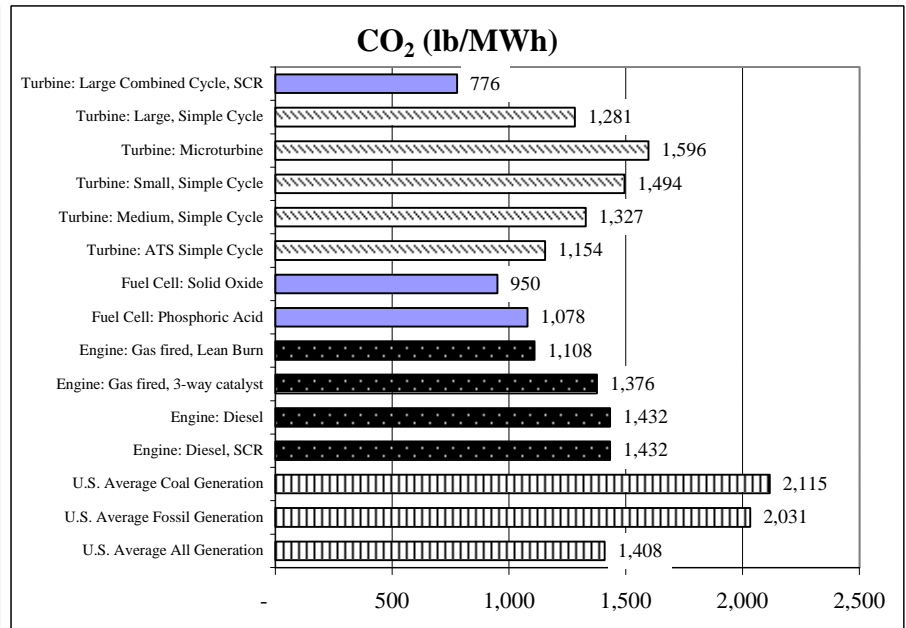
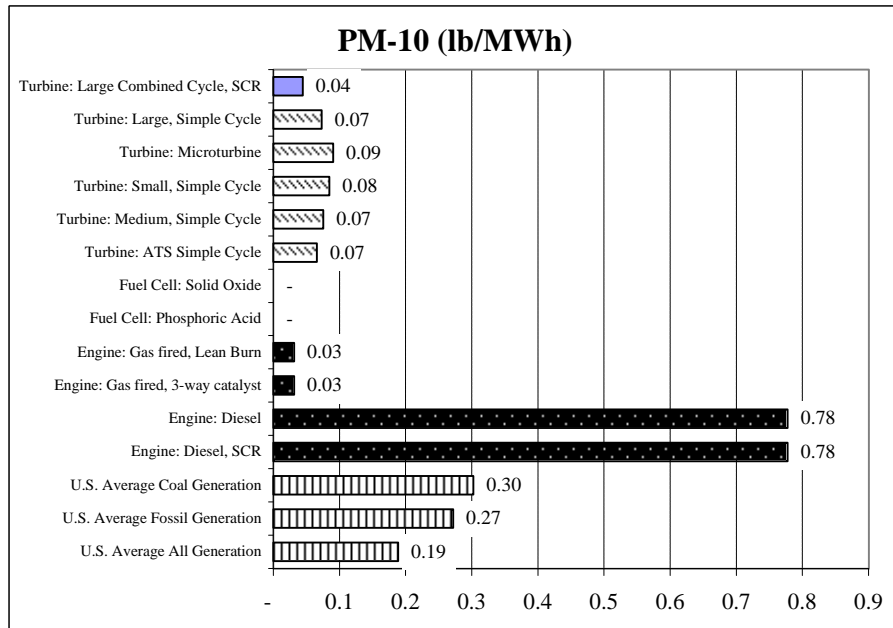
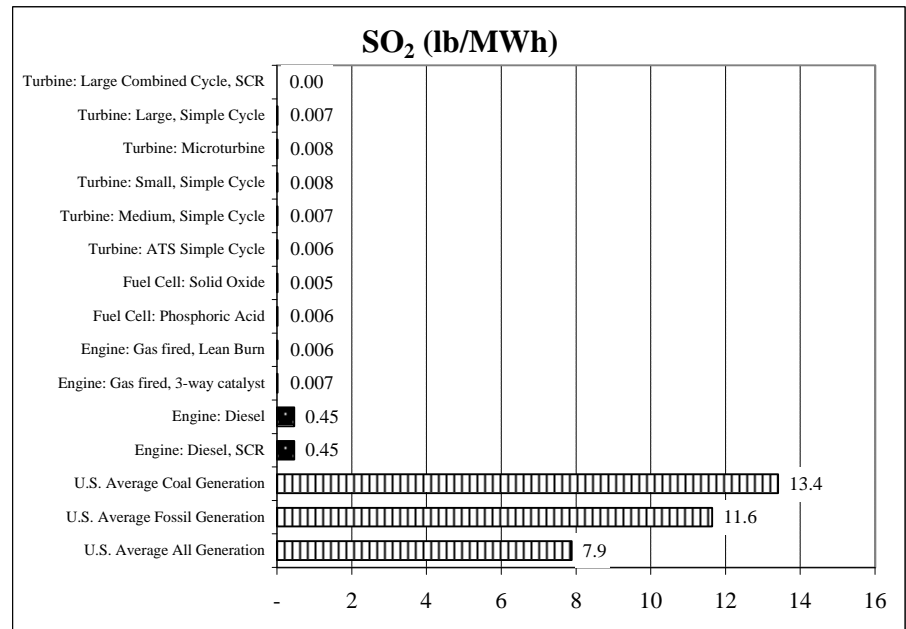
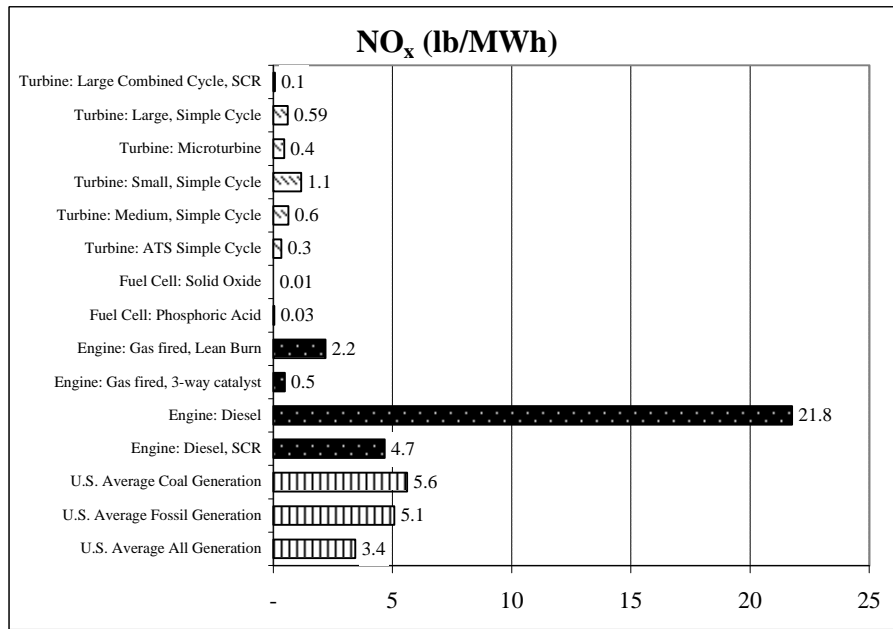


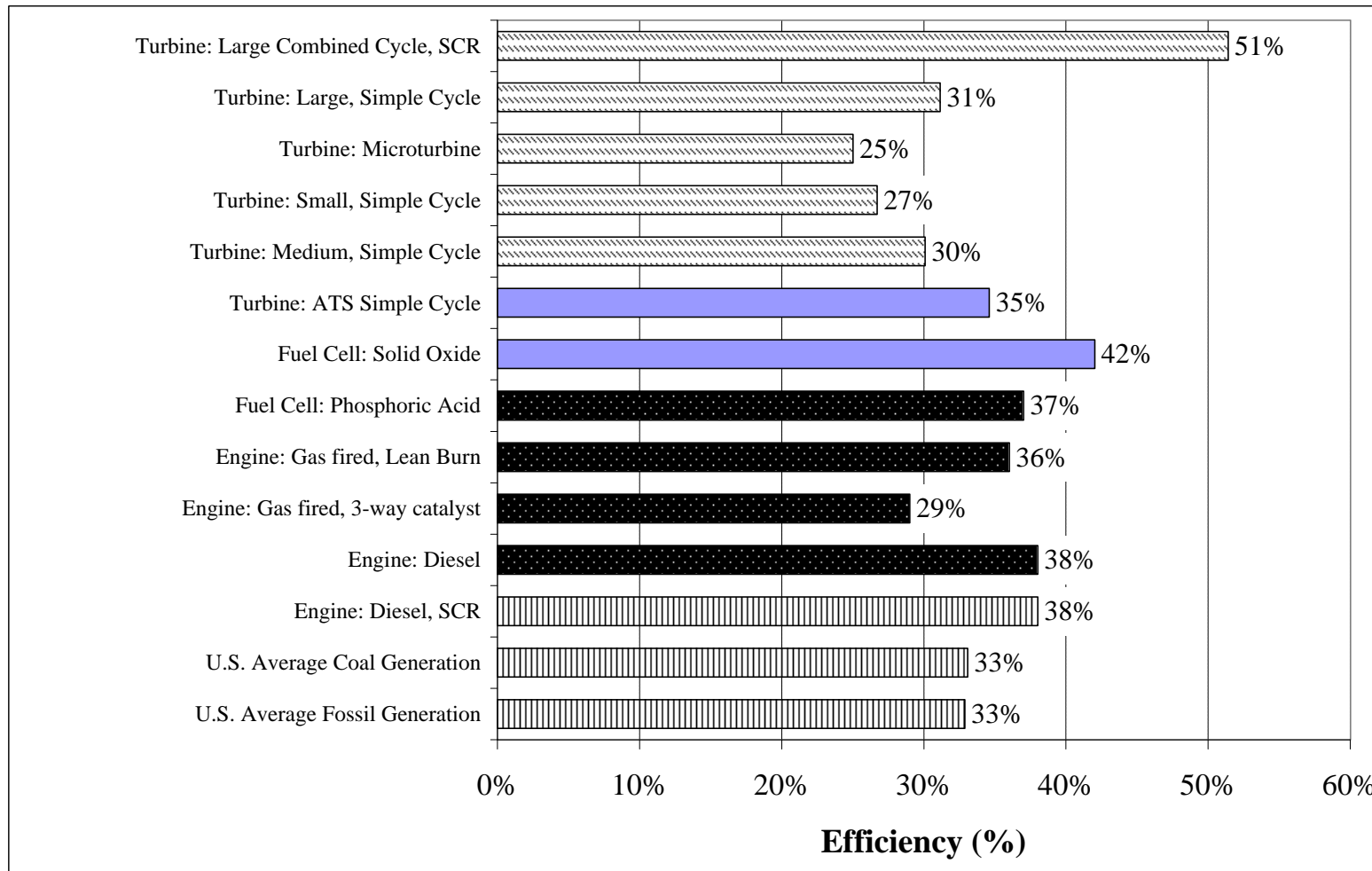
**Table 1
Emission Rates for New DG Technologies**

		Solid Oxide Fuel Cell	Phosphoric Acid Fuel Cell	Uncontrolled		3-way Catalyst		SCR		Micro Turbine	Small Gas Turbine	Medium Gas Turbine	Large Gas Combined Cycle	Large Gas Turbine	ATS Simple Cycle Gas Turbine	1998 Average Coal Boiler	1998 Average Fossil	1998 Average PowerGen
				Gas-Fired Lean Burn IC Engine	Gas-Fired Rich Burn IC Engine	Uncontrolled Diesel Engine	Controlled Diesel Engine	Diesel Engine	Diesel Engine									
Efficiency	% (HHV) Btu/kWh	42% 8,126	37% 9,224	36% 9,481	29% 11,769	38% 8,982	38% 8,982	25% 13,652	27% 12,780	30% 11,353	51% 6,640	31% 10,964	35% 9,870	33% 10,322	33% 10,382	47% 7,197		
Typical Capacity (kW)		25	200	1,000	1,000	1,000	1,000	25	4,600	12,900	500,000	70,140	4,200	300,000	300,000	300,000		
NOx	gm/hp-hr			0.70	0.15	7	1.5	9	25	15	2.5	15.0	9.0					
	ppm@15%O2	0.2	1.0					0.03	0.09	0.05	0.01	0.05	0.03					
	lb/MMBtu	0.0007	0.0036					0.3	126.9	189.7	716.5	996	32.2	40,291	36,448	24,684		
	lb/day	0.0035	0.2	52.2	11.2	522.1	111.9	0.05	23.2	34.6	131	182	5.9	7,353	6,652	4,505		
SO2	Tons/yr	0.001	0.03	9.5	2.0	95.3	20.4	0.006	0.0006	0.0006	0.0006	0.0006	0.0006					
	lb/MMBtu	0.0006	0.0006	0.0006	0.0006	0.0505	0.0505	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	96,490	83,771	56,732		
	lb/day	0.0029	0.0266	0.14	0.17	10.9	10.9	0.0009	0.8	2.1	47.8	11.1	0.60	17,610	15,288	10,354		
	Tons/yr	0.0005	0.0048	0.02	0.031	2.0	2.0	0.0009	0.15	0.38	8.7	2.0	0.11	17,610	15,288	10,354		
PM-10	gm/hp-hr			0.01	0.01	0.25	0.25	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066					
	ppm@15%O2	0	0					0.05	9.3	23.2	525.9	121.8	6.6	2,175.0	1,952.9	1,353.9		
	lb/MMBtu	0	0	0.75	0.75	18.6	18.6	0.01	1.7	4.2	96.0	22.2	1.2	396.9	356.4	247.1		
	lb/day	-	-	0.14	0.14	3.4	3.4	0.01	1.7	4.2	96.0	22.2	1.2	396.9	356.4	247.1		
CO2	Tons/yr	-	-	0.14	0.14	3.4	3.4	0.01	1.7	4.2	96.0	22.2	1.2	396.9	356.4	247.1		
	lb/MMBtu	117	117	117	117	159	159	117	117	117	117	117	117	15,229,728	14,622,394	10,137,077		
	lb/day	570	5,175	26,594	33,014	34,356	34,356	957	164,912	410,826	9,313,126	2,157,211	116,289	2,779,425	2,668,587	1,850,017		
	Tons/yr	104	944	4,853	6,025	6,270	6,270	175	30,097	74,976	1,699,645	393,691	21,223	2,779,425	2,668,587	1,850,017		
CO	gm/hp-hr			1.6	1.3	2	2	40	25	25	6	25	25					
	ppm@15%O2	?	?					0.09	0.05	0.05	0.01	0.05	0.05					
	lb/MMBtu	?	?	-	-	-	-	1	77	193	1048	1012	55	0	0	0		
	lb/day	0.0000	0.0	119	96	149	149	0	14	35	191	185	10	0	0	0		
UHC	Tons/yr	0.000	0.00	22	18	27	27	0	14	35	191	185	10	0	0	0		
	gm/hp-hr	?	?	5.3	0.13	0.4	0.4	9	25	25	2	25	25					
	ppm@15%O2	?	?					0.03	0.09	0.09	0.01	0.09	0.09					
	lb/MMBtu	?	?	-	-	-	-	0.3	122	303	550	1591	86	0	0	0		
UHC	lb/day	0.0000	0.0	395	10	30	30	0.3	122	303	550	1591	86	0	0	0		
	Tons/yr	0.000	0.00	72	2	5	5	0.0	22	55	100	290	16	0	0	0		
	lb/MWh	0.01	0.03	2.2	0.5	21.8	4.7	0.44	1.15	0.61	0.06	0.59	0.32	5.60	5.06	3.43		
	lb/MWh	0.005	0.006	0.006	0.007	0.454	0.454	0.008	0.008	0.007	0.004	0.007	0.006	13.4	11.6	7.9		
PM-10	lb/MWh	-	-	0.03	0.03	0.78	0.78	0.09	0.08	0.07	0.04	0.07	0.07	0.30	0.27	0.19		
CO2	lb/MWh	950	1,078	1,108	1,376	1,432	1,432	1,596	1,494	1,327	776	1,281	1,154	2,115	2,031	1,408		
CO	lb/MWh	?	?	5.0	4.0	6.2	6.2	1.2	0.7	0.6	0.1	0.6	0.5					
UHC	lb/MWh	?	?	16.5	0.4	1.2	1.2	0.42	1.10	0.98	0.05	0.95	0.85					

Emission Rates for Power Generation Technologies



Efficiencies for Power Generation Technologies



Disclaimer

This Excel spreadsheet shows air emissions values for a number of distributed generation technologies. The values are given for a variety of emissions – nitrogen oxides, sulfur dioxide, carbon monoxide, carbon dioxide, particulate matter (PM-10), and unburned hydrocarbons – and they are characterized in terms of pounds of emissions per unit of electrical output. These are typical values for new units of the specified technologies. They do not apply to older, existing units. The values were calculated on the basis of assumptions about typical operating conditions; however, because actual operating conditions are rarely typical, the actual emissions performance of a unit may differ from these values.

The source material, assumptions, and formulas underpinning these calculations are given in the spreadsheet. This spreadsheet was produced as part of the on-going work in the NREL/RAP DR Emissions Collaborative. We consider it a work in progress and we welcome comments and suggestions on it. Thank you.

Table 2
References for Emissions Data

Value	Factor	Source	Notes
Solid Oxide Fuel Cells			
42%	efficiency	http://www.fe.doe.gov/techline/tl_sofcdemo.html	
0.2	ppm NOx	http://www.fe.doe.gov/techline/tl_sofcdemo.html	
0.0006	lb/MMBtu SO2	AP-42 Chapter 1, Section 4	
0	ppm PM-10	no data, no source	
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	
Phosphoric Acid (ONSI) Fuel Cells			
37%	efficiency	NREL paper	http://www.sercobe.es/espejo/Energia/EnergiasNoNucleares/UsorRacional/IndustEnergia/PilaComb/Tutorial/Fuelce
1.00	ppm NOx	Phone: Herb Healy, ONSI, 860-727-2200	
0.0006	lb/MMBtu SO2	AP-42 Chapter 1, Section 4	
0	ppm PM-10	no data, no source	
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	
Gas IC Engine			
7,011	Btu/hp-hr for 770 kW Cat Model G3516	Caterpillar Website, gas model G3516, 130 LE	
36%	efficiency lean burn	Onsite Energy/Caterpillar	36%
29%	efficiency rich burn	Onsite Energy/Caterpillar	
0.70	gm/hp-hr NOx lean burn engine	NSR/RBLC Identifier NM-0026	Clean Burn engine Cat 3612
9.00	ppm NOx @15% O2	NSR/RBLC Identifier CA-0645	3-way catalyst
0.150	gm/hp-hr NOx 3-way catalyst	Bluestein assumption	
0.0006	lb/MMBtu SO2	AP-42 Chapter 1, Section 4	
0.0100	gm/hp-hr PM-10 - filterable+condensable	NSR/RBLC Identifier CO-0032,CO-0033	
1.6	g/hp-hr CO lean burn	Caterpillar G3516 Data Sheet DM5150	
5.3	g/hp-hr UHC lean burn	Caterpillar G3516 Data Sheet DM5150	
12.9	g/hp-hr CO rich burn engine out	Caterpillar G3516 Data Sheet DM5145	
90%	TWC cat CO reduction		
1.3	g/hp-hr HC rich burn	Caterpillar G3516 Data Sheet DM5145	
90%	TWC cat HC reduction		
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	
Diesel Engine			
114	gal/hr for 1,640 kW Cat Model 3516B	Caterpillar Website, diesel model 3516B	
38.0%	efficiency	calculated	35%
	gm/hr NOx uncontrolled	Caterpillar Website, diesel model 3516B	
7	gm/hp-hr NOx uncontrolled	Caterpillar Website, diesel model 3516B	-
1.50	gm/hp-hr NOx with SCR	Hedman/SCAQMD	SCR
500.00	ppm sulfur in diesel, on road	current requirement for road diesel	Federal Register: 5/13/99 Vol 64 #92
3,300.00	ppm sulfur in diesel, nonroad	typical, offroad diesel	Federal Register: 5/13/99 Vol 64 #92
30.00	ppm sulfur in diesel, possible proposed	potential future requirement	Federal Register: 5/13/99 Vol 64 #92
0.25	gm/hp-hr PM-10	NSR/RBLC Identifier CA-0691	
0.4	g/hp-hr HC	Caterpillar	
2	g/hp-hr CO	Caterpillar	
159.38	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	
Microturbine			
25%	Efficiency	Capstone Model 330, 30 kW	Capstone Turbines webpage
9	ppm NOx	Capstone Model 330, 30 kW	Capstone Turbines webpage
0.0006	lb/MMBtu SO2	AP-42 Chapter 3, Section 1	
0.0066	lb/MMBtu total PM-10 filterable+condensable	AP-42 Chapter 3, Section 1	
40	ppm CO	Capstone	
9	ppm HC	Capstone	
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	
Small Turbine			

Table 2
References for Emissions Data

Value	Factor	Source	Notes
12,780	Btu/kWh heat rate HHV	Solar Centaur 50 - 4.6 MW	Solar Data
25	ppm NOx	Solar	
0.0006	lb/MMBtu SO2	AP-42 Chapter 3, Section 1	
0.0066	lb/MMBtu total PM-10 filterable+condensate	AP-42 Chapter 3, Section 1	
25	ppm CO		
25	ppm UHC		
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	

Medium Turbine

11,353	Btu/kWh HHV	Alstom Cyclone - 12.9 MW	Intl. Turbomachinery Handbook 1999, page 121 10,900 kj/kWh LHV
15	ppm NOx	Bluestein assumption	
0.0006	lb/MMBtu SO2	AP-42 Chapter 3, Section 1	
6.60E-03	lb/MMBtu total PM-10 filterable+condensate	AP-42 Chapter 3, Section 1	
25	ppm CO		
25	ppm UHC		
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	

Large Gas Combined Cycle

6,640	Btu/kWh heat rate HHV	GE S-207FA (MS7001FA), 529.9 MW	Intl. Turbomachinery Handbook 1999, page 128 6375 kj/kWh LHV
2.5	ppm NOx	NSR/RBLC Identifier ME-0018	
0.0006	lb/MMBtu SO2	AP-42 Chapter 3, Section 1	
6.60E-03	lb/MMBtu total PM-10 filterable+condensate	AP-42 Chapter 3, Section 1	
6	ppm CO		
2	ppm HC		
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	

Large Gas Turbine

10,964	Btu/kWh heat rate HHV	GE PG6101(FA), 70.1 MW	Intl. Turbomachinery Handbook 1999, page 116 10,526 kj/kWh LHV
15	ppm NOx	Bluestein estimate	
0.0006	lb/MMBtu SO2	AP-42 Chapter 3, Section 1	
6.60E-03	lb/MMBtu total PM-10 filterable+condensate	AP-42 Chapter 3, Section 1	
25	ppm CO		
25	ppm UHC		
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	

ATS Gas Turbine

9,870	Btu/kWh heat rate	Caterpillar/Solar Turbines website	
9	ppm NOx	Stategic Goal of ATS program	http://www.fe.doe.gov/coal_power/ats/ats_so.html
0.0006	lb/MMBtu SO2	AP-42 Chapter 3, Section 1	
6.60E-03	lb/MMBtu total PM-10 filterable+condensate	AP-42 Chapter 3, Section 1	
25	ppm CO		
25	ppm UHC		
116.88	lb/MMBtu CO2	EIIP Report, Vol. VIII, Table 1.4-3	

AEO Data

6,701,000	tons/year NOx from coal boilers	1998 EPA Vol 2, Table 25	
11,671,000	tons/year SO2 from coal boilers	1998 EPA Vol 2, Table 25	
273,000	tons/year PM10 from coal boilers	1998 National Emissions Trends, Table A-5	
138,000	tons/year PM25 from coal boilers	1998 National Emissions Trends, Table A-5	
1,911,627,000	tons/year CO2 from coal boilers	1998 EPA Vol 2, Table 25	
377,000	tons/year NOx from gas boilers	1998 EPA Vol 2, Table 25	
1,000	tons/year SO2 from gas boilers	1998 EPA Vol 2, Table 25	
1,000	tons/year PM10 from gas combustion	1998 National Emissions Trends, Table A-5	

Table 2
References for Emissions Data

Value	Factor	Source	Notes
1,000	tons/year PM25 from gas combustion	1998 National Emissions Trends, Table A-5	
195,868,000	tons/year CO2 from gas boilers	1998 EPA Vol 2, Table 25	
137,000	tons/year NOx from oil boilers	1998 EPA Vol 2, Table 25	
759,000	tons/year SO2 from oil boilers	1998 EPA Vol 2, Table 25	
9,000	tons/year PM10 from oil combustion	1998 National Emissions Trends, Table A-5	
8,000	tons/year PM25 from oil combustion	1998 National Emissions Trends, Table A-5	
100,895,000	tons/year CO2 from oil boilers	1998 EPA Vol 2, Table 25	
19,000	tons/year PM10 from IC engines	1998 National Emissions Trends, Table A-5	
19,000	tons/year PM25 from IC engines	1998 National Emissions Trends, Table A-5	
0.1022	lb/MMBtu NOx rate for turbines	2000 1st Qtr CEM data	include only blrtype=CC or CT, delete 16 records with no NOx rate
0.0102	lb/MMBtu SO2 rate for turbines	2000 1st Qtr CEM data	include only blrtype=CC or CT, delete 16 records with no NOx rate
1,807,480,000	MWh/year coal boiler generation	1998 EPA Vol 1, Table A2	
247,956,000	MWh/year gas boiler generation	1998 EPA Vol 1, Table A4	
102,669,000	MWh/year oil boiler generation	1998 EPA Vol 1, Table A3	
673,702,000	MWh/year nuclear generation	1998 EPA Vol 1, Table A2	
304,403,000	MWh/year hydro generation	1998 EPA Vol 1, Table A2	
7,206,000	MWh/year renewable generation	1998 EPA Vol 1, Table A2	
7,489,000	MWh/year oil turbine/IC generation	1998 EPA Vol 1, Table A3	
61,266,000	MWh/year gas turbine/IC generation	1998 EPA Vol 1, Table A4	
910,867,000	tons/year consumption for coal boilers	1998 EPA Vol 1, Table A5	
161,821,000	bbls/year consumption for oil boilers	1998 EPA Vol 1, Table A6	
16,793,000	bbls/year consumption for oil turbine/IC	1998 EPA Vol 1, Table A6	
2,618,037,000	mcf/year consumption for gas boilers	1998 EPA Vol 1, Table A7	
640,017,000	mcf/year consumption for gas turbine/IC	1998 EPA Vol 1, Table A7	
511,000	tons/year consumption anthracite coal	1998 Cost and Quality of Fuels, Table ES4	
478,252,000	tons/year consumption bituminous coal	1998 Cost and Quality of Fuels, Table ES4	
373,496,000	tons/year consumption sub-bituminous coal	1998 Cost and Quality of Fuels, Table ES4	
77,189,000	tons/year consumption lignite coal	1998 Cost and Quality of Fuels, Table ES4	
8,255,000	bbls/year consumption of #2 oil	1998 Cost and Quality of Fuels, Table 9	
156,851,000	bbls/year consumption of #4,#5,#6 oil	1998 Cost and Quality of Fuels, Table 9	
7,479	Btu/lb anthracite coal	1998 Cost and Quality of Fuels, Table ES4	
12,033	Btu/lb bituminous coal	1998 Cost and Quality of Fuels, Table ES4	
8,728	Btu/lb sub-bituminous coal	1998 Cost and Quality of Fuels, Table ES4	
6,471	Btu/lb lignite coal	1998 Cost and Quality of Fuels, Table ES4	
10,241	Btu/lb average U.S. Coal	1998 Cost and Quality of Fuels, Table 4	
151,066	Btu/gallon average U.S. oil	1998 Cost and Quality of Fuels, Table 9	
138,766	Btu/gallon average U.S. fuel oil	1998 Cost and Quality of Fuels, Table 9	
151,723	Btu/gallon average U.S. #4, #5, #6 oil	1998 Cost and Quality of Fuels, Table 9	
1,022	Btu/cf average U.S. gas	1998 Cost and Quality of Fuels, Table 14	
	Btu/gallon #1 distillate (diesel)		
7,248,543	NOx tons/yr from fossil generation	calculated	
12,434,348	SO2 tons/yr from fossil generation	calculated	
302,000	PM-10 tons/yr from fossil generation	calculated	
2,261,251,666	CO2 tons/yr from fossil generation	calculated	

CEM Data

5,425,799	tons/year NOx from Title IV units	1999 CEM Data	
474,399	tons/year NOx from T4 units, not coal	1999 CEM Data	
4,951,400	tons/year NOx from T4 coal units	calculated	
12,470,504	tons/year SO2 from Title IV units	1999 CEM Data	
612,716	tons/year SO2 from T4 units, not coal	1999 CEM Data	
11,857,788	tons/year SO2 from T4 coal units	calculated	
1,769,627,431	MWh/year coal generation	1999 EIA Form 759	
2,143,656,841	MWh/year fossil generation	1999 EIA Form 759	
3,165,331,454	MWh/year generation	1999 EIA Form 759	

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References for Emissions Data

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