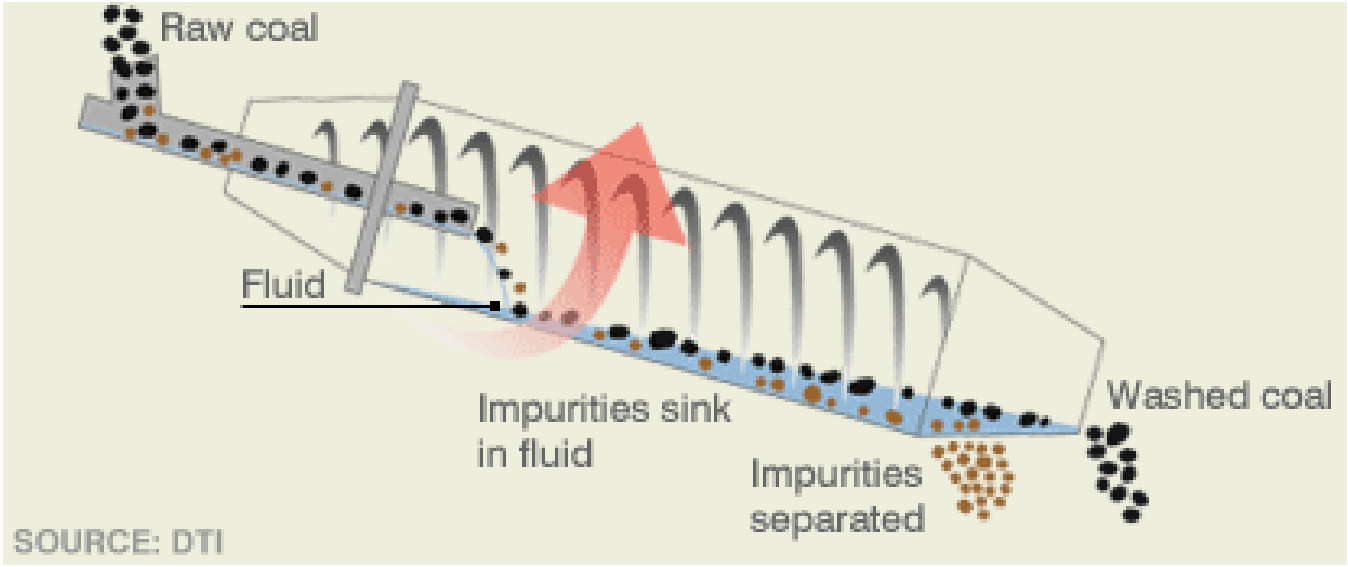
- Cleaning the coal to remove the sulfur
- Switching to lower SO_2 fuel
- Purchasing SO_2 allowances
- Installing flue gas desulfurization systems, FGD

Clean Coal & Remove SO_2

Coal washing removes 25% to 40% of the sulfur.

Only the pyritic sulfur is washed out.

