PART 1 OF 2

Reducing Greenhouse Gas Emissions

and the Impact on U.S. Energy Prices

The international effort to halt global warming may send energy prices soaring

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Over the past 12 months, crude-oil prices have surged to the highest level since the Persian Gulf War, proving once again that we have very little control over a critical cornerstone of our economy: energy prices. The oil embargo of 1973 led to long lines at service stations, higher overall energy prices, double-digit inflation, and a general sense of panic. It's important to remember that the latest shortage, which tripled the price of a barrel of oil, occurred because OPEC cut oil production by only about 5 percent of world demand.

The current international effort to reduce greenhouse-gas emissions from the burning of carbon fuels is going to have a significant impact on the price of energy in the U.S. and on our economy. In 1998, the Energy Information Administration (EIA) of the Dept. of Energy released a study titled "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity." The report details five different scenarios, the worse of which has coal prices increasing by over 800 percent in 10 years compared to a "reference case" which assumes no changes in U.S. policy, law, or taxation regarding the coal industry. The EIA's worse-case scenario assumes that two significant policy changes will occur in the U.S. in next 10 years: Senate ratification of the Kyoto Protocol, an international agreement to reduce greenhouse-gas emissions, as well as the passage of a carbon tax, which is a fee designed to strongly discourage the use of fuels that produce CO_2. The best-case scenario in the same study has coal prices increasing 152 percent by 2010.

If the Kyoto Protocol is ratified, the EIA maintains that the U.S. could reduce greenhouse-gas emissions in other ways, besides slashing coal use: for example, international carbon trading with other countries; developing higher efficiency motors, as well as hybrid motors, which consume less fuel; and planting more trees.

While the EIA likes to discuss these alternate means of cutting greenhouse emissions, an analysis of U.S. fuel consumption trends reveals that it would be virtually impossible to achieve the reductions set forth by Kyoto without penalizing coal use.

The intent of this article is to provide the reader with some insight into future prices of coal, petroleum, natural gas, and electricity through 2020, with a focus on the possible outcome on fuel prices resulting from a concentrated effort to slash our carbon emissions. Since energy is used to produce most goods and services in this country, higher energy prices are a major concern to everyone. Decisions your company makes today should reflect the reality that energy prices are poised to change dramatically due to the restructuring of the U.S. electric-power industry and the worldwide commitment to reduce greenhouse-gas emissions. The fact that coal prices may increase somewhere in the range of 150 to 800 percent in the next decade should be a consideration if your plant or facility, for example, plans to install a new coal-fired boiler in the near future.

Of course, reducing our use of coal will increase our dependency on other energy sources. What follows in this article (Part 1 of a 2-part series) is an analysis of our energy sources and what the impact of both electric utility restructuring and the Kyoto Protocol will be on each of them.

The Touchy Topic of the "Carbon Tax"

The EIA performed the "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity" study at the request of the U.S. Congress. The EIA has no official position regarding the adoption of a carbon fee or tax. The EIA is sticking with its reference case projection, which actually has coal prices decreasing over the next 20 years. However, as an arm of the federal government, EIA cannot publicly advocate measures that would seriously impact the U.S. coal (or any other) industry.

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Table 1

1997 AVERAGE REVENUE PER KILOWATT HOUR FOR EXISTING ELECTRIC UTILITY GENERATION SYSTEMS

	Coal	Nuclear	Hydro	Nat. gas combined turbo
1. **Fuel 1** (Primary Fuel)	1.2178¢/KWH	0.5076¢/KWH	—-	2.3185¢/KWH
2. **Fuel 2**	0.0140¢/KWH	—-	—-	—-
3. **Labor - Oper. + Maint. + Super. + Engr.**	0.3613¢/KWH	0.2720¢/KWH	0.2440¢/KWH	0.0515¢/KWH
4. **Subtotal**	1.5931¢/KWH	0.7796¢/KWH	0.2440¢/KWH	2.3700¢/KWH
5. **Operations & Maintenance** (w/o labor)	0.1580¢/KWH	1.1840¢/KWH	0.6770¢/KWH	0.4000¢/KWH
6. Subtotal (1+2+3+5)	**1.7511¢/KWH**	**1.9636¢/KWH**	**0.9210¢/KWH**	**2.7700¢/KWH**
7. **Other O&M Costs**				
a. Admin & Sales (Includes Labor)	0.6610¢/KWH	0.6610¢/KWH	0.6610¢/KWH	0.6610¢/KWH
b. Transmission (Includes Labor)	0.0910¢/KWH	0.0910¢/KWH	0.0910¢/KWH	0.0910¢/KWH
c. Distribution (Includes Labor)	0.3080¢/KWH	0.3080¢/KWH	0.3080¢/KWH	0.3080¢/KWH
d. Purchased Electricity	0.3900¢/KWH	0.3900¢/KWH	0.3900¢/KWH	0.3900¢/KWH
8. Subtotal All O&M (1+2+3+5+7)	**3.2011¢/KWH**	**3.4136¢/KWH**	**2.3710¢/KWH**	**4.2200¢/KWH**
9. **Fixed Costs**				
a. State Income Taxes	0.0450¢/KWH	0.0450¢/KWH	0.0450¢/KWH	0.0450¢/KWH
b. Federal Income Taxes	0.3440¢/KWH	0.3440¢/KWH	0.3440¢/KWH	0.3440¢/KWH
c. Other Income Taxes	0.0810¢/KWH	0.0810¢/KWH	0.0810¢/KWH	0.0810¢/KWH
d. Taxes Other Than Income	0.2400¢/KWH	0.2400¢/KWH	0.2400¢/KWH	0.2400¢/KWH
e. Depreciation - Cogeneration	0.1970¢/KWH	1.2500¢/KWH	0.2090¢/KWH	0.3748¢/KWH
Transmission	0.0360¢/KWH	0.0360¢/KWH	0.0360¢/KWH	0.0360¢/KWH
Distribution	0.1570¢/KWH	0.1570¢/KWH	0.1570¢/KWH	0.1570¢/KWH
General Plant	0.0100¢/KWH	0.0100¢/KWH	0.0100¢/KWH	0.0100¢/KWH
Electric Plant	0.0360¢/KWH	0.0360¢/KWH	0.0360¢/KWH	0.0360¢/KWH
f. Capital Additions - Cogeneration	0.1310¢/KWH	0.0250¢/KWH	0.0470¢/KWH	0
Transmission	0.0550¢/KWH	0.0550¢/KWH	0.0550¢/KWH	0.0550¢/KWH
Distribution	0.2370¢/KWH	0.2370¢/KWH	0.2370¢/KWH	0.2370¢/KWH
General Plant	0.0090¢/KWH	0.0090¢/KWH	0.0090¢/KWH	0.0090¢/KWH
g. Interest on Long Term Debt	0.2090¢/KWH	0.2090¢/KWH	0.2090¢/KWH	0.2752¢/KWH
h. Deferred Income Taxes - Due	0.3670¢/KWH	0.3670¢/KWH	0.3670¢/KWH	0.3670¢/KWH
i. Deferred Income Taxes	-0.4790¢/KWH	-0.4790¢/KWH	-0.4790¢/KWH	-0.4790¢/KWH
10. Total Fixed Costs	**1.6750¢/KWH**	**2.6220¢/KWH**	**1.6030¢/KWH**	**1.7880¢/KWH**
11. **Nuclear Decommissioning Cost**	—	0.3060¢/KWH	—-	—-
12. **Profit**	0.7480¢/KWH	0.7480¢/KWH	0.7480¢/KWH	0.7480¢/KWH
13. Total Costs (8+10+11+12)	**5.6241¢/KWH**	**7.0896¢/KWH**	**4.7220¢/KWH**	**6.7560¢/KWH**
a. Fuel 1 HHV	8665.06 BTU/lb	81,000,000 BTU/Gram	0	1014.31 BTU/FT^3
b. Total Labor (Manhours/MWH)	0.1445 MH/MWH	0.1088 MH/MWH	0.0974 MH/MWH	0.0206 MH/MWH
c. Average Utilization Rate	71.56%	67.45%	63.39%	67%
d. Burned Fuel Cost	$19.8139/Ton $1.1433/$10^6$ BTU	$38.230/Gram $0.4720/$10^6$ BTU	0	$2.8623/$10^6$ BTU
e. Internal Plant elect. Usage	9.54%	8.65%	Unknown	1%
f. Heat Rate $\left[\frac{\text{BTU-HHV}}{\text{KWH NET}}\right]$	10,651.72 BTU/KWH	10,754 BTU/KWH	—-	8100 BTU/KWH
g. Avg. Wages & Benefits	$25/MH	$25/MH	$25/MH	$25/MH
h. Transmission & Distribution Elect. Losses	7%	7%	7%	7%

