Table 5.1. Summary of Emission Control Technology Retrofit Options in EPA Base Case 2006

SO_2 Control Technology Options	NO_x Control Technology Options	Mercury Control Technology Options
Limestone Forced Oxidation (LSFO) Scrubber	Selective Catalytic Reduction (SCR) System	Activated Carbon Injection (ACI) System
Lime Spray Dryer (LSD) Scrubber	Selective Non-Catalytic Reduction (SNCR) System	SO_2 and NO_x Control Technology Removal Cobenefits
	Combustion Controls	

Table 5.2. Summary of SO_2 Retrofit Emission Control Performance Assumptions

	Limestone Forced Oxidation (LSFO)	Lime Spray Dryer (LSD)
Percent Removal	95% with a floor of 0.06 lbs/MMBtu	90% with a floor of 0.09 lbs/MMBtu
Capacity Penalty	- 1.65%	- 0.7%
Heat Rate Penalty	1.68%	0.71%
Cost (2004$)	See Table 5.3	See Table 5.3
Applicability	Units ≥ 100 MW	Units ≥ 100 MW
Sulfur Content Applicability		Coals ≤ 2.0% Sulfur by Weight
Applicable Coal Types	BA, BB, BD, BE, BG, BH, SA, SB, SD, SE, LA, LD, LE, and LG	BA, BB, BD, BE, SA, SB, SD, SE, LA, LD, LE, and LG

Table 5.3. Illustrative Scrubber Costs (2004$) for Representative MW and Heat Rates under the Assumptions in EPA Base Case 2006

Scrubber Type	Capacity (MW)	Heat Rate (Btu/kWh)			Cost
		9,000	10,000	11,000	
LSFO	100	466	468	470	Capital Cost ($/kW)
Minimum Cutoff: ≥ 100 MW		19	19	19	Fixed O&M ($/kW-yr)
Maximum Cutoff: None		1.3	1.4	1.5	Variable O&M (mills/kWh)
Assuming 5.0 lbs/MMBtu SO_2 Coal	300	228	230	232	Capital Cost ($/kW)
		11	11	11	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
	500	171	174	176	Capital Cost ($/kW)
		9	9	9	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
	700	140	142	144	Capital Cost ($/kW)
		8	8	8	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
	1000	118	120	123	Capital Cost ($/kW)
		7	7	7	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
LSD	100	279	286	293	Capital Cost ($/kW)
Minimum Cutoff: ≥ 100 MW		11	13	12	Fixed O&M ($/kW-yr)
Maximum Cutoff: None		2.1	2.4	2.6	Variable O&M (mills/kWh)
Assuming 3.0 lbs/MMBtu SO_2 Coal	300	148	155	163	Capital Cost ($/kW)
		8	8	8	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)
	500	124	131	139	Capital Cost ($/kW)
		6	6	6	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)
	700	111	118	126	Capital Cost ($/kW)
		5	5	5	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)
	1000	104	112	120	Capital Cost ($/kW)
		4	4	4	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)

Table 5.4. Cost (2004$) of NO_x Combustion Controls for Coal Boilers (300 MW Size)

Boiler Type	Technology	Capital ($/kW)	Fixed O&M ($/kW-yr)	Variable O&M (mills/kWh)
Dry Bottom Wall-Fired	Low NO_x Burner without Overfire Air (LNB without OFA)	19.24	0.29	0.06
	Low NO_x Burner with Overfire Air (LNB with OFA)	26.12	0.40	0.08
Tangentially-Fired	Low NO_x Coal-and-Air Nozzles with Close-Coupled Overfire Air (LNC1)	10.14	0.16	0.00
	Low NO_x Coal-and-Air Nozzles with Separated Overfire Air (LNC2)	14.17	0.21	0.027
	Low NO_x Coal-and-Air Nozzles with Close-Coupled and Separated Overfire Air (LNC3)	16.19	0.25	0.027

Scaling Factor

For all of the above combustion controls the following scaling factor is used to obtain the capital and fixed operating and maintenance costs applicable to the capacity (in MW) of the unit taking on combustion controls. No scaling factors is applied in calculating the variable operating and maintenance cost.

$$(\$ \text{ for X MW Unit}) = (\$ \text{ for 300 MW Unit}) \times \left(\frac{300}{X}\right)^{0.359}$$

where

($ for 300 MW Unit) is the value obtained using the factors shown in the above table and
X is the capacity (in MW) of the unit taking on combustion controls.

Table 5.5. Summary of Retrofit NO_x Emission Control Performance Assumptions

	Selective Catalytic Reduction (SCR)		Selective Non-Catalytic Reduction (SNCR)	
Unit Type	Coal	Oil/Gas	Coal	Oil/Gas
Percent Removal	90% down to 0.06 lb/mmBtu	80%	Pulverized Coal: 35% Fluidized Bed: 50%	50%
Size Applicability	Units ≥ 100 MW	Units ≥ 25 MW	Units ≥ 25 MW and Units < 200 MW (for non FBC units)	Units ≥ 25 MW
Costs (2004$)	See Table 5.6	See Table 5.7	See Table 5.6	See Table 5.7

Table 5.6. Post-Combustion NO_x Controls for Coal Plants (2004$)

Post-Combustion Control Technology	Capital ($/kW)	Fixed O&M ($/kW/Yr)	Variable O&M (mills/kWh)	Percent Removal
SCR[2]	111.48	0.74	0.67	90%[1]
SNCR[3]	Term 1 - 19.06 Term 2 - 21.74	Term 1 - 0.28 Term 2 - 0.33	0.98	35%
SNCR[4] (Cyclone)	11.04	0.16	1.46	35%
SNCR[5] (Fluidized Bed)	19.10	0.29	See Note 5	50%

Notes:
[1] Cannot provide reductions any further beyond 0.06 lbs/mmBtu.

[2] SCR Cost Scaling Factor:
SCR Capital and Fixed O&M Costs: $(242.72/MW)^{0.27}$
SCR Variable O&M Costs: $(242.72/MW)^{0.11}$
Scaling factor applies up to 600 MW.

[3] SNCR Cost Scaling Factor:
SNCR Capital and Fixed O&M Costs: $(Term1*(200/MW)^{0.577} + Term2*(100/MW)^{0.681})/2$

[4] Cyclone Cost Scaling Factor:
High NO_x Coal SNCR—Cyclone Capital and Fixed O&M Costs: $(300/MW)^{0.577}$
VO&M = 1.27 for MW $\leq$ 300,
VO&M = 1.27 – ((MW – 300)/100) * 0.015 for MW > 300.

[5] Fluidized Bed Cost Scaling Factor:
SNCR - Fludized Bed Capital and Fixed O&M Costs: $(200/MW)^{0.577}$
VO&M = .85

Reference

Khan, S. and Srivastava, R. "Updating Performance and Cost of NO_x Control Technologies in the Integrated Planning Model," Mega Symposium, August 30, 2004 - September 2, 2004, Washington, D.C.

Table 5.7. Post-Combustion NO_x Controls for Oil/Gas Steam Units (2004$)

Post-Combustion Control Technology	Capital ($/kW)	Fixed O&M ($/kW/Yr)	Variable O&M (mills/kWh)	Percent Removal
SCR[1]	32.2	0.99	0.11	80%
SNCR[2]	10.8	0.17	0.50	50%

Notes:
[1] SCR Cost Scaling Factor:
SCR and Gas Reburn Capital Cost and fixed O&M: $(200/MW)^{0.35}$
Scaling factor applies up to 500 MW

[2] SNCR Cost Scaling Factor: :
SNCR Capital Cost and fixed O&M: $(200/MW)^{0.577}$
Scaling factor applies up to 500 MW

Reference
Cost Estimates for Selected Applications of NOx Control Technologies on Stationary Combustion Boilers, Bechtel Power Corporation for US EPA, June 1997.

Table 5.8 Mercury Emission Factors in the EPA Base Case 2006

Coal Type by Sulfur Grade	Mercury Emission Factors by Coal Sulfur Grades (lbs/TBtu)		
	Cluster #1	Cluster #2	Cluster #3
Low Sulfur Eastern Bituminous (BA)	3.13	4.37	--
Low Sulfur Western Bituminous (BB)	4.44	19.10	--
Low Medium Sulfur Bituminous (BD)	5.11	8.94	21.67
Medium Sulfur Bituminous (BE)	25.83	16.21	7.80
High Sulfur Bituminous (BG)	23.36	7.10	15.72
High Sulfur Bituminous (BH)	7.58	15.20	34.71
Low Sulfur Subbituminous (SA)	3.54	4.24	5.61
Low Sulfur Subbituminous (SB)	4.22	6.44	6.25
Low Medium Sulfur Subbituminous (SD)	4.43	--	--
Medium Sulfur Subbituminous (SE)	6.44	--	--
Low Sulfur Lignite (LA)	9.88	--	--
Low Medium Sulfur Lignite (LD)	6.43	12.00	--
Medium Sulfur Lignite (LE)	7.81	14.65	--
High Sulfur Lignite (LG)	14.88	--	--

Table 5.9. Assumptions on Mercury Concentrations in Non-Coal Fuel in EPA Base Case 2006

Fuel Type	Mercury Concentration (lbs/TBtu)
Oil	0.48
Natural Gas	0.00*
Biomass	0.57
Municipal Solid Waste	71.85
Geothermal Resource	2.97 - 3.7

*The values appearing in this table are rounded to two decimal places. The zero value shown for natural gas is based on an EPA study that found a mercury content of 0.00014 lbs/TBtu. Values for geothermal resources represent a range.