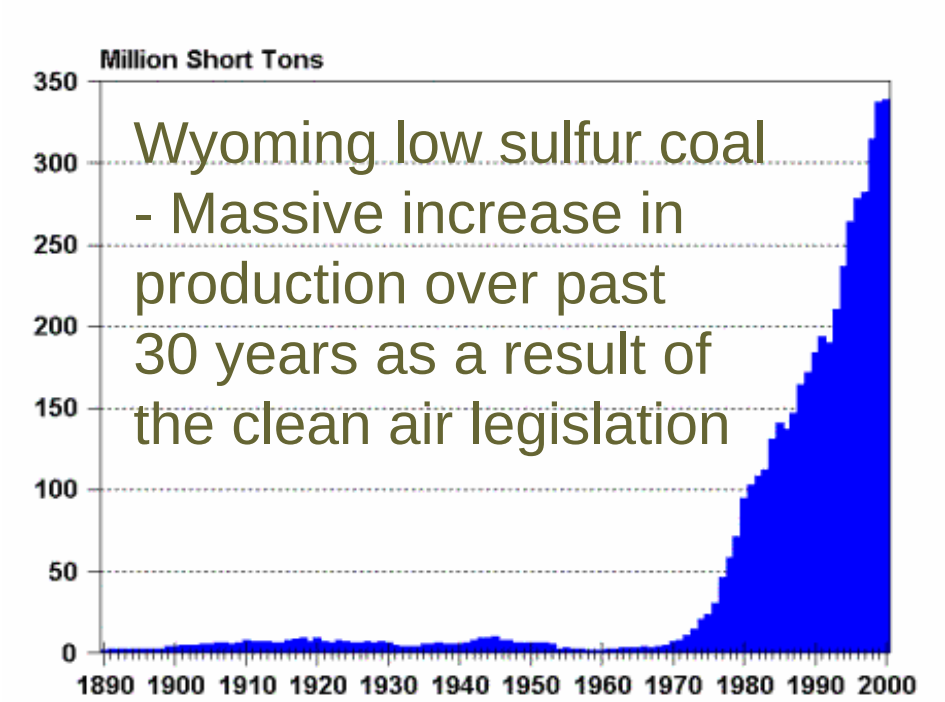
Organic sulfur doesn't wash out

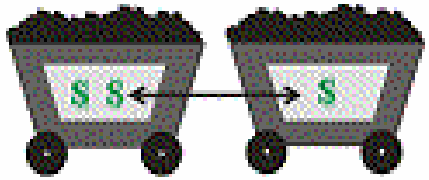



http://news.bbc.co.uk/1/hi/sci/tech/4468076.stm

Coal washing involves grinding the coal into smaller pieces & passing it through a process called gravity separation. Technique involves feeding the coal into barrels containing a fluid that has a density which causes the coal to float, while unwanted material sinks & is removed from the fuel mix