Notes:
1. Data from the following sources:
a. Federal Energy Regulatory Commission (FERC) Form No. 1 Financial Statistics of Specific Utilities.
b. Financial Statistics of Major U.S. Investor-owned Electric Utilities 1997.
c. Electric Sales and Revenue 1997. Energy Information Administration.
d. *Electric Light & Power Magazine* articles on "Investor owned electric utilities top 100 financial performances."
e. Magazine articles on new cogeneration systems.

2. USA Average Utilization Rate 1998
a. Nuclear 79.24%.
b. Coal Steam 67.96%.
c. Petroleum and Natural Gas and boiler Steam and Gas Turbine 21.70%.
d. Hydro 46.54%.
e. Wind Turbine 19.45 %.

Table 2

1997 AVERAGE REVENUE PER KILOWATT-HOUR FOR EXISTING ELECTRIC UTILITY GENERATION SYSTEMS

CHECKS AND BALANCES

A. Coal Generation States

	% Electricity from Coal	State Average Retail Price	Fuel Price
1. West Virginia	99.36%	5.02¢/KWH	$1.237/10^6 BTU or $30.43/Ton
2. Indiana	98.59%	5.29¢/KWH	$1.164/10^6 BTU or $24.49/Ton
3. Wyoming	96.44%	4.33¢/KWH	$0.806/10^6 BTU or $13.83/Ton

B. Hydro Generation States

	% Electricity from Hydro	State Average Retail Price
1. Idaho	100%	3.87¢/KWH
2. Oregon	94.32%	4.61¢/KWH
3. Washington	88.24%	4.04¢/KWH

C. Petroleum Steam States

	% Electricity from Petrol.	State Average Retail Price	Fuel Price
1. District of Columbia	74.65%	7.39¢/KWH	$2.779/10^6 BTU
2. Hawaii	79.12%	12.49¢/KWH	$3.643/10^6 BTU

D. Nuclear states

	% Electricity from Nuclear	State Average Retail Price	% Electricity from Other Technologies
1. Vermont	80.16%	9.89¢/KWH	16.88% Hydro
2. New Jersey	58.53%	10.54¢/KWH	28.71% Coal
3. New Jersey - 1998	75.55%	10.20¢/KWH	15.56% Coal

Notes: State Average Retail Price—The average sales price of electricity supplied to all sectors utilizing all of the generation technologies that produced that electricity. Data provided by EIA.

U.S. ELECTRIC POWER INDUSTRY

The electric-power industry in the United States is composed of traditional electric utilities as well as power marketers and non-utility power producers. Currently, the industry is being restructured so that the three primary components of electric service—generation, transmission, and distribution—are separated. Instead of purchasing power from the local utility, consumers will be able to purchase from other generators across the U.S. Proposed legislation will deregulate the generation part of the industry; however, transmission and distribution utilities will continue to be controlled by state regulatory commissions. This section of the article will review the costs that makeup the total delivered cost of electricity (Busbar cost) for each generation system technology. The author chose to review total costs so that the data could be compared to data from the EIA (1998 Electric Power Annual, Vol. 1; 1997 Electric Power Annual, Vol. 2; Financial Statistics of Major U.S. Investor-owned Electric Utilities, 1996; Electric Sales and Revenue, 1997; Emissions of Greenhouse Gases in the U.S., 1998; and Annual Energy Outlook 2000).

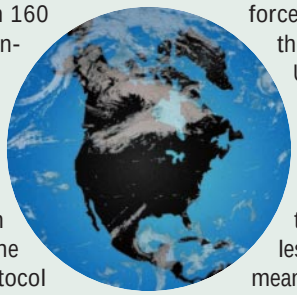
Table 1 provides the electric utility

Kyoto Protocol or Not, Emission Reductions Likely in U.S.

THE "KYOTO PROTOCOL" is the agreement that resulted from the "Third Session of the Conference of the Parties to the Framework Convention on Climate Change," which was held in Kyoto, Japan Dec. 1-11, 1997. Representatives from more than 160 countries met to negotiate binding limits on greenhouse-gas emissions for developed nations.

The Kyoto agreement established a legally binding Protocol under which industrialized countries would reduce their collective emissions of six greenhouse gases by 5.2 percent below their 1990 levels by the first commitment period, which begins in 2008 and ends in 2012. The target for the U.S. is 7 percent below 1990 levels. Because the Protocol does not specify any targets beyond the first commitment period, the target is assumed to hold constant from 2013 through 2020.

The participating developed countries, or Annex I countries, are the United States, Eastern and Western Europe, Russia and the Ukraine, Japan, Australia, New Zealand and Canada. There are 133 nations under the Kyoto Protocol that are considered developing and therefore are exempt from any emissions requirements under the treaty. They include Mexico, India, China, and South Korea.



Non-Annex I countries have no targets under the Protocol. If the Kyoto Protocol is ratified by the requisite number of countries, the reductions would be legally binding on all parties and enforceable under international law. To become binding in the United States, the Protocol must be approved by the U.S. Senate. So far, it has not been submitted to the Senate for ratification.

As currently written, the Kyoto Protocol commits the U.S. to reducing its greenhouse-gas emissions to 7 percent below 1990 national emissions. Few believe this document will ever be ratified in the U.S. Nonetheless, it is being used as a non-binding model to achieve meaningful reductions in carbon fuel use.

Many industrialized nations are moving faster than the U.S. to reduce their emissions. As the rest of the world actively promotes carbon reduction and fuel efficiency, the U.S. and in particular, U.S. industry, will have to adapt to compete in the world market. While it might not be the Kyoto Protocol, Congress may pass legislation in the near future to reduce carbon fuel dependency.

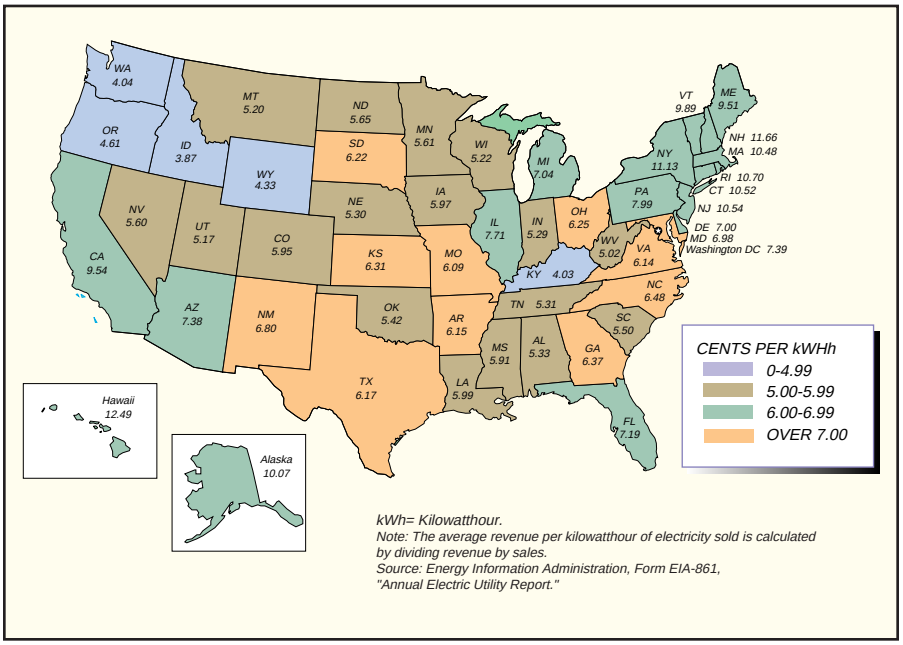


Fig. 1: Average Revenue per kWh for all sectors by state, 1997. U.S. total average revenue per kWh is 6.85 cents.