Table 5.10. Mercury Emission Modification Factors Used in EPA Base Case 2006

Burner Type	Particulate Control	Post Combustion Control-NOx	Post Combustion Control-SO_2	Bituminous EMF	Sub-bituminous EMF	Lignite EMF
Cyclone	No Control	None	None	1	1	1
Cyclone	No Control	None	Dry FGD	1	1	1
Cyclone	No Control	None	Wet FGD	0.45	0.6	1
Cyclone	No Control	SCR	None	1	1	1
Cyclone	No Control	SCR	Wet FGD	0.1	0.7	1
Cyclone	No Control	SNCR	None	1	1	1
Cyclone	No Control	SNCR	Wet FGD	0.45	0.6	1
Cyclone	Cold Side ESP	None	None	0.64	0.97	0.93
Cyclone	Cold Side ESP + FF	SCR	Dry FGD	0.4	0.95	0.91
Cyclone	Cold Side ESP + FF	SCR	None	0.11	0.27	1
Cyclone	Cold Side ESP + FF	None	None	0.11	0.27	1
Cyclone	Cold Side ESP	None	Wet FGD	0.46	0.84	0.58
Cyclone	Cold Side ESP	None	Dry FGD	0.64	0.65	0.93
Cyclone	Cold Side ESP	SCR	None	0.64	0.97	0.93
Cyclone	Cold Side ESP	SCR	Wet FGD	0.1	0.84	0.58
Cyclone	Cold Side ESP	SCR	Dry FGD	0.64	0.65	0.93
Cyclone	Cold Side ESP	SNCR	None	0.64	0.97	0.93
Cyclone	Cold Side ESP	SNCR	Wet FGD	0.46	0.84	0.58
Cyclone	Cold Side ESP	SNCR	Dry FGD	0.64	0.65	0.93
Cyclone	Cold Side ESP + FF	None	Dry FGD	0.4	0.95	0.91
Cyclone	Hot Side ESP	SNCR	Dry FGD	0.9	1	1
Cyclone	Fabric Filter	None	None	0.11	0.27	1
Cyclone	Fabric Filter	None	Wet FGD	0.1	0.27	0.58
Cyclone	Fabric Filter	None	Dry FGD	0.4	0.95	0.91
Cyclone	Fabric Filter	SCR	None	0.11	0.27	1
Cyclone	Fabric Filter	SCR	Wet FGD	0.1	0.27	0.58
Cyclone	Fabric Filter	SCR	Dry FGD	0.4	0.95	0.91
Cyclone	Fabric Filter	SNCR	None	0.11	0.27	1
Cyclone	Fabric Filter	SNCR	Wet FGD	0.03	0.27	0.58
Cyclone	Fabric Filter	SNCR	Dry FGD	0.4	0.95	0.91
Cyclone	Hot Side ESP	None	None	0.9	1	1
Cyclone	Hot Side ESP	None	Wet FGD	0.58	0.6	1
Cyclone	Hot Side ESP	None	Dry FGD	0.9	1	1
Cyclone	Hot Side ESP	SCR	None	0.9	1	1
Cyclone	Hot Side ESP	SCR	Wet FGD	0.1	0.8	1
Cyclone	Hot Side ESP	SNCR	None	0.9	1	1
Cyclone	Hot Side ESP	SNCR	Wet FGD	0.58	0.6	1
Cyclone	No Control	SNCR	Dry FGD	1	1	1
Cyclone	PM Scrubber	None	None	0.8	1	1
Cyclone	No Control	SCR	Dry FGD	1	1	1
Cyclone	Hot Side ESP	SCR	Dry FGD	0.9	1	1
FBC	No Control	None	None	1	1	1
FBC	No Control	None	Wet FGD	1	1	1
FBC	No Control	None	Dry FGD	0.45	0.45	1
FBC	No Control	SCR	None	1	1	1
FBC	No Control	SCR	Wet FGD	0.1	0.7	1
FBC	No Control	SNCR	None	1	1	1
FBC	No Control	SNCR	Wet FGD	1	1	1
FBC	No Control	SNCR	Dry FGD	0.45	0.45	1
FBC	Cold Side ESP	None	None	0.65	0.65	0.62

Burner Type	Particulate Control	Post Combustion Control-NOx	Post Combustion Control-SO_2	Bituminous EMF	Sub-bituminous EMF	Lignite EMF
FBC	Cold Side ESP + FF	None	None	0.05	0.43	0.43
FBC	Cold Side ESP + FF	SNCR	None	0.05	0.43	0.43
FBC	Cold Side ESP	None	Wet FGD	0.65	0.65	0.62
FBC	Cold Side ESP	SCR	Wet FGD	0.1	0.84	0.62
FBC	Cold Side ESP	SNCR	None	0.65	0.65	0.62
FBC	Cold Side ESP	SNCR	Wet FGD	0.65	0.65	0.62
FBC	Fabric Filter	None	None	0.05	0.43	0.43
FBC	Fabric Filter	None	Dry FGD	0.05	0.43	0.43
FBC	Fabric Filter	None	Wet FGD	0.1	0.43	0.43
FBC	Fabric Filter	SCR	None	0.05	0.43	0.43
FBC	Fabric Filter	SCR	Wet FGD	0.05	0.27	0.43
FBC	Fabric Filter	SCR	Dry FGD	0.05	0.43	0.43
FBC	Fabric Filter	SNCR	None	0.05	0.43	0.43
FBC	Fabric Filter	SNCR	Wet FGD	0.05	0.43	0.43
FBC	Fabric Filter	SNCR	Dry FGD	0.05	0.43	0.43
FBC	Hot Side ESP	None	None	1	1	1
FBC	No Control	SCR	Dry FGD	0.45	0.45	1
Other	No Control	None	None	1	1	1
Other	No Control	None	Wet FGD	0.58	0.7	1
Other	No Control	SCR	None	1	1	1
Other	No Control	SCR	Wet FGD	0.1	0.7	1
Other	No Control	SNCR	None	1	1	1
Other	No Control	SNCR	Wet FGD	0.58	0.7	1
Other	Cold Side ESP	None	None	0.64	0.97	1
Other	Cold Side ESP	None	Wet FGD	0.34	0.84	0.56
Other	Cold Side ESP	None	Dry FGD	0.64	0.65	1
Other	Cold Side ESP	SCR	None	0.64	0.97	1
Other	Cold Side ESP	SCR	Wet FGD	0.1	0.84	0.56
Other	Cold Side ESP	SNCR	None	0.64	0.97	1
Other	Cold Side ESP	SNCR	Wet FGD	0.34	0.73	0.56
Other	Cold Side ESP	SCR	Dry FGD	0.64	0.65	1
Other	Cold Side ESP	SNCR	Dry FGD	0.64	0.65	1
Other	Hot Side ESP	SCR	Dry FGD	1	1	1
Other	Hot Side ESP	SNCR	Dry FGD	1	1	1
Other	Fabric Filter	None	None	0.11	0.27	1
Other	Fabric Filter	None	Wet FGD	0.1	0.27	0.56
Other	Fabric Filter	None	Dry FGD	0.4	0.75	1
Other	Fabric Filter	SCR	None	0.11	0.27	1
Other	Fabric Filter	SCR	Wet FGD	0.1	0.27	0.56
Other	Fabric Filter	SCR	Dry FGD	0.4	0.75	1
Other	Fabric Filter	SNCR	None	0.45	0.75	1
Other	Fabric Filter	SNCR	Wet FGD	0.03	0.27	0.56
Other	Fabric Filter	SNCR	Dry FGD	0.4	0.75	1
Other	No Control	None	Dry FGD	1	1	1
Other	Hot Side ESP	None	None	1	1	1
Other	Hot Side ESP + FF	None	None	0.11	0.27	1
Other	Hot Side ESP	None	Wet FGD	0.58	1	1
Other	Hot Side ESP	None	Dry FGD	1	1	1
Other	Hot Side ESP	SCR	None	1	1	1
Other	Hot Side ESP	SCR	Wet FGD	0.1	0.8	1

Burner Type	Particulate Control	Post Combustion Control-NOx	Post Combustion Control-SO_2	Bituminous EMF	Sub-bituminous EMF	Lignite EMF
Other	Hot Side ESP	SNCR	None	1	1	1
Other	Hot Side ESP	SNCR	Wet FGD	0.58	1	1
Other	No Control	SCR	Dry FGD	1	1	1
Other	No Control	SNCR	Dry FGD	1	1	1
PC	No Control	None	None	1	1	1
PC	No Control	None	Wet FGD	0.58	0.7	1
PC	No Control	None	Dry FGD	0.6	0.85	1
PC	No Control	SCR	None	1	1	1
PC	No Control	SCR	Wet FGD	0.1	0.7	1
PC	No Control	SCR	Dry FGD	0.6	0.85	1
PC	No Control	SNCR	None	1	1	1
PC	No Control	SNCR	Wet FGD	0.58	0.7	1
PC	No Control	SNCR	Dry FGD	0.6	0.85	1
PC	Cold Side ESP	None	None	0.64	0.97	1
PC	Cold Side ESP + FF	None	None	0.2	0.75	1
PC	Cold Side ESP + FF	None	Wet FGD	0.3	0.3	0.56
PC	Cold Side ESP + FF	None	Dry FGD	0.05	0.75	1
PC	Cold Side ESP + FF	SCR	None	0.2	0.75	1
PC	Cold Side ESP + FF	SCR	Wet FGD	0.1	0.3	0.56
PC	Cold Side ESP + FF	SCR	Dry FGD	0.05	0.75	1
PC	Cold Side ESP + FF	SNCR	None	0.2	0.75	1
PC	Cold Side ESP + FF	SNCR	Wet FGD	0.1	0.3	0.56
PC	Cold Side ESP	None	Wet FGD	0.34	0.84	0.56
PC	Cold Side ESP	None	Dry FGD	0.64	0.65	1
PC	Cold Side ESP	SCR	None	0.64	0.97	1
PC	Cold Side ESP	SCR	Wet FGD	0.1	0.84	0.56
PC	Cold Side ESP	SCR	Dry FGD	0.64	0.65	1
PC	Cold Side ESP	SNCR	None	0.64	0.97	1
PC	Cold Side ESP	SNCR	Wet FGD	0.34	0.65	0.56
PC	Cold Side ESP	SNCR	Dry FGD	0.64	0.65	1
PC	Cold Side ESP + FF	SNCR	Dry FGD	0.05	0.75	1
PC	Fabric Filter	None	None	0.11	0.27	1
PC	Fabric Filter	None	Wet FGD	0.1	0.27	0.56
PC	Fabric Filter	None	Dry FGD	0.05	0.75	1
PC	Fabric Filter	SCR	None	0.11	0.27	1
PC	Fabric Filter	SCR	Wet FGD	0.1	0.27	0.56
PC	Fabric Filter	SCR	Dry FGD	0.05	0.75	1
PC	Fabric Filter	SNCR	None	0.11	0.27	1
PC	Fabric Filter	SNCR	Wet FGD	0.03	0.27	0.56
PC	Fabric Filter	SNCR	Dry FGD	0.05	0.75	1
PC	Hot Side ESP	None	None	0.9	0.94	1
PC	Hot Side ESP + FF	None	None	0.11	0.27	1
PC	Hot Side ESP + FF	None	Wet FGD	0.03	0.27	0.56
PC	Hot Side ESP + FF	None	Dry FGD	0.05	0.75	1
PC	Hot Side ESP + FF	SCR	None	0.11	0.27	1
PC	Hot Side ESP + FF	SCR	Wet FGD	0.1	0.15	0.56
PC	Hot Side ESP + FF	SCR	Dry FGD	0.05	0.75	1
PC	Hot Side ESP + FF	SNCR	None	0.11	0.27	1
PC	Hot Side ESP + FF	SNCR	Wet FGD	0.03	0.27	0.56
PC	Hot Side ESP + FF	SNCR	Dry FGD	0.05	0.75	1

Burner Type	Particulate Control	Post Combustion Control-NOx	Post Combustion Control-SO_2	Bituminous EMF	Sub-bituminous EMF	Lignite EMF
PC	Hot Side ESP	None	Wet FGD	0.58	0.8	1
PC	Hot Side ESP	None	Dry FGD	0.6	0.85	1
PC	Hot Side ESP	SCR	None	0.9	0.9	1
PC	Hot Side ESP	SCR	Wet FGD	0.1	0.8	1
PC	Hot Side ESP	SCR	Dry FGD	0.6	0.85	1
PC	Hot Side ESP	SNCR	None	0.9	0.9	1
PC	Hot Side ESP	SNCR	Wet FGD	0.58	0.75	1
PC	Hot Side ESP	SNCR	Dry FGD	0.6	0.85	1
PC	PM Scrubber	None	None	0.9	0.91	1
PC	PM Scrubber	SCR	None	0.9	1	1
Stoker	Hot Side ESP	SCR	Dry FGD	1	1	1
Stoker	No Control	None	None	1	1	1
Stoker	No Control	None	Wet FGD	0.58	1	1
Stoker	No Control	SCR	None	1	1	1
Stoker	No Control	SCR	Wet FGD	0.1	0.7	1
Stoker	No Control	SNCR	None	1	1	1
Stoker	No Control	SNCR	Wet FGD	0.58	1	1
Stoker	Cold Side ESP	None	None	0.65	0.97	1
Stoker	Cold Side ESP	None	Wet FGD	0.34	0.84	0.56
Stoker	Cold Side ESP	None	Dry FGD	0.65	0.65	1
Stoker	Cold Side ESP	SCR	None	0.65	0.97	1
Stoker	Cold Side ESP	SCR	Wet FGD	0.1	0.84	0.56
Stoker	Cold Side ESP	SCR	Dry FGD	0.65	0.65	1
Stoker	Cold Side ESP	SNCR	None	0.65	0.97	1
Stoker	Cold Side ESP	SNCR	Wet FGD	0.34	0.73	0.56
Stoker	Cold Side ESP	SNCR	Dry FGD	0.65	0.65	1
Stoker	Hot Side ESP	SNCR	Dry FGD	1	1	1
Stoker	Fabric Filter	None	None	0.11	0.27	1
Stoker	Fabric Filter	None	Wet FGD	0.1	0.27	0.56
Stoker	Fabric Filter	None	Dry FGD	0.1	0.75	1
Stoker	Fabric Filter	SCR	None	0.11	0.27	1
Stoker	Fabric Filter	SCR	Wet FGD	0.1	0.27	0.56
Stoker	Fabric Filter	SCR	Dry FGD	0.1	0.75	1
Stoker	Fabric Filter	SNCR	None	0.11	0.27	1
Stoker	Fabric Filter	SNCR	Wet FGD	0.03	0.27	0.56
Stoker	Fabric Filter	SNCR	Dry FGD	0.1	0.75	1
Stoker	No Control	None	Dry FGD	1	1	1
Stoker	Hot Side ESP	None	None	1	1	1
Stoker	Hot Side ESP	None	Wet FGD	0.58	1	1
Stoker	Hot Side ESP	None	Dry FGD	1	1	1
Stoker	Hot Side ESP	SCR	None	1	1	1
Stoker	Hot Side ESP	SCR	Wet FGD	0.1	0.8	1
Stoker	Hot Side ESP	SNCR	None	1	1	1
Stoker	Hot Side ESP	SNCR	Wet FGD	0.58	1	1
Stoker	No Control	SNCR	Dry FGD	1	1	1
Stoker	No Control	SCR	Dry FGD	1	1	1

Table 5.11. Key to Burner Type Designations in Table 5.10

“PC” refers to conventional pulverized coal boilers. Typical configurations include wall-fired and tangentially fired boilers (also called T-fired boilers). In wall-fired boilers the burner’s coal and air nozzles are mounted on a single wall or opposing walls. In tangentially fired boilers the burner’s coal and air nozzles are mounted in each corner of the boiler.

“Cyclone” refers to cyclone boilers where air and crushed coal are injected tangentially into the boiler through a “cyclone burner” and “cyclone barrel” which create a swirling motion allowing smaller coal particles to be burned in suspension and larger coal particles to be captured on the cyclone barrel wall where they are burned in molten slag.

“Stoker” refers to stoker boilers where lump coal is fed continuously onto a moving grate or chain which moves the coal into the combustion zone in which air is drawn through the grate and ignition takes place. The carbon gradually burns off, leaving ash which drops off at the end into a receptacle, from which it is removed for disposal.

“FBC" refers to “fluidized bed combustion” where solid fuels are suspended on upward-blowing jets of air, resulting in a turbulent mixing of gas and solids and a tumbling action which provides especially effective chemical reactions and heat transfer during the combustion process.

“Other" refers to miscellaneous burner types including cell burners and arch- , roof- , and vertically-fired burner configurations**.**

Table 5.12. Cost Components for 90% Mercury Removal Efficiency Using ACI, for Representative 500 MW, 10,000 Btu/kWh Heat Rate Unit

Coal Type	Existing Pollution Control Technology	Sulfur Level	Capital Cost (2004$/kW)	FOM (2004$/kW/yr)	VOM (2004mills/kWh)
Bituminous	ESP	L	41.44	5.90	0.30
Bituminous	ESP/O	L	41.44	5.90	0.30
Bituminous	ESP+FF	L	1.93	0.89	0.25
Bituminous	ESP+FGD	H	58.23	8.03	0.35
Bituminous	ESP+FGD+SCR	H	ACI not applicable		
Bituminous	ESP+SCR	L	41.44	5.90	0.30
Bituminous	FF	L	1.93	0.89	0.25
Bituminous	FF+DS	H	1.97	0.90	0.26
Bituminous	FF+FGD	H	1.97	0.90	0.26
Bituminous	HESP	L	41.44	5.90	0.30
Bituminous	HESP+FGD	H	58.23	8.03	0.35
Bituminous	HESP+SCR	L	41.44	5.90	0.30
Bituminous	PMSCRUB+FGD	H	58.23	8.03	0.35
Bituminous	PMSCRUB+FGD+SCR	H	ACI not applicable		
Bituminous	ESP	H	58.85	8.10	0.47
Bituminous	ESP/O	H	58.85	8.10	0.47
Bituminous	ESP+FF	H	2.59	0.97	0.38
Bituminous	ESP+FGD	L	40.98	5.84	0.22
Bituminous	ESP+FGD+SCR	L	ACI not applicable		
Bituminous	ESP+SCR	H	58.85	8.10	0.47
Bituminous	FF	H	2.59	0.97	0.38
Bituminous	FF+DS	L	1.47	0.84	0.16
Bituminous	FF+FGD	L	1.47	0.84	0.16
Bituminous	HESP	H	58.85	8.10	0.47
Bituminous	HESP+FGD	L	40.98	5.84	0.22
Bituminous	HESP+SCR	H	58.85	8.10	0.47
Bituminous	PMSCRUB+FGD	L	40.98	5.84	0.22
Bituminous	PMSCRUB+FGD+SCR	L	ACI not applicable		
Lignite	ESP	L	80.57	10.77	0.61
Lignite	ESP+FF	L	15.68	2.54	0.50
Lignite	ESP+FGD	L	80.57	10.77	0.61
Lignite	FF+DS	L	80.57	10.77	0.61
Lignite	FF+FGD	L	15.68	2.54	0.50
Subbituminous	ESP	L	53.88	7.47	0.42
Subbituminous	ESP+DS	L	53.88	7.47	0.42
Subbituminous	ESP+FGD	L	53.88	7.47	0.42
Subbituminous	ESP+SCR	L	53.88	7.47	0.42
Subbituminous	FF	L	2.41	0.95	0.33
Subbituminous	FF+DS	L	53.88	7.47	0.42
Subbituminous	FF+FGD	L	2.41	0.95	0.33
Subbituminous	HESP	L	53.88	7.47	0.42
Subbituminous	HESP+FGD	L	53.88	7.47	0.42
Subbituminous	HESP+SCR	L	53.88	7.47	0.42
Subbituminous	PMSCRUB	L	53.88	7.47	0.42
Subbituminous	PMSCRUB+FGD+SCR	L	53.88	7.47	0.42

Table 5.14. Definition of Acronyms for Existing Controls

Acronym	Description
ESP	Electro Static Precipitator - Cold Side
HESP	Electro Static Precipitator - Hot Side
ESP/O	Electro Static Precipitator - Other
FF	Fabric Filter
FGD	Flue Gas Desulfurization - Wet
DS	Flue Gas Desulfurization - Dry
SCR	Selective Catalytic Reduction
PMSCRUB	Particulate Matter Scrubber

Table 5.15. Sorbent-Feed Concentration and Cost Components for 90% Mercury Removal Efficiency Using ACI

#	Coal Type	Existing Pollution Control Technology	Sulfur Grade: H-High; L-Low	Sorbent Feed 90%	CAPITAL COST COMPONENTS	O&M COST COMPONENTS
1A	Bituminous	ESP	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
2A	Bituminous	ESP/O	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
3A	Bituminous	ESP+FF	L	3	(2)+(3)	1a+2b+2c+2e+2f
4A	Bituminous	ESP+FGD	H	2	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
5A	Bituminous	ESP+FGD+SCR	H	none	none	none
6A	Bituminous	ESP+SCR	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
7A	Bituminous	FF	L	3	(2)+(3)	1a+2b+2c+2e+2f
8A	Bituminous	FF+DS	H	2	(2)+(3)	1a+2b+2c+2e+2f
9A	Bituminous	FF+FGD	H	2	(2)+(3)	1a+2b+2c+2e+2f
10A	Bituminous	HESP	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
11A	Bituminous	HESP+FGD	H	2	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
12A	Bituminous	HESP+SCR	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
13A	Bituminous	PMSCRUB+FGD	H	2	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
14A	Bituminous	PMSCRUB+FGD+SCR	H	none	none	none
1B	Bituminous	ESP	H	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
2B	Bituminous	ESP/O	H	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
3B	Bituminous	ESP+FF	H	3	(2)+(3)	1a+2b+2c+2e+2f
4B	Bituminous	ESP+FGD	L	2	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
5B	Bituminous	ESP+FGD+SCR	L	none	none	none
6B	Bituminous	ESP+SCR	H	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
7B	Bituminous	FF	H	3	(2)+(3)	1a+2b+2c+2e+2f
8B	Bituminous	FF+DS	L	2	(2)+(3)	1a+2b+2c+2e+2f
9B	Bituminous	FF+FGD	L	2	(2)+(3)	1a+2b+2c+2e+2f
10B	Bituminous	HESP	H	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
11B	Bituminous	HESP+FGD	L	2	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
12B	Bituminous	HESP+SCR	H	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
13B	Bituminous	PMSCRUB+FGD	L	2	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
14B	Bituminous	PMSCRUB+FGD+SCR	L	none	none	none
15	Lignite	ESP	L	3	(1)+(2)+(3)+(4)	1a+2a+2b+2c+2d+2e+2g+1b
16	Lignite	ESP+FF	L	3	(1)+(2)+(3)	1a+2a+2b+2c+2d+2e+2f
17	Lignite	ESP+FGD	L	3	(1)+(2)+(3)+(4)	1a+2a+2b+2c+2d+2e+2g+1b
18	Lignite	FF+DS	L	3	(1)+(2)+(3)+(4)	1a+2a+2b+2c+2d+2e+2g+1b
19	Lignite	FF+FGD	L	3	(1)+(2)+(3)	1a+2a+2b+2c+2d+2e+2f
20	Subbituminous	ESP	L	3	(2)+(3)+(4)	1a+2b+2c+2e+1b
21	Subbituminous	ESP+DS	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
22	Subbituminous	ESP+FGD	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
23	Subbituminous	ESP+SCR	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
24	Subbituminous	FF	L	3	(2)+(3)	1a+2b+2c+2e+2f
25	Subbituminous	FF+DS	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
26	Subbituminous	FF+FGD	L	3	(2)+(3)	1a+2b+2c+2e+2f
27	Subbituminous	HESP	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
28	Subbituminous	HESP+FGD	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
29	Subbituminous	HESP+SCR	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
30	Subbituminous	PMSCRUB	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b
31	Subbituminous	PMSCRUB+FGD+SCR	L	3	(2)+(3)+(4)	1a+2b+2c+2e+2g+1b

Appendix 5-2. Cost Equations for ACI

(A.1) MERCURY CONTROL CAPITAL COST ESTIMATION

Assumptions:

All costs are in December 2004 Dollars

Capital Cost units are in $/kW
Bare Installed Retrofit Cost (BIRC) is provided for the following subsystems:

(1) Spray Cooling
(2) Sorbent Injection
(3) Sorbent Disposal
(4) New pulse-jet fabric filter (PJFF)

BIRC accounts for Process Equipment, Field Materials, Field Labor, and Indirect Field Costs

Total Control Capital Cost (TCCC) is calculated as follows:

TCCC = 1.3725 x BIRC

TCCC multiplier accounts for Engineering & Home Office Overhead/Fees, Process Contingency, Project Contingency and General Facilities.

BIRC Costing Algorithms:

(1) Spray Cooling System

Spray Cooling BIRC, $/kW = 6716 x ((GPM/215)^0.65) / MWe

Where,
GPM = Water Consumption, units = gallons/minute (GPM)
MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

GPM is calculated as follows:

GPM = 4.345E-7 x (Flue Gas Flow Rate, Lb/hr) x (Gas Temperature Change, F)

Flue Gas Flow Rate, Lb/hr = 1000 x MWe x (Heat Rate, Btu/Kw-Hr) x (Gas Flow Factor, Lb gas/Lb coal) /(Coal HHV, Btu/Lb)
where,
Gas Flow Factor, Lb gas/Lb coal = 15 for Bituminous Coal
Gas Flow Factor, Lb gas/Lb coal = 9 for Subbituminous Coal
Gas Temperature Change, F = 40 for Low Sulfur Bituminous Coal and Subbituminous Coal
Gas Temperature Change, F = 0 for High Sulfur Bituminous Coal

(2) Sorbent Injection System

Sorbent Injection BIRC, $/kW = 33 x (Sorbent Feed Rate, Kg/hr)^0.65 / MWe

Where,
Sorbent Feed Rate, Kg/hr = 4.54E-4 x (Sorbent Concentration, Lb/MMacf) x (Gas Flow Factor, acf/Lb coal) x (Heat Rate, Btu/kW-Hr) x MWe / (Coal HHV, Btu/Lb)

Sorbent Concentration, Lb/Mmacf = values specified in Table A. 5.3.2 above.

Gas Flow Factor, acf/Lb coal = 280 for High Sulfur Bituminous Coal
180 for Subbituminous Coal and Low Sulfur Bituminous Coal with Gas Cooling

(3) Sorbent Disposal System

Sorbent Disposal BIRC, $/kW = 0.22 x (Sorbent Feed Rate, Kg/hr) / MWe

Sorbent Feed Rate, Kg/hr = same as previous calculation provided in (2) Sorbent Injection System

(4) New Pulse-Jet Fabric Filter System

PJFF BIRC, $/kW = 0.19 x (Flue Gas Volumetric Flow, ACFM)^0.8 / MWe

Where,

Flue Gas Volumetric Flow, ACFM = 16.67 x (Heat Rate, Btu/Kw-Hr) x MWe x (Gas Flow Factor, acf/Lb coal) / (Coal HHV, Btu/Lb)

Gas Flow Factor, acf/Lb coal = 280 for High Sulfur Bituminous Coal
180 for Subbituminous Coal and Low Sulfur Bituminous Coal with Gas Cooling

(A.2) MERCURY CONTROL O&M COST ESTIMATION

Assumptions:

All costs are in December 2004 Dollars
Fixed O&M costs are in $/kW-Yr
Variable O&M (i.e., Consumables) costs are in mills/kW-Hr

Fixed O&M cost account for operating labor and maintenance labor and materials and do not include cost of consumables. Variable O&M costs include consumables, i.e., the cost of water, sorbent-feed, sorbent disposal, and electricity costs.

(1) Fixed and Variable O&M Cost Estimation

Fixed O&M Cost, $/kW-Yr = [(330.25 / MWe) + (0.184 x Total BIRC)]

Where,

Total BIRC is the sum of the BIRCs calculated in A.1 above
MWe = Power plant net capacity, MW (e.g., 100)

(2) Variable O&M (i.e., Consumables only) Cost Estimation

(2a) Water

Annual Water Cost, mills/kW-Hr = 2.81E-2 x GPM / MWe

Where,

GPM = Water Consumption, units = gallons/minute (GPM)
MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

GPM is calculated as follows (same calculations as provided in capital cost estimation sheet):

GPM = 4.345E-7 x (Flue Gas Flow Rate, Lb/hr) x (Gas Temperature Change, F)

Flue Gas Flow Rate, Lb/hr = 1000 x MWe x (Heat Rate, Btu/Kw-Hr) x (Gas Flow Factor, Lb gas/Lb coal) / (Coal HHV, Btu/Lb)

where,
Gas Flow Factor, Lb gas/Lb coal = 15 for Bituminous Coal
Gas Flow Factor, Lb gas/Lb coal = 9 for Subbituminous Coal
Gas Temperature Change, F = 40 for Low Sulfur Bituminous Coal and Subbituminous Coal
Gas Temperature Change, F = 0 for High Sulfur Bituminous Coal

(2b) Sorbent (Powdered Activated Carbon only)

Annual Sorbent Cost, mills/kW-Hr = (Sorbent Feed Rate, Kg/hr) / MWe

Where,
Sorbent Feed Rate, Kg/hr = 4.54E-4 x (Sorbent Concentration, Lb/MMacf) x (Gas Flow Factor, acf/Lb coal) x (Heat Rate, Btu/kW-Hr) x MWe / (Coal HHV, Btu/Lb)
Sorbent Concentration, Lb/Mmacf = values specified in Table A 5.3.2 above
Gas Flow Factor, acf/Lb coal = 280 for High Sulfur Bituminous Coal
180 for Subbituminous Coal and Low Sulfur Bituminous Coal with Gas Cooling
MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

(2c) Sorbent Disposal

Annual Sorbent Disposal Cost, mills/kW-Hr = 0.037 x (Sorbent Feed Rate, Kg/hr) / MWe

Where,
Sorbent feed rate is the same value calculated in 2b
MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

(2d) Power Cost for Water Injection

Water Injection Power Cost, mills/kW-Hr = 0.182 x GPM/ MWe

Where,
GPM = Water Consumption, units = gallons/minute (GPM)
MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

GPM is the same value calculated in 2a

(2e) Power Cost for Sorbent Injection

Sorbent Injection Power Cost, mills/kW-Hr = 3.8E-3 x (Sorbent Feed Rate, Kg/hr) / MWe

Where,
Sorbent feed rate is the same value calculated in 2b
MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

(2f) Incremental Fan Power without New PJFF

Fan Power Cost without New PJFF, mills/kW-Hr = 1.022E-6 x (Flue Gas Volumetric Flow, ACFM) / MWe

Where,
Flue Gas Volumetric Flow, ACFM = 16.67 x (Heat Rate, Btu/Kw-Hr) x MWe x (Gas Flow Factor, acf/Lb coal) / (Coal HHV, Btu/Lb)

Gas Flow Factor, acf/Lb coal = 280 for High Sulfur Bituminous Coal

180 for Subbituminous Coal and Low Sulfur Bituminous Coal with Gas Cooling

MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

(2g) Incremental Fan Power with New PJFF

Fan Power Cost with New PJFF, mills/kW-Hr = 2.55E-5 x (Flue Gas Volumetric Flow, ACFM) / MWe

-

Where,

Flue Gas Volumetric Flow, ACFM = 16.67 x (Heat Rate, Btu/Kw-Hr) x MWe x (Gas Flow Factor, acf/Lb coal) / (Coal HHV, Btu/Lb)

Gas Flow Factor, acf/Lb coal = 280 for High Sulfur Bituminous Coal

180 for Subbituminous Coal and Low Sulfur Bituminous Coal with Gas Cooling

MWe = Power plant net capacity, units = MW, (e.g., 100 MWe)

Appendix 5-3. Memo from ADA Environmental Solutions to U.S. Environmental Protection Agency, July 2002

ADA Environmental Solutions, LLC

8100 SouthPark Way, B-2
Littleton, Colorado 80120
Fax: 303.734.0330
303.734.1727 or 1.888.822.8617

To: Maryjo Krolewski
From: Michael Durham
CC: Jean Bustard, ADA-ES; Scott Renninger, DOE-NETL
Date: July 30, 2002

RE: Model Inputs for Sorbent Injection

We have reviewed the various configurations that EPA is using for modeling the cost of mercury control using sorbent injection. The attached spreadsheet provides a summary of our estimates for sorbent usage and capital equipment required to achieve 60% and 90% removal levels.

In addition we provide the following assumptions and comments:

1. To achieve 90% removal levels, we have assumed that a fabric filter will be required. This is justified by the fact that total amortized costs will be minimized with a new fabric filter at a sorbent feed rate of 3 lb/Macf as compared to a feedrate of greater than 10 lb/Macf if a fabric filter is not used.
2. Based upon information available from ICR tests and testing conducted by EPRI, it appears that a spray dryer on a subbituminous coal cannot achieve either 60% or 90% removal levels of mercury even with a fabric filter downstream of the SDA. Therefore, for both levels of mercury control for this configuration, we would recommend that the model include the cost of a fabric filter upstream of the SDA to capture the sorbent and ash. This ash could be used in the recycle for the SDA to maintain the economics of SO2 removal in the SDA.
3. We believe that with high-capacity sorbents, spray cooling will not be required except in cases that ESP temperatures are in excess of 350 oF. Therefore, for most bituminous and subbituminous applications spray cooling will not be required. However, for many lignite applications, spray cooling (or cooling in another form) will be necessary.
4. We have no data that indicates that there will be any difference in performance of PAC injection between high- and low-sulfur coals except as reflected by the likely presence of a wet scrubber for high sulfur.
5. In the variable costs for fabric filters, you should add a component for bag replacement costs. We would recommend a 3 yr bag life.
6. In the equation for Sorbent costs, there appears to be a necessary term missing and that is the cost of the activated carbon. We would recommend using an average delivered cost of $0.50/lb.
7. Costs associated for ash disposal is very complicated but here are a few recommendations:
    a. If the plant is currently landfilling their ash (70% of plants), then the cost of disposal will be only the incremental increase in ash due to the sorbent.
    b. If a COHPAC baghouse is added (whether they are selling or landfilling their ash), the cost of disposal will be for the sorbent and 2% of the total ash collected in the baghouse. However, this may have to be disposed of as a hazardous waste.
    c. If the plant is currently selling the ash (30% of plants), then the cost of disposal will need to include loss of sales of the ash, plus landfilling of the ash plus sorbent.
8. For the cost of the installed baghouse, we would recommend that you use $40-45/kW which is what EPRI uses in their cost model.