Switch to Lower SO_2 Coal





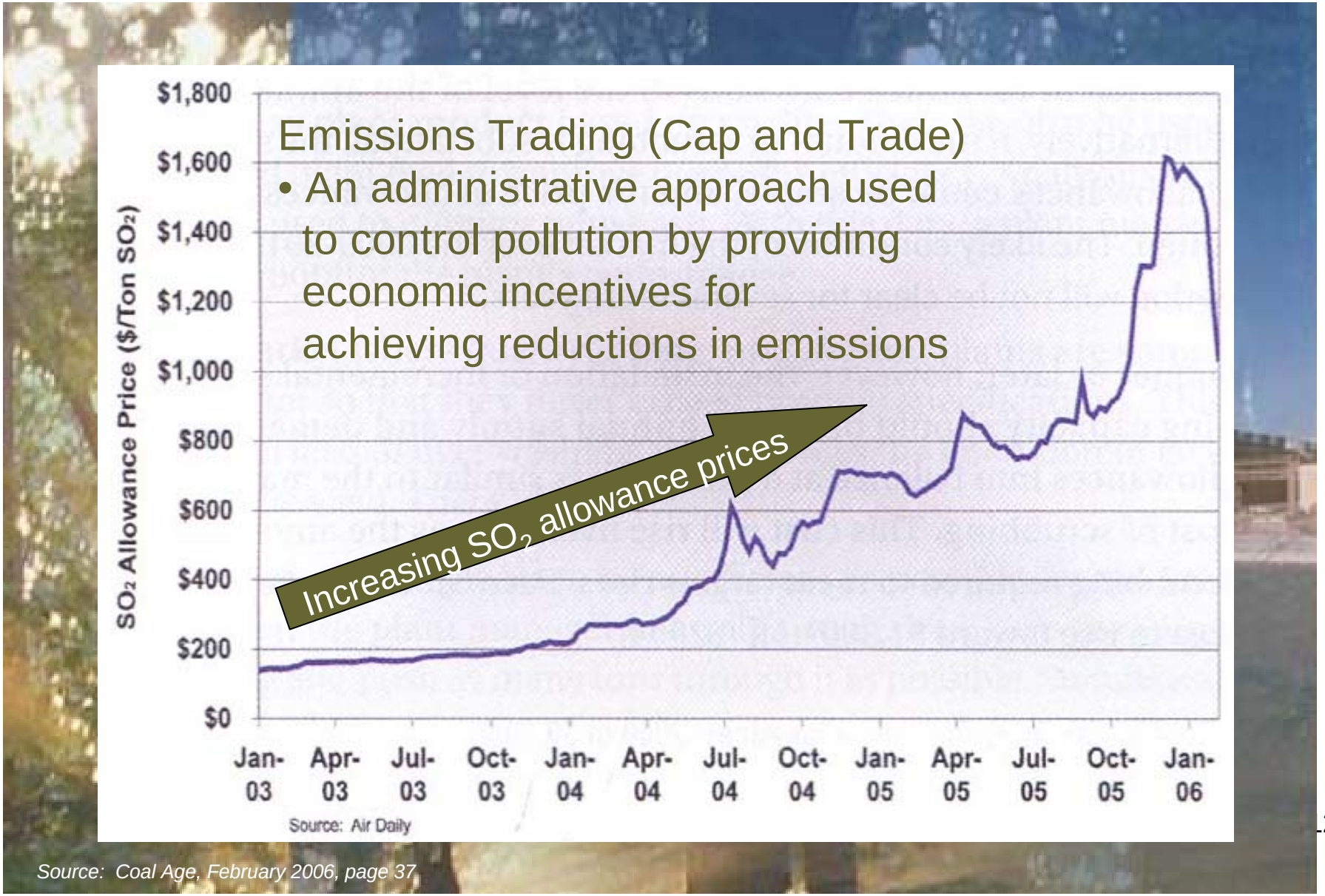
Transportation Rate per Ton

What is the transportation cost ($/Ton mile)?

Midwest utilities are importing western coals with their low sulfur content but transportations costs are increasing & extra railroad capacity is needed

Source: http://www.eia.doe.gov/cneaf/coal/statepro/imagemap/wy.htm

SO_2 Allowance Prices, $/Ton SO_2



Source: Coal Age, February 2006, page 37

Flue Gas Desulfurization Systems, FGD

FGD systems are normally known as wet scrubbers or dry scrubbers (defined according to the state of the by-product)

- Wet Scrubbers – Most common technology

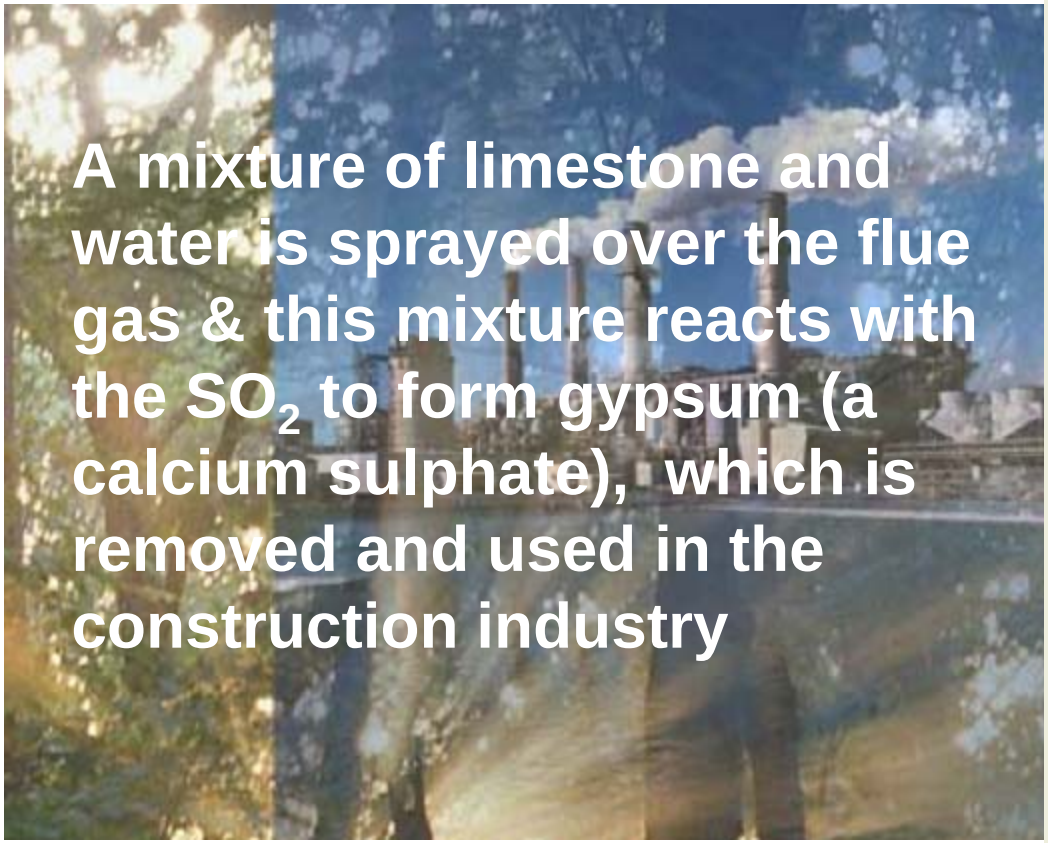
Others (used to much lesser extent):

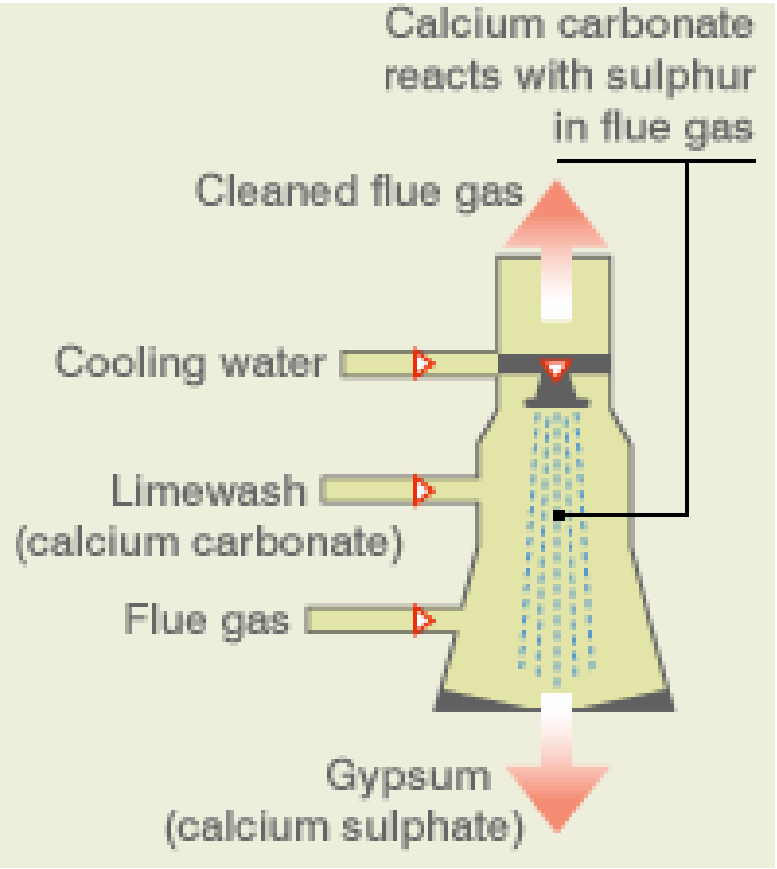
- Spray dryers
- Dry (sorbent) injection systems
- Regenerable systems
- Circulating fluid-bed & moving bed scrubbers
- Combined SO_2/NOx removable systems

Source: Bruce G. Miller, "Coal Energy Systems", 2005

Flue Gas Desulfurization, FGD since 1970s

FGD systems are used to remove SO_2. "Wet scrubbers" are the most widespread method & can be up to 99% effective





Source: http://news.bbc.co.uk/1/hi/sci/tech/4468076.stm

Duct Sorbent Injection

Duct Spray Drying

Second most used method – over 12,000MW of total capacity. Lime is usually the sorbent used. A slake-lime slurry is sprayed Directly into the ductwork to remove SO2. Reaction products & fly ask are captured down-stream in the particulate removal Device

Dry Sorbent Injection (in-duct dry injection)

Hydrated lime is the sorbent typically used. It is injected either upstream or downstream of a flue gas humidification zone

Regenerative Processes

Regenerate the alkaline reagent. Process is costly.

Extent of Global SO_2 Controlled Capacity on Power Plants (MW)

Year	World	USA
1970	None	None
1980	30,000	25,000
1990	130,000	75,000
2000	230,000*	100,000**

* 87% are wet scrubbers

** 10% of U.S. total 1,105,227MW (78% of MW are thermal)

Source: Bruce G. Miller, "Coal Energy Systems", 2005

Scrubber Capital Costs

Medium Removal Technology
$50,000/MW, with 70% SO_2 removal

High Removal Technology
$250,000/MW, with 95% SO_2 removal

< $150,000 /MW, SO_2 emissions could be cut in half
& mercury emissions could be reduced by >60%

Sources: http://www.epri.com/portfolio/product.aspx?id=2055
http://www.paconsulting.com/news/by_pa/2004/Is+it+time+to+take+another+look+at+PRB+coal.htm