Table 3

1997 AVERAGE REVENUE PER KILOWATTHOUR BY SECTOR

	Average Revenue for Each Sector	Percentage of Total KWH/Year	Determine Average Retail Price
1. **Residential**	8.430¢/KWH	34.26%	2.89¢/KWH
2. **Commercial**	7.590¢/KWH	29.57%	2.24¢/KWH
3. **Industrial**	4.530¢/KWH	32.89%	1.49¢/KWH
4. **Other**	6.910¢/KWH	3.28%	0.23¢/KWH
5. **Avg. revenue per KWH - All Sectors (retail price)**			**6.850¢/KWH**

Retail Price: *Average sales price covering all electrical energy supplied for residential, commercial, industrial, and other small classes, such as agriculture and street lighting.*

1997 HIGHEST AND LOWEST SECTOR PRICES IN THE U.S.

	Lowest Cost	Avg. U.S. Cost	Highest Cost
1. **Residential**	4.95¢/KWH (Washington)	8.43¢/KWH	14.80¢/KWH (Hawaii)
2. **Commercial**	4.17¢/KWH (Idaho)	7.59¢/KWH	13.26¢/KWH (Hawaii)
3. **Industrial**	2.59¢/KWH (Washington)	4.53¢/KWH	10.32¢/KWH (Hawaii)
4. **Other**	3.83¢/KWH (Nevada)	6.91¢/KWH	23.23¢/KWH (Maine)
5. **Average all sectors**	**3.87¢/KWH** (Idaho)	**6.85¢/KWH**	**12.49¢/KWH** (Hawaii)

1996 WHOLESALE PRICE OF ELECTRICITY (SALES FOR RESALE)

	Sales for resale
1. **Investor-owned electric utility**	3.10¢/KWH
2. **Publicly owned electric ultility**	3.50¢/KWH
3. **Cooperative**	3.60¢/KWH
4. **Federal electric utility**	3.00¢/KWH
5. **Average**	**3.30¢/KWH**

Wholesale price : *The sale of large amounts of electricity from traditional utilities (or from nonutility power producers) sold to each other for resale to ultimate consumers. All data provided by the EIA.*

costs to produce, transmit and distribute electricity to the customer with existing generation systems. The primary source of financial data in this table comes from Federal Energy Regulatory Commission (FERC) Form 1 manuals of low-cost utility providers. The data were then compared to government publications which summarize the data taken from the utilities FERC Form 1. The total Busbar cost or revenue per KWH from these existing systems tend to be lower because they are older systems with low depreciation and low long-term debt.

The average age of coal-fired systems in the U.S. is approximately 41 years, hydro is 54 years, oil steam is 31 years, natural gas is 30 years and nuclear is 18 years. The gas-turbine system represented in Table 1 would be a fairly young plant. The prices are 1997 costs per KWH. The low-cost producer in this table is hydroelectric at 4.72 cents per KWH followed by coal steam at 5.72 cents per KWH. Due to limited resources, hydroelectric power is not the predominant technology in the U.S. It is coal steam, which produces over 55 percent of our electricity. Due to upcoming environmental pressures, coal usage will decrease over the next 20 years. The degree to which it decreases is subject to debate. According to the EIA's Annual Energy Outlook, coal usage will continue to increase, but lose market share over the next two decades.

Table 2 is information taken from the EIA's "Electric Power Annual." The average revenue in cents per KWH is calculated by dividing the total revenue by the corresponding KWH sales for each sector (residential, commercial, industrial, and other) and from all generation technologies in that state. To compare the Busbar cost of each technology, it was important to look at states that had high percentages of electricity generation for that technology. The numbers in the two tables seem to compare rather favorably to Table 1 data except for nuclear. After further review the author did find somewhat high costs from sales for resale that could be adding as much as a cent per KWH. According to data from the Nuclear Energy Institute (NEI) on operations, maintenance and fuel, there is a 1.6 cent/KWH variation

Table 4

1997 AVERAGE REVENUE PER KILOWATT-HOUR FOR NEW ELECTRIC UTILITY GENERATION SYSTEMS
USING 1997 INSTALLED COSTS AND FUEL PRICES

Generation Technology	System size (MW)	Overnight Capital Cost ($/KW)	Heat Rate HHV (BTU/KWH)	Fuel Cost ($/$10^6$ BTU)	Average Revenue* (cents/KWH)
1. Nat. Gas Combined Cycle Gas Turbine Conventional F-Frame	250	440	8030	$2.76	5.7240
2. Nat. Gas Combined Cycle Gas Turbine Advanced G&H-Frame	400	572	6985	$2.76	6.2970
3. Conventional Nat. Gas Gas Turbine	160	325	11,900	$2.76	6.7448
4. Pulverized Coal with 95% Eff. SO_2 Scrubber	400	1079	9585	$1.273	6.8743
5. Nat. Gas Simple Cycle Gas Turbine Advanced Turbine System	120	458	9700	$2.76	6.9292
6. Nat. Gas Boiler & Steam Turbine	300	991	9500	$2.76	7.6212
7. Advanced Coal - Integrated Gasification Combined Cycle (IGCC)	380	1833	8470	$1.273	7.7297
8. Nuclear (Evolutionary Advanced Reactor)	1300	2356	10,400	$0.472	8.3011
9. #2 Fuel Oil Boiler & Steam Turbine	300	991	9400	$2.88	8.3969
10. Wind Turbine	50	1235	NA	NA	8.4642
11. Fuel Cell (Molten Carbonate)	10	2189	6,000	$2.76	9.4446
12. Nuclear (Evolutionary Advanced Reactor) (Reduced Installation Charge)	1300	1550	10,400	$0.472	7.1178

*Average Revenue = Fuel + Overhead + Maintenance + Labor + Capital Recovery + Admin. & Sales + Transmission & Distribution + Purchased Elect. + Taxes + Income Taxes + Profit

Notes.
1. Capital recovery operating cost assumes a 20 year bond at 6% interest rate.
2. Average utilization rate is 67.96% except wind turbine which is 30%.
3. Capitol costs are in 1997 dollars per KW.
4. Operating coss are in 1997 cents per KWH.
5. Fuel prices are average utility fuel prices for 1997.

from low -cost plants to high-cost plants. At this point, it is difficult to say exactly how much of the added cost (2.8 to 3.50 cents per KWH) is from nuclear plants and how much might be from other technologies, sales for resale, and outside contracts.

Figure 1 is a map of the U.S., which illustrates the average revenue per KWH in all sectors by state for 1997 (also called retail price). These data were taken from EIA Form EIA861 "Annual Electric Utility Report". Table 3 provides a breakdown of the average retail price into an average price for residential, commercial, industrial and other. This table also provides the average 1996 price from each type of electric utility.

Many existing utility generation systems in the United States are fairly old and their construction costs already have been recovered. For this reason, it is important to look at the total revenue costs for new capacity as well. Table 4 illustrates the total revenue operating costs for new electric utility generating systems. For new capacity additions, the low capital cost and high operating efficiencies of natural-gas, combined-cycle gas turbine plants are the most economical. The total revenue (or operating costs) will be higher in new capacity additions verses existing capacity because of the capital recovery costs. You will note that the older, depreciated coal-steam generation systems produce electricity at 5.62 cents per KWH (Table 1) versus a newly installed natural gas combined cycle turbine at 5.72 cents per KWH (Table 4). Therefore, a low-cost utility would want to keep its older coal units running. However, as electric demand increases, requiring new construction, the preferred system is a natural gas combined cycle turbine.

Hydroelectric systems were not included in Table 4 because, under current circumstances, hydroelectric generating capacity is expected to remain virtually unchanged due to water use priorities moving away from electricity generation and toward environmental improvement, such as fish, habitat preservation, and recreation (EIA's Annual Energy Outlook 2000).

Information from the EIA on utility capacity additions also supports natural-gas turbines as the choice system. From 1996 to 2010, combined-cycle gas-turbine system installations are expected to grow from 15,200 to 90,100 MW, a 493-percent increase. Coal- steam systems, however, will only increase from 303,700 MW to 307,800 MW, a 1.35 percent increase (assuming no Kyoto Protocol). Coal system electric generators will increase their electricity output approximately 18 percent from existing systems by increasing their average utilization rate. Although, coal maintains its fuel cost advantage over both oil and natural gas, gas-fired generation is the most economical choice for construction of new power-generation units when capital, operating and fuel costs are considered. Another reason for the slow-down in coal-fired installations may be the upcoming environmental pressures. The biggest challenge for coal fired utilities is facing the regulatory uncertainty.

Table 5

EMISSIONS FROM FOSSIL FUEL FIRED UTILITY GENERATION SYSTEMS

1997 AND FUTURE TECHNOLOGIES IN U.S.	Heat Rate HHV (BTU/KWH)	CO_2 (lbs/ KWH)	CO_2 (lbs/ 10^6BTU)	NOx (lbs/ KWH)	NOx (lbs/ 10^6BTU)	SO_2 (lbs/ KWH)	SO_2 (lbs/ 10^6BTU)	SO_2 Before Scrubber (lbs/10^6 BTU)	Sulfur in the Fuel (% Wt.)	Particulate (lbs/ KWH)	Particulate (lbs/ 10^6BTU)	Fuel HHV
1. Existing Natural Gas Boiler & Steam Turbine	10,300	1.2085	117.33	0.00171	0.1660	0.00000604	0.000586	No Scrub	0.000624	0.000052	0.005	1023 BTU/ft^3
2. All Existing Natural Gas Systems	10,705	1.0255	95.797	0.00178	0.1660	0.0000070	0.000659	No Scrub	0.000624	0.000054	0.005	1023 BTU/ft^3
3. Natural Gas Turbines												
A. Conventional Turbine	10,600	1.2437	117.33	0.00176	0.1660	0.00000621	0.000586	No Scrub	0.000624	0.000053	0.005	1023 BTU/ft^3
B. Advanced Turbine	8000	0.9386	117.33	0.00080	0.10	0.00000469	0.000586	No Scrub	0.000624	0.000040	0.005	1023 BTU/ft^3
C. Conventional Comb. Cycle	7000	0.8213	117.33	0.00070	0.10	0.00000410	0.000586	No Scrub	0.000624	0.000035	0.005	1023 BTU/ft^3
D. Advanced Comb. Cycle	6350	0.7450	117.33	0.00064	0.10	0.00000372	0.000586	No Scrub	0.000624	0.000032	0.005	1023 BTU/ft^3
4. Molten Carbonate Fuel Cell	5361	0.6290	117.33	0.0004	0.0746	0.000003	0.000586	No Scrub	0.000624	0.000027	0.005	1023 BTU/ft^3
5. Coal Fired												
A. Existing Boiler/ Steam Turbine	10,297	2.1294	206.80	0.00765	0.7425	0.01344	1.3052	2.0487	1.08	0.000296	0.02879	10,227 BTU/lb
B. New Capacity Additions	9087	1.8792	206.80	0.00136	0.15	0.00091	0.10	2.0487	1.08	0.000262	0.02879	10,227 BTU/lb
C. Advanced Coal Tech.	7308	1.5113	206.80	0.00110	0.15	0.00073	0.10	2.0487	1.08	0.000037	0.005	10,227 BTU/lb
6. All Existing Petroleum Fired Systems	10,182	1.5628	153	0.00208	0.2046	0.01119	1.0989	No Scrub	1.13	0.000916	0.090	150,795 BTU/gal
7. Petroleum Fired												
A. Exising Boiler/Steam Turbine	10,050	1.6784	167	0.00231	0.230	0.01104	1.0989	No Scrub	1.13	0.000905	0.090	150,795 BTU/gal
B. Conventional Turbine	10,300	1.7201	167	0.00237	0.230	0.01132	1.0989	No Scrub	1.13	0.000927	0.090	150,795 BTU/gal
C. Conventional Comb.Cycle	7150	1.1941	167	0.00164	0.230	0.00786	1.0989	No Scrub	1.13	0.000644	0.090	150,795 BTU/gal

Notes: The SO_2 emissions from existing coal-fired boiler steam systems was used as the overal average of all systems.

The impact of future compliance costs to handle particulate, SO_2, SO_3, lead, mercury, and arsenic eventually will result in higher electricity costs from coal-steam systems. The total operating maintenance and capital recovery cost of a flue gas desulfurization system is around 0.5 cents per KWH. Each existing coal-fired plant must weigh the impact of compliance cost on the projected cost of electricity in their region. The flue gas emission discharge for each generation technology in Table 5 illustrates the significantly higher rates from coal steam generation systems.

Coal-fired electric utilities in the U.S. have made a lot of improvements over the last 10 years to clean their flue gas emissions, however, current environmental pressures will require further improvements which will result in higher operating costs. If you compare coal-fired systems to conventional natural-gas combined-cycle turbines (Table 5), the lbs of CO_2 per KWH from the coal system is around 159-percent higher. If you compare lbs of SO_2 per KWH, the coal system without an SO_2 scrubber is approximately 240,000 times higher. With a scrubber, it is 3300 times higher. Currently, there are 1207 coal-fired generation systems in the U.S. and only 193 systems (19 percent) have SO_2 scrubbers.

In summary, as individual states restructure their electricity markets, increasing numbers of customers will have the opportunity to chose their electricity suppliers resulting in lower electricity prices for most. The 1998 plan issued by the Clinton Administration said that consumers would save $20 billion per year under deregulation (0.55cents per KWH), which apparently would save the U.S. around 8 percent on the average retail price of electricity. According to the Annual Energy Outlook 2000, the average price of electricity will decline (assuming no Kyoto Protocol) from 6.7 cents per KWH in 1998 to 6.1 cents per KWH in 2005, to 6 cents per KWH in 2010, to 5.9 cents per KWH in 2015, and finally to 5.8 cents per KWH in 2020. This represents an average annual decline of 0.6 percent. According to the "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity" report, this translates into decreases for residential, commercial, and industrial electricity users of 10 percent, 17 percent and 14 percent, respectively, from 1998 to 2020. Some states, however, are expected to experience a price increase, such as Idaho, which currently has low cost hydroelectric power. In March 1999, the Agriculture Dept. issued a report that listed 19 states expected to have higher electricity prices. The states are in the Pacific Northwest, Mountain States, Mid-South, Northern Plains and in some Great Lakes states. In Figure 1, states that are very low- cost producers of electricity may see their rates increase because under

deregulation these low-cost utilities will have the opportunity to sell their power to more expensive states (or regions) and thus increase their profit margins.

IMPACTS OF THE KYOTO PROTOCOL

As currently written, the Kyoto Protocol requires the U.S. to reduce its carbon emissions to 7 percent below 1990 levels.

In 1990, the six greenhouse-gas emissions in the United States totaled 5,489,900,000 tons of gas. When each gas is weighted by its global warming potential, the total is 1,642,000,000 metric tons of carbon or carbon equivalent. Of this total, the combustion of energy fuels produced 5,440,267,390 tons of CO_2 gas or 1,346,000,000 metric tons of carbon which is 82 percent of the total emissions. By 1998, the energy related emissions increased to 6,003,290,605 tons of CO_2 or 1,485,400,000 metric tons of carbon.

The greenhouse gases that absorb infrared radiation (heat) are water vapor (H_2O), carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O), and a host of engineered synthetic chemicals such as Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Water vapor is the most common with an atmospheric concentration of almost 1 percent, carbon dioxide is 0.0356 percent, methane is 0.00017 percent and nitrous oxide is 0.000031 percent. The greenhouse gases covered by the Protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. For the three synthetic greenhouse gases, countries have the option of using 1995 as the base year.

Basically, there are three ways that the U.S. plans to reduce energy related carbon emissions: cut the demand for energy, use more efficient equipment, or switch to less carbon-intensive fuels (from coal to natural gas), or noncarbon fuels.

Fossil fuels derive their energy content primarily from oxidation of the hydrogen and carbon in the fuels. However, coal derives a higher percentage of its energy content from the oxidation of carbon than oil or natural gas. This is illustrated in Table 5 under CO_2 (lbs per million BTU of fuel). The CO_2 formation from coal combustion is around 76 percent higher than natural gas and around 24 percent higher than petroleum. As you can see, the proposed Kyoto Protocol limitations on carbon emissions will have a significant impact on the coal industry, the mining industry and the railroad industry, all of which will trickle down into dozens of other industries. The impacts to fuel costs and the U.S. economy from the international effort to reduce greenhouse gas emissions will be discussed in the second half of this two-part series, which will appear in the September, 2000 issue of HPAC Engineering. ■

PART 2 OF 2

REDUCING Greenhouse Gas Emissions and the Impact on U.S. Energy Prices

The international effort to halt global warming may send energy prices soaring

By WILLIAM G. ACKER
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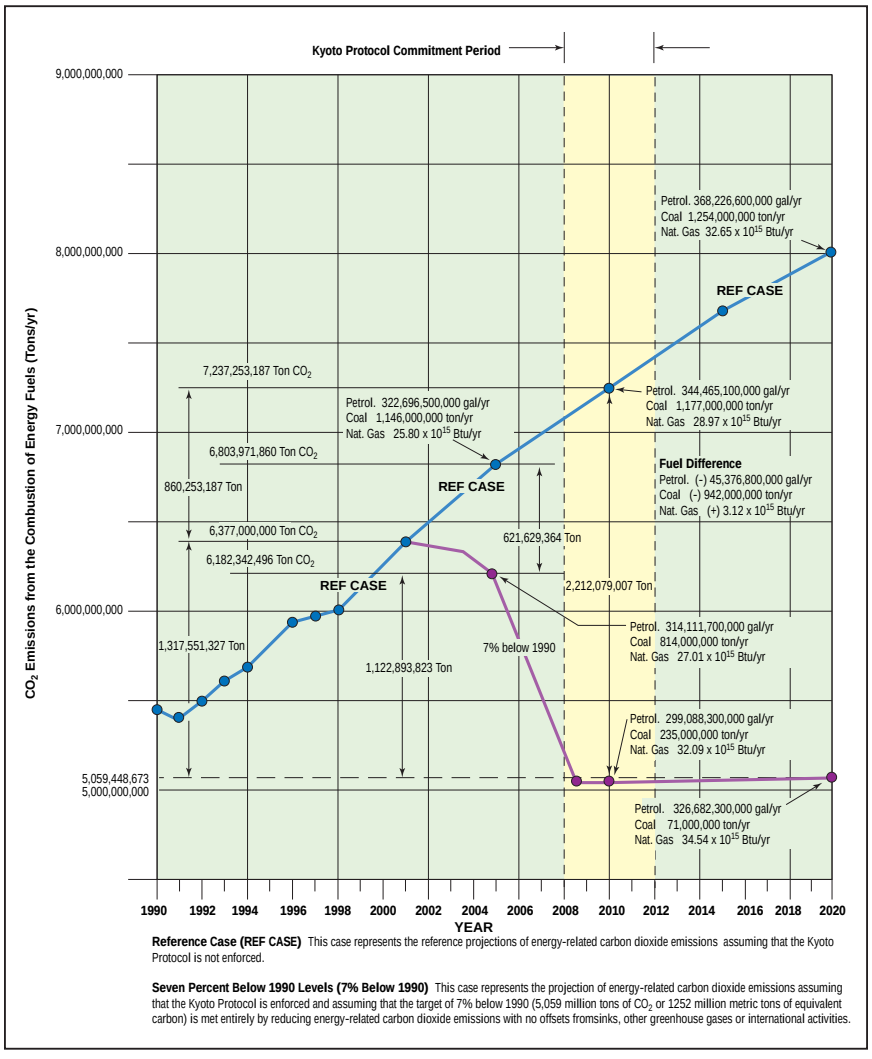

Figure 1. CO_2 emissions graph for reference case and 7 percent below 1990 levels.

The Kyoto Protocol is the name commonly used to describe the agreement that came from the "Third Session of the Conference of the Parties to the Framework Convention on Climate Change," which was held in Kyoto, Japan, in December 1997. During that meeting, representatives from more than 160 countries met to negotiate binding limits on greenhouse-gas emissions for developed nations.

WHAT KYOTO DEMANDS

The Kyoto agreement established a legally binding protocol under which industrialized countries would reduce their collective emissions of six greenhouse gases—carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride— by 5.2 percent below their 1990

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levels by the first commitment period, which begins in 2008 and ends in 2012. The target for the U.S. is 7 percent below 1990 levels. Because the Protocol does not specify any targets beyond the first commitment period, the target is assumed to hold constant from 2013 through 2020. The participating developed countries, or Annex I countries, are the U.S., Eastern and Western Europe, Russia, Ukraine, Japan, Australia, New Zealand, and Canada. The 133 non-Annex I countries, which include Mexico, India, China, and South Korea, have no targets under the Protocol. To become binding in the U.S. , the Senate must approve the Protocol. So far it has not been submitted to the Senate for ratification.

To recap Part 1 of this series, there are three ways that the U.S. can reduce energy-related carbon emissions: cut the demand for energy, use more efficient equipment, and switch to less carbon-intensive fuels (from coal to natural gas) or non-carbon fuels. Figure 1 shows the usage of the three primary fuels (petroleum, coal and natural gas) for both the reference case, which assumes no Kyoto Protocol, and the case of 7 percent below 1990 levels. By comparing the fuel usages of the two cases, one can get a sense of how the three ways to reduce energy-related carbon emissions will work.

In 1990, the six greenhouse-gas emissions in the U.S. totaled 5,489,900,000 tons of gas. When each gas is weighed by its global-warming potential, the total is 1,642,000,000 metric tons of carbon or carbon equivalent. Of this total, the combustion of energy fuels produced 5,440,267,390 tons of CO_2 gas or 1,346,000,000 metric tons of carbon, which is 82 percent of the total emissions. By 1998, energy-related emissions increased to 6,003,290,605 tons of CO_2 or 1,485,400,000 metric tons of carbon. Figure 1 illustrates emissions from the combustion of energy fuels from 1990 through 2020. There are two graphs plotted on this chart: the reference case graph and the 7-percent-below-1990 graph. The reference case graph represents actual emissions from 1990 through 1998 and reference projections from 1998 through 2020, assuming that the Kyoto Protocol is not enforced. The second graph, 7-percent-below-1990, represents the projections of emissions assuming the Protocol is approved by the Senate and assuming that the target of 7 percent below 1990 levels is met entirely by reducing energy-related carbon emissions with no offsets from sinks (land use and forestry issues) and other greenhouse gases or international activities. This graph represents the worst-case scenario in regard to the amount of emissions reductions required to meet the Kyoto Protocol goal and on the potential impact on U.S. energy prices, energy uses and the economy. The Energy Information Administration's (EIA's)analysis of the Kyoto Protocol has five less stringent scenarios that may or may not be the final goal of energy-related emissions.[1] This article will only focus on the reference case and the 7-percent-below-1990 case.

Table 1 provides the CO_2-emissions

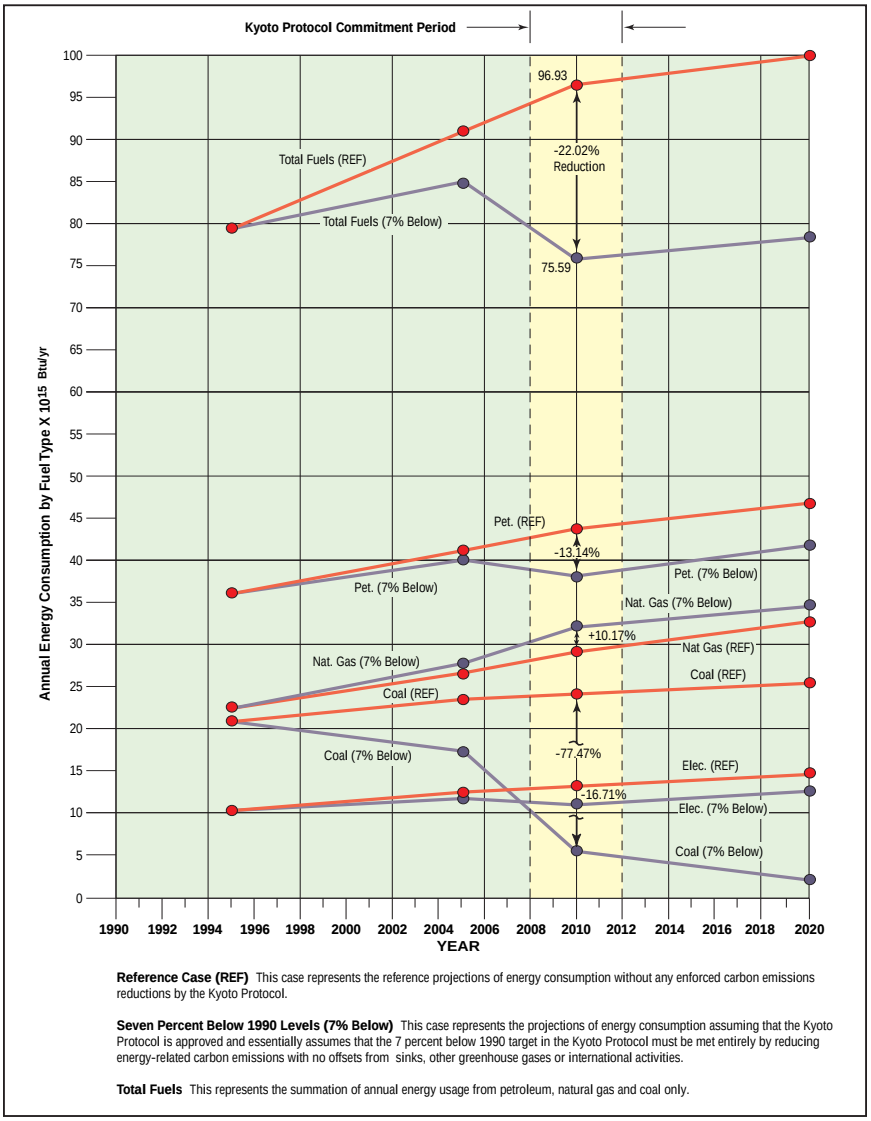
TABLE 1. Greenhouse-gas emissions from the combustion of energy fuels

Year	Energy-related CO_2 emissions	Amount above or below the target	Percent above or below target	Energy-related carbon equivalent emissions	Amount above or below the target
7% below 1990 target level	5,059,448,673 ton CO_2	0		1,251,780,000 m ton C	
1990 (Actual)	5,440,267,390 ton CO_2	+380,818,717 ton CO_2	+7.53%	1,346,000,000 m ton C	+94,220,000 m ton C
1991 (Actual)	5,396,800,000 ton CO_2	+337,351,327 ton CO_2	+6.67%	1,335,245,546 m ton C	+83,465,546 m ton C
1992 (Actual)	5,477,900,000 ton CO_2	+418,451,327 ton CO_2	+8.27%	1,355,310,846 m ton C	+103,530,846 m ton C
1993 (Actual)	5,594,300,000 ton CO_2	+534,851,327 ton CO_2	+10.57%	1,384,109,872 m ton C	+132,329,872 m ton C
1994 (Actual)	5,668,200,000 ton CO_2	+608,751,327 ton CO_2	+12.03%	1,402,393,789 m ton C	+150,613,789 m ton C
1995 (Actual)	5,719,556,000 ton CO_2	+660,107,327 ton CO_2	+13.05%	1,415,100,000 m ton C	+163,320,000 m ton C
1996 (Actual)	5,912,754,208 ton CO_2	+853,305,535 ton CO_2	+16.87%	1,462,900,000 m ton C	+211,120,000 m ton C
1997 (Actual)	5,977,423,063 ton CO_2	+917,974,390 ton CO_2	+18.14%	1,478,900,000 m ton C	+227,120,000 m ton C
1998 (Actual)	6,003,290,605 ton CO_2	+943,841,932 ton CO_2	+18.66%	1,485,400,000 m ton C	+233,620,000 m ton C
2005 (Ref Case)	6,803,971,860 ton CO_2	+1,744,523,187 ton CO_2	+34.48%	1,683,400,000 m ton C	+431,620,000 m ton C
2005 (7% Below)	6,182,342,496 ton CO_2	+1,122,893,823 ton CO_2	+34.65%	1,529,600,000 m ton C	+272,820,000 m ton C
2008 (Beginning of Protocol)					
2010 (Ref Case)	7,237,253,187 ton CO_2	+2,177,804,514 ton CO_2	+43.04%	1,790,600,000 m ton C	+538,820,000 m ton C
2010 (7% Below)	5,025,174,180 ton CO_2	-34,274,493 ton CO_2	-0.67%	1,243,400,000 m ton C	-8,380,000 m ton C
2012 (End of Protocol)					
2015 (Ref Case)	7,652,750,576 ton CO_2	+2,161,637,299 ton CO_2	+51.26%	1,893,400,000 m ton C	+641,620,000 m ton C
2020 (Ref Case)	7,795,426,237 ton CO_2	+2,735,977,564 ton CO_2	+54.08%	1,928,700,000 m ton C	+676,920,000 m ton C
2020 (7% Below)	5,055,487,705 ton CO_2	-3,960,968 ton CO_2	-0.08%	1,250,800,000 m ton C	-980,000 m ton C

numbers used in the graph as well as the metric tons of carbon equivalent. By 2010 (mid-year of the Kyoto commitment period), the reference case emissions are 43 percent above the 7-percent-below 1990 emissions, which is 2,177,804,514 tons of CO_2 over the target of 5,059,448,673 tons of CO_2.

In the reference case, all fuels continue to grow in demand but in the 7-percent below 1990 case, petroleum and coal usage drops and natural gas usage increases. By 2020, coal consumption drops dramatically to 71,000,000 tons per year for the case of 7- percent-below-1990, which is a 91-percent drop from the usage in 2005. In comparison to the reference case, coal consumption is down by 94 percent. This major drop in coal consumption is related to its CO_2 formation.

Figure 2 illustrates the changes in future fuel consumption for the reference case and the 7-percent-below-1990 level (on a Btu basis). One also can compare the differences in fuel consumption from the reference case to the case of 7-percent-below-1990 level. For coal, petroleum, and electricity, there is a drop in consumption from the reference case to 7-percent-below-1990 levels of 77.47 percent, 13.47 percent and 16.71 percent, respectively. Natural gas, however, increases by 10.17 percent. Even though total natural-gas usage in the U.S. increases only 10.17 percent,



Reference Case (REF) This case represents the reference projections of energy consumption without any enforced carbon emissions reductions by the Kyoto Protocol.

Seven Percent Below 1990 Levels (7% Below) This case represents the projections of energy consumption assuming that the Kyoto Protocol is approved and essentially assumes that the 7 percent below 1990 target in the Kyoto Protocol must be met entirely by reducing energy-related carbon emissions with no offsets from sinks, other greenhouse gases or international activities.

Total Fuels This represents the summation of annual energy usage from petroleum, natural gas and coal only.

Figure 2. Annual energy consumption for reference case and 7 percent below 1990 levels.

U.S. Energy Consumption	2010 (Ref Case)
A. Energy not used for electricity generation	
1. Petroleum	43.46x10^{15} BTU/YR
2. Nat. Gas	22.06x10^{15} BTU/YR
3. Coal	2.80x10^{15} BTU/YR
4. Others	3.12x10^{15} BTU/YR
5. Subtotal	71.44x10^{15} BTU/YR
B. Energy used for electricity generation	
1. Petroleum	0.36x10^{15} BTU/YR
2. Nat. Gas	6.91x10^{15} BTU/YR
3. Coal	21.35x10^{15} BTU/YR
4. Other	11.12x10^{15} BTU/YR
5. Subtotal	39.74x10^{15} BTU/YR
C. Total USA Energy Consumption (A + B)	111.18x10^{15} BTU/YR
D. Total Energy By Fuel Type (A+B)	
1. Petroleum	43.82x10^{15} BTU/YR
2. Nat. Gas	28.97x10^{15} BTU/YR
3. Coal	24.15x10^{15} BTU/YR
4. Other	14.24x10^{15} BTU/YR
5. Total U.S. Energy Consumption	111.18x10^{15} BTU/YR

USA Electricity	2010 (Ref Case)
E. Electricity Consumption Data	
1. Electricity Consumption by all sectors	3,865,000,000,000 KWH/YR
2. Generation Efficiency	10,282.01 BTU/KWH
3. Fuel Switching	
4. Total	

USA Electricity
F. Electricity Consumption Data
1. Electricity consumption by all sectors
2. Electricity related losses
3. Total energy consumption by electric generators

electric generators will see a very significant increase in their natural-gas usage under this Kyoto Protocol goal. Their natural-gas usage from 1996 to 2005 will increase 133 percent (or 4.06 quadrillion Btu), while from 2005 to 2010, it will increase 78.31 percent (or 5.56 quadrillion Btu), and from 2010 to 2020, it will increase 13.11 percent (or 1.66 quadrillion Btu). The critical question is whether natural-gas capacity can be built in sufficient quantity, if interstate natural-gas pipelines can be built on time, and if natural gas imports from Canada and Mexico can support this much expansion.

Table 2 provides fuel-usage and CO_2 emissions data for each of the fuel types and CO_2-emissions reductions from the reference case and the case of 7-percent below-1990 levels. To meet the 7- percent-below-1990 goal, U.S. energy con-

TABLE 2 . CO_2 emissions in 2010
From reference case (no Kyoto Protocol) to 7 percent Below 1990 levels

2010 (7% Below 1990)	Amount of fuel usage increase or decrease	Fuel usage change, %	2010 CO_2 Emissions (Ref Case)	2010 Co_2 Emissions (7% Below 1990)	CO_2 Emissions Reduction	CO_2 Emissions Change, %
37.68x10^{15} BTU/YR	-5.78x10^{15} BTU/YR	-13.30%	3,008,314,278 ton	2,563,715,903 ton	-444,598,375 ton	-14.78%
19.43x10^{15} BTU/YR	-2.63x10^{15} BTU/YR	-11.92%	1,275,188,976 ton	1,122,812,987 ton	-152,375,989 ton	-11.95%
1.73x10^{15} BTU/YR	-1.07x10^{15} BTU/YR	-38.21%	286,563,862 ton	177,435,170 ton	-109,128,692 ton	-38.08%
3.05x10^{15} BTU/YR	-0.07x10^{15} BTU/YR	-2.24%	10,104,509 ton	9,296,148 ton	-808,361 ton	-8.00%
61.89x10^{15} BTU/YR	-9.55x10^{15} BTU/YR	-13.37%	4,580,171,625 ton	3,873,260,208 ton	-706,911,417 ton	-15.43%
0.38x10^{15} BTU/YR	+0.02x10^{15} BTU/YR	+5.56%	30,313,526 ton	31,930,247 ton	+1,616,721 ton	+5.33%
12.66x10^{15} BTU/YR	+5.75x10^{15} BTU/YR	+83.21%	402,159,439 ton	736,820,762 ton	+334,661,323 ton	+83.22%
3.71x10^{15} BTU/YR	-17.64x10^{15} BTU/YR	-82.62%	2,224,608,597 ton	383,162,963 ton	-1,841,445,634 ton	-82.78%
13.03x10^{15} BTU/YR	+1.91x10^{15} BTU/YR	+17.18%	0 ton	0 ton	0 ton	0%
29.78x10^{15} BTU/YR	-9.96x10^{15} BTU/YR	-25.06%	2,657,081,562 ton	1,151,913,972 ton	-1,505,167,590 ton	-56.65%
91.67x10^{15} BTU/YR	-19.51x10^{15} BTU/YR	-17.55%	7,237,253,187 ton	5,025,174,180 ton	-2,212,079,007 ton	-30.57%
38.06x10^{15} BTU/YR	-5.76x10^{15} BTU/YR	-13.14%	3,038,627,804 ton	2,595,646,150 ton	-442,981,654 ton	-14.58%
32.09x10^{15} BTU/YR	+3.12x10^{15} BTU/YR	+10.77%	1,677,348,415 ton	1,859,633,749 ton	+182,285,334 ton	+10.87%
5.44x10^{15} BTU/YR	-18.71x10^{15} BTU/YR	-77.47%	2,511,172,459 ton	560,598,133 ton	-1,950,574,326 ton	-77.68%
16.08x10^{15} BTU/YR	+1.84x10^{15} BTU/YR	+12.92%	10,104,509 ton	9,296,148 ton	-808,361 ton	-8.00%
91.67x10^{15} BTU/YR	-19.51x10^{15} BTU/YR	-17.55%	7,237,253,187 ton	5,025,174,180 ton	-2,212,079,007 ton	-30.57%

2010 (7% Below 1990)	Electricity demand change	% electricity demand change	CO_2 Emissions Reduction from Electric Generators	% CO_2 Emissions Change	% of the total U.S. CO_2 Emissions Reduction
3,219,000,000,000 KWH/YR	-646,000,000,000 KWH/YR	-16.71%	-437,919,983 ton due to demand change	-29.09%	19.80%
9251.32 BTU/KWH	1030.69 BTU/KWH		-266,351,196 ton due to generation efficiency	-17.70%	12.04%
			-800,896,411 ton due to fuel switching	-53.21%	36.20%
			-1,505,167,590 ton Total	100%	68.04%

2010 (Ref Case)	2010 (7% Below 1990)	Energy Usage Reduction
13.19x10^{15} BTU/YR	10.98x10^{15} BTU/YR	-2.21x10^{15} BTU/YR
26.55x10^{15} BTU/YR	18.80x10^{15} BTU/YR	-7.75x10^{15} BTU/YR
39.74x10^{15} BTU/YR	29.78x10^{15} BTU/YR	-9.96x10^{15} BTU/YR

sumption would have to drop 19.51 quadrillion Btu in 2010—a 17.55-percent reduction. Electric generators created 9.96 quadrillion Btu per year of the energy savings and remaining fuel consumers created the other 9.55 quadrillion Btu per year. The reductions in carbon emissions from electric generators account for 68-percent of the total CO_2 emissions reduction, while the remaining fuel consumers (residential, commercial, industrial, and other) account for 32 percent. The electric generators accomplished the CO_2 reductions through electricity-usage reductions, generation efficiency, and fuel switching.

KYOTO PROTOCOL IMPACT

Projected fuel and electricity prices in the U. S. can be found in Table 3. The data was taken from the EIA's Kyoto Protocol study.[1] Prices provided are actual 1996 prices, while projected prices are for 2005, 2010, and 2020. All prices are in 1996 dollars and costs (no escalation). By providing the prices in 1996 dollars, one can see price variations that occur without escalation variations.

Energy prices in the reference case are fairly stable over the next 20 years. Motor gasoline, distillate oil, and residual oil show moderate price increases through the year 2020. The Annual Energy Outlook 2000 (AEO 2000) prepared by the EIA illustrates slightly higher prices than Table 3.[2]

Coal prices are declining due to gains in coal-mine labor productivity and lower transportation costs. Natural-gas prices are fairly stable over this period, with most sectors experiencing a slow increase in prices. Electricity prices are dropping due to increased competition, higher generating efficiencies, and lower prices. The carbon reduction target of 7-percent-below-1990 reflects a "carbon price," which is a tax that is applied to the cost of energy intended to make carbon-rich fuels financially untenable. In its report, the EIA included projections based on this tax at the request of Congress. The carbon price that is applied to each of the energy fuels is related to its carbon content. With the carbon price included in this delivered cost of energy, energy prices are expected to rise significantly above the reference-case projections. Because of the higher carbon content of coal and petroleum products, the use of both fuels are reduced and there is a greater reliance on natural gas, renewable energy and nuclear power. Coal is the most carbon intensive of all the fossil fuels, there-

fore the delivered coal prices are most affected by the carbon prices. As a result of the carbon price, aggregate energy prices in the U.S. will change significantly.

Table 3 provides energy-price projections for the carbon-emissions-reduction case of 7 percent below 1990 levels. It reveals that fuel prices increase significantly, especially in 2010. Coal prices are 867 percent higher than the reference case , which is why coal consumption drops by 80 percent in that year (Figure 1). These changes will have a significant negative impact on coal industry, the railroads and manufacturing that relies on coal. Regionally, the price impact will be the greatest in regions in which electricity generation is currently dominated by coal-fired power plants. Electricity prices also increase significantly due to higher fuel prices and capital investing to replace coal-fired plants.

It is important to keep in mind that the case of 7 percent below 1990 level is the worst-case scenario (with respect to fuel prices and emissions reductions), which assumes that the U.S. does not get any carbon-emission credits for land-use forestry and agriculture, existing programs to reduce emissions of the other five greenhouse gases, or for International Trade of Carbon Permits. The Impact of the Kyoto Protocol document prepared by the EIA includes five less severe cases (3 percent below 1990 levels, equal to 1990, 9 percent above 1990, 14 percent above 1990, and 24 percent above 1990). The energy prices in each of these scenarios are less than the figures in Table 3, but price increases are still significant, even in the most generous scenario: 24 percent above 1990 levels. For example, in the year 2010 under that scenario, coal prices will have increased 156 percent above the reference case while industrial natural gas will have increased 33 percent and electricity

TABLE 3. Reference case energy prices & Kyoto Protocol-impacted energy prices

		1996	2005		2010		2020	
Energy type		Price	Price	Percent variation	Price	Percent variation	Price	Percent variation
A. Electricity								
1. Commercial	(Ref. case)	7.5 cents/KWH	6.6 cents/KWH	33.3%	6.4 cents/KWH	93.8%	6.0 cents/KWH	71.7%
2. Commercial	(7% below 1990)		8.8 cents/KWH		12.4 cents/KWH		10.3 cents/KWH	
3. Industrial	(Ref. case)	4.6 cents/KWH	3.9 cents/KWH	35.9%	3.8 cents/KWH	92.1%	3.5 cents/KWH	71.4%
4. Industrial	(7% below 1990)		5.3 cents/KWH		7.3 cents/KWH		6 cents/KWH	
B. Natural gas								
1. Commercial	(Ref. case)	$5.28/10^6 BTU	$4.73/106 BTU	35.1%	$4.61/10^6 BTU	132.5%	$4.57/10^6 BTU	121.4%
2. Commercial	(7% below 1990)		$6.39/106 BTU		$10.72/10^6 BTU		$10.12/10^6 BTU	
3. Industrial	(Ref. case)	$2.96/10^6 BTU	$2.80/106 BTU	55.7%	$2.98/10^6 BTU	190.3%	$3.25/10^6 BTU	161.5%
4. Industrial	(7% below 1990)		$4.36/106 BTU		$8.65/10^6 BTU		$8.50/10^6 BTU	
C. Coal								
1. Industrial	(Ref. case)	$32.28/ton	$28.68/ton	206.6%	$27.58/ton	714.8%	$25.83/ton	656.6%
2. Industrial	(7% below 1990)		$87.93/ton		$224.73/ton		$195.43/ton	
3. Elec. Generators	(Ref. case)	$26.45/ton	$23.37/ton	238.8%	$22.20/ton	867.3%	$19.56/ton	910.3%
4. Elec. Generators	(7% below 1990)		$79.18/ton		$214.75/ton		$197.61/ton	
D. Motor Gasoline								
1. Transportation	(Ref case)	122.5 cents/gal.	123 cents/gal.	19.3%	125.4/gal.	52.8%	124 cents/gal.	45.5%
2. Transportation	(7% below 1990)		146.8 cents/gal		191.6 cents/gal.		180.2 cents/gal	
3. Average all	(Ref. case)	122.5 cents/gal	122.8 cents/gal.	19.4%	125.2 cents/gal.	52.9%	123.9 cents/gal.	45.4%
4. Average all	(7% below 1990)		146.6 cents/gal.		191.4 cents/gal.		180.1 cents/gal.	
E. Distillate Oil (No. 4., 5 and 6 fuel oil)								
1. Commercial	(Ref. case)	73.1 cents/gal.	74.5 cents/gal.	36.1%	77.3 cents/gal.	108.5%	78.5 cents/gal.	91.7%
2. Commercial	(7% below 1990)		101.4 cents/gal.		161.2 cents/gal.		150.5 cents/gal.	
3. Industrial	(Ref. case)	76.3 cents/gal.	75.3 cents/gal.	36%	78.7 cents/gal.	106.1%	81.3 cents/gal.	87.1%
4. Industrial	(7% below 1990)		102.4 cents/gal.		162.2 cents/gal.		152.1 cents/gal.	
F. Residual Oil: (No. 1 & 2 fuel oil)								
1. Commercial	(Ref. case)	48.4 cents/gal.	46.0 cents/gal.	70.7%	47.6 cents/gal.	215.3%	50.5 cents/gal.	176.4%
2. Commercial	(7% below 1990)		78.5 cents/gal.		150 cents/gal.		139.6 cents/gal.	
3. Industrial	(Ref. case)	44.8 cents/gal.	41.1 cents/gal.	78.6%	44 cents/gal.	228.4%	47.3 cents/gal.	182%
4.Industrial	(7% below 1990)		73.4 cents/gal.		144.5 cents/gal.		133.4 cents/gal.	

Notes: All prices are in 1996 dollars. The reference case represents the reference projections without any enforced greenhouse-gas reductions and is presented as baseline. Seven-percent-below-1990 numbers represent an added carbon price, or tax, applied to each of the energy fuels to achieve a carbon -emissions reduction of 7 percent below the 1990 emissions level. Electricity produces no carbon at the point of use. The carbon price is applied to the fuels used to generate electricity. The higher prices are reflected in the delivered price of electricity. All data derived from "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity."

will have increased 24 percent.

Each case implicitly assumed different levels of reductions for forestry and agriculture sinks, reductions from five other greenhouse gases, the international trading of emissions permits, and other international activities, which may offset the required reductions of energy-related carbon emissions.

U.S. FUEL IMPORTS

When the oil embargo hit in 1973, almost 17 percent of the U.S.'s electricity was generated by burning more than 560,000,000 barrels of oil per year. Today's utilities are less reliant on oil. Only 3.8 percent of our electricity is produced by burning 197,000,000 barrels per year. The transportation sector, however, continues to rely heavily on petroleum fuels. In 1973, oil consumption was at 3,285,000,000 barrels per year; today, it is more than 4,600,000,000 barrels per year. The transportation sector accounts for 66.7 percent of U.S. petroleum consumption.

Over the next two decades, imports of natural gas and petroleum will continue to rise. Under the reference case, natural-gas imports will increase from 12 percent in 1996 to 17 percent in 2005 to 17 percent in 2010 and to 16 percent in 2020.[2] Petroleum imports will grow from 46 percent in 1996 to 60 percent in 2005 to 62 percent in 2010 and 64 percent in 2020.[2]

During the 1970s, the decade of energy crisis, OPEC members produced about 50 percent of the world's daily production and had control over petroleum prices. Then in the 1980s, OPEC production dