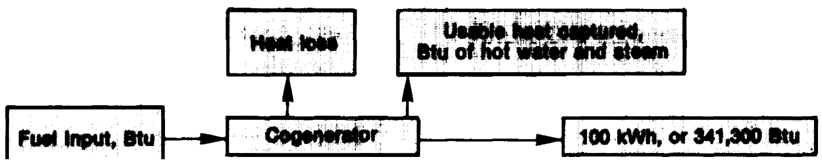
Appendix B
Emissions Changes

A number of analyses of emissions changes caused by cogeneration have been conducted. All of these analyses, however, are site-specific and do not illustrate the effects of changing critical assumptions, or they have extrapolated to regional or national emissions changes by using simplifying assumptions about critical parameters (e.g., the type of fuels "backed out" of the utilities' centralized systems) that may be significantly in error.

The following tables display the emissions attributable to each component in a possible switch from a system using central station-generated electricity and a local heat source to a system using cogeneration. A number of options for the central plant, cogenerator, and heat source are shown in order to allow a range of circumstances to be evaluated. Because of the significant variation possible in each of the components (for example, the thermal efficiencies and emissions

Table B-l.—Emissions From Cogenerator Options



Type	Fuel Input	Heat captured[a]	Thermal efficiency	NO_x	Particulate	CO	HC	So_xb	Comment
				Emissions (lb/100 kWh)					
Diesel	990,000[c]	350,000[c]	0.70[d]	3.43°	0.07[f]	owe	O.l0[e]	0.29	Oil, Uric.
				2.49[e]	ND	0.64*	0.87[e]	0.02[g]	Dual Fuel, Uric.
				2.20[h]	NS	NS	NS	NS	NSPS
Gas turbine	1,365,000	610,000	0.70[k]	.8	0.03[m]	0.15[m]	0.05[m]	O.0l[m]	Gas, Unc.
				1.2	0.08"	0.03	0.05	0.2[g]	Oil, Unc.
				0.4°	NS	NS	NS	1.09	NSPS
NSPS steam turbine.	2,970,000P	2,000,000P	0.79P	2.08[q]	0.30[q]	0.12	0.03	3.56[q]	Coal
				0.89[q]	0.30[q]	NEG	0.03	2.38q	oil
				0.59[q]	0.03	NEG	0.12	0.21	Gas

ND - No data found
NS - No standard
NEG - Negligible

aUnless the cogeneratlng system has heat storage capability and/or very careful balancing of heat production and actual need, less heat than this will be *usefully* captured, the system efficiency will decrease, and the overall emissions balance between cogeneratlon end the central station power/local heating source will worsen.
b values for So_x are entirely fuel dependent, Essentially 100 percent of the sulfur contained in the fuel is transformed into $S0_x$ upon combustion.
c Based on fuel rate data in Environment Protection Agency, Standards Support and Environmental Impact Statement for Stationary Internal Combustion Engines, draft, EPA-450/2-78-125a July 1979, assuming 95 percent generator efficiency.
dTh data sources did not converge on any efficiency value as "best," but values ranged from 62 to 80 percent. The major source Of variability appears to be the amount of heat captured rather than the total fuel input.
eBased on sales-weighted averages for large-bore diesels, data in EPA, op. cit. (note c).
fEnvironmental Protection Agency, *Compilation* of *Air Pollutant Emission Factors* (AP-42), 1976.
gAssumes 0.2 percent sulfur diesel fuel or distillate oil.
hTh. New Source Performance Standard for diesels burning oil or oil/natural gas combinations is 600 ppm of NO_x. This is *roughly* translatable into about 7 grams per horsepower hour, or about 2.2 lb/MMBtu, personal communication from Douglas Bell, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.
iThe application of NO_x emission controls may have an effect on emissions of other pollutants. Because efficiency may decrease somewhat with such controls the effect on CO and HC may be adverse.
jTotal fuel input and heat captured in a gas turbine cogenerator are extremely variable. Data shown are from ICF, Inc., *A Technical and Economic Evaluation of Dispersed Electric Generation Technologies,* draft final report to OTA, October 19S0, table 3-3, simple-cycle turbine.
kIbid. pages. With the "typical" turbine in General Accounting Office, *Industrial Cogeneration—What It Is, How It Works, Its Potential,* EMD-80-7, Apr. 29, 1960.
lEnvironmental Protection Agency, *Standards Support and Environmental Impact Statement* for Stationary *Gas Turbines,* EPA-450/2-77-017a, September 1977, PP. 3-110, for "typical," uncontrolled turbines.
mEnvironmental protection Agency, AP-42, op. cit. (note f). Note that the AP-42 value for NO_x is [illegible] lb/MMBtu V. 0.6 lb/MMBtu fOr EPA, OP. cit. (note l).
nFew data were found. This value applies to a GE 7821 B combustion turbine, cited in J. A, Taylor, *An Air @@l~ Assessment for ICES Options,* Argonne National Laboratory, September 1960, draft.
oThe New Source Performance Standard for gas turbines is 75 ppm of NO_x, roughly translatable into about 0.225 to 0.3 lb/MMBtu, personal communication from Douglas Bell, OAQPS, RTP, N.C. Table 3-11 in EPA, op. cit. (note 1) equates 75 pm at 15 percent oxygen to 0.3 lb/MMBtu, but the significant variability in fuel rates of gee turbines implies a range of "lb/MMBtu" rates.
pFrom General Accounting Office, 1980, op. cit., (note k), p. 92. Because a steam turbine may be designed to convert anywhere from zero to over 30 percent of its fuel energy to electricity, these values represent only one possible combination in an extremely broad range.
q40 CFR 60 subpt. D, NSPS for steam generators other than utility over 73 MW input. Generators smaller than this size are subject to State implementation plan regulations.

SOURCE: Office of Technology Assessment.

from a gas turbine or diesel can vary over a fairly wide range), however, the tables capture only a portion of the potential variability in emissions balances.

The values of energy flow and emissions displayed are normalized to an "electrical output of 100 kiloWatt-hours. Emission "balances" for particular combinations of cogenerator, central power facility, and local heat source can be calculated by using the formula:

(net emissions in lbs/100 kWh of cogenerated power) = (cogenerator emissions, table B-1) – (central station power emissions, table B-2) – (hot water and steam emission factor, table B-3)* (heat captured, table B-l/l O,)

Table B-2.—Emissions From Central Station Power Stations (to provide 100 kWh of delivered power)

		Emissions[a], lb/100 kWh					
Type	Fuel input	NO_x	Part	CO	HC	SO_x	
Coal-fired powerplant, NSPS, scrubber	1,100,000[b]	0.55	0.03	0.04	0.01	1.32[c]	
Older coal-fired plant, 3% sulfur 10% ash with 95% control, 13,000 Btu/lb	1,000,000	0.69	0.31	0.04	0.01	4.38	
Oil-fired plant, NSPS, low sulfur oil	1,000,000	0.30	0.03	0.04	0.01	0.80	
Older oil-fired plant, 1 % sulfur	1,000,000	0.70	0.05	0.04	0.01	1.05	
Older natural gas-fired plant	1,000,000	0.67	0.01	0.02	0.04	NEG.	
Existing gas turbine peaking plants	1,100,000[d]	0.43 (.66)[e]	0.01	0.12	NEG.	NEG.	Gas
Existing gas turbine peaking plants	1,100,000[d]	0.53 (.99)[e]	0.04	0.12	0.04	0.03	Oil
NSPS gas turbine		0.3					

[a]Emissions from the following source: 1) Compilation of Air Pollutant Emission Factors, Third Edition, Environmental protection Agency, August 1977; and 2) Federal Regulations 40 CFR, Part 60, defining New Source Performance Standards for Fossil-fueled steam-electric powerplants.
[b]The higher heat rate is accounted for by the efficiency loss caused by the scrubber.
[c]Assumes high sulfur coal. Requirement for continuous control systems achieving 70 to 90 percent efficiency would reduce SO_x emissions to as low as 0.6 lb/MMBtu for low to medium sulfur coals.
[d]Although gas turbine rates are quite variable, the larger GE and Westinghouse turbines (over 50 MW) tend to have fuel rates between 10,500 and and 12,000 Btu/kWh, Environmental Protection Agency, *Standards* Support and *Environmental Impacts Statement for Stationary* Gas *Turbines,* EPA-450/77-017a, September 1977, pp. 3-46.
[e]The first values are those given in footnote al. above, the second are "typical" values for a range of turbines given in EPA, 1977, op. cit. (footnote d). An examination of turbine data (Ibid., pp. 3-46) indicates that the larger utility turbines do not appear to emit nitrogen oxides at a lower unit rate than smaller industrial turbines. The *larger* emissions value is used to construct the emission balances.

SOURCE: Office of Technology Assessment.

Table B-3.—Emissions From Hot Water and Steam Systems (to provide 1,000,000 Btu of usable heat energy)

			Emissions, lb/10[6] Btu usable heat				
Heat source	Fuel input	NO_x	Particulate	CO	HC	SO_x	
Furnace and hot water heater	1,250,000 Btu	0.12	0.01	0.02	0.01	NEG.	Gas
		0.16	0.02	0.04	0.01	0.24	Oil (.2%S)
NSPS steam boilers	1,250,000 Btu		0.13	0.05	0.01	1.50	Coal
		0.37	0.13	0.04	0.01	1.00	Oil
		0.25	0.01	0.02	NEG.	NEG.	Gas
Small (<250 x 10[6] Btu/hr) industrial boiler	1,250,000 Btu	0.72	0.63	0.10	0.05	3.65	Coal[a]
		0.50	0.19	0.04	0.01	1.31	Oil (1%S)
		0.21	0.02	0.02	NEG.	NEG.	Gas

[a] 10 percent ash, 2 percent sulfur, 13,000 Btu/lb, 90 percent particulate control.

SOURCE: Office of Technology Assessment.