Scrubbers on Indiana's 10 Largest Power Stations 2005

Station (Age of units)	Utility	MW	Station Efficiency (%)	IN coal of total coal used (%)	WY coal of total coal used (%)	SO_2 (Tons)	MW with Scrubbers in 2005 (MW)	MW Scrubbed in 2005 (%)	Scrubber Efficiency in 2005 (%)	Scrubber Installations Date installed per unit EPA Model Results for 2015
1. Gibson 1975-1982	Duke Energy	3,131	32.2	79%	0%	136,536	1,336	43%	89%	Unit 1 – 2007, Unit 2 – 2007 Unit 3 – 2006 Unit 4 – Upgrade in 2005 Unit 5 – Upgrade in 2008
2. Rockport 1984-1989	IMPCo	2,600	35.4	16%	84%	53,561	0	0		Unit 1 Unit 2
3. R M Schahfer 1976-1986	NIPSCo	1,780	30.6	21%	58%	35,301	847	48%	90%	Unit 1 - Unit 2 – Unit 3 - Unit 4 – Unit 5 - Unit 6 -
4. Petersburg 1967-1986	IPL	1,672	32.6	100%	0%	42,535	1,672	100%	95%	Units 1 - 7
5. Clifty Creek 1955-6	IKECorp	1,209	32.7	22%	78%	32,753	0	0		Units 1 – 5 2015 (five units) Unit 6
6. Cayuga 1970-1972	Duke Energy	1,096	33.7	64%	36%	66,962	0	0		Unit 1 - 2015 Unit 2 – 2015
7. Merom 1982-1983	Hoosier	1,000	32.4	100%	0%	14,689	1,000	100%	90%	Units 1 – 2
8. Tanners Creek 1951-1964	IMPCo	980	34.1	92%	5%	53,175	0	0		Units 1 – 3 Unit 4 – 2015 (580MW)
9. Harding St 1973-2002	IPLCo	924	34.2	100%	0%	51,016	0	0		Units 1 - 8
10. Wabash R. 1953-1995	Duke Energy	918	32.4	100%	0%	64,606	0	0		Units 1 – 5 Unit 6 - 2015
	TOTAL	15,310				551,134	4,855	32%		

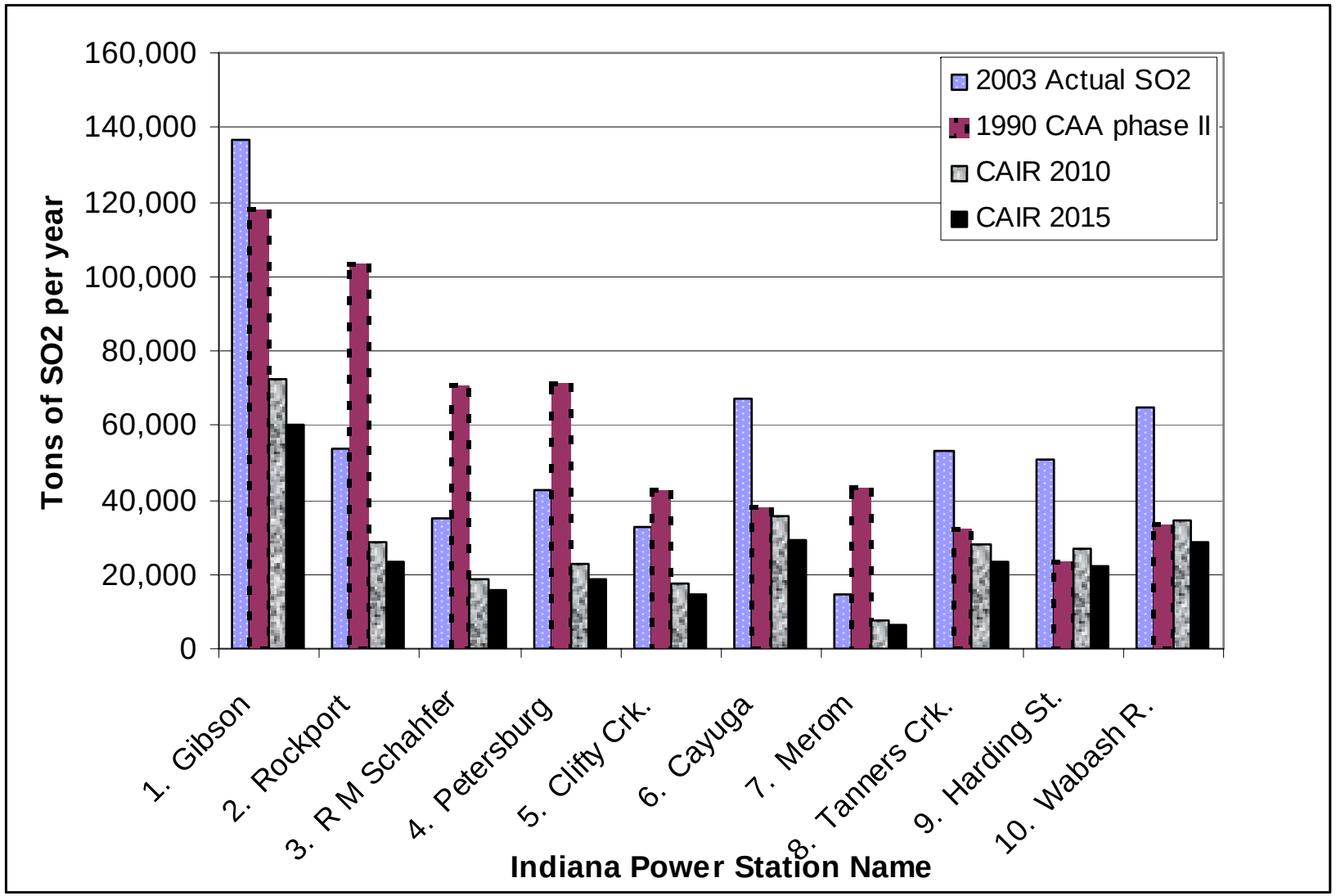
Source: http://www.ladco.org/reports/rpo/MWRPOprojects/Emissions/FinalReport_Methods.pdf

Indiana's 10 Largest Power Plants & Emission Controls (IDEM January 2007)

Plant Name	Boiler Unit	Output Capacity (MW)	On Line (Year)	Fuel Type	NOx Control	NOx Control Efficiency (%)	PM10 Control	PM Control Efficiency (%)	SO2 Control	SO2 Control Efficiency (%)
Gibson	1,2,3,4,5	**3,131**	1975-82	Coal	LNB & SCR	50 – 90	ESP	99.1 – 99.7	FGD	82 – 91%
Rockport	1,2	**2,600**	1984 & 1989	Coal (WY)	LNB & OFA	-	ESP	99.82	-	-
R.M. Schaffer	14,15 16A-B Gas	**1,780**	1976 -79 1979	Coal (WY) N.Gas	SCR & OFA	-	ESP	95.8 – 97.7	-	-
Petersburg	1,2,3,4	**1,672**	1967-86	Coal	LNB SCR OFA	-	ESP	98.0 – 99.5	Wet FGD scrubbers	-
Clifty Creek	1,2,3,4,5,6	**1,209**	1955-56	Coal (WY)	OFA & SCR	45	ESP	98.4 – 99.3	FGD	-
Cayuga	1,2 Turbine	**1,096**	1970-72	Coal N.Gas	Mod.Burner Wet injection	52.99 – 54.99 90.99	ESP	99.0	FGD (U/C)	-
Merom	1,2	**1,000**	1980-82	Coal	LNB & SCR	-	-	-	Wet FDG scrubbers	-
Tanners Creek	1,2,3,4	**980**	1951-64	Coal	LNB & OFA	-	ESP	99.15 – 99.75	-	-
Harding Street	5 boilers & 6 turbines	**924**	1942-02	Coal & Oil	LNB & SNCR	-	ESP on 3 boilers	99.40 – 99.47	FGD 2008 on 1 boiler	-
Wabash River	5 boilers & Turbine	**918**	1953-01	Coal & Syngas	Mod. Burners Steam/water injection	37.99 – 49.99 76.99	ESP	98.49	-	-

Note: LNB – Low NOx Burners, SCR – Selective Catalytic Reduction, FGD – Flue Gas Desulfurization
ESP – Electrostatic Precipitators OFA – Overfire Air WY – Wyoming
U/C - Under Construction

SO_2 Phase II Clean Air Act & Estimated CAIR Allowances on Indiana's 10 Largest Power Stations



EPRI 2007 Analysis of Scrubber Technologies

- Multipollutant capabilities of new SO_2 control systems - will look at how well each system supports the co-capture & retention of Hg, reduction in opacity & PM2.5 emissions, & possible moderate removal of NOx, while providing reliable, high levels of SO_2 removal
- Determine how FGD suppliers & architect/engineers are minimizing water consumption
- Provide a system that uses microchip-based sensors that could facilitate & expand FGD chemistry measurements

Source: http://www.epri.com/portfolio/product.aspx?id=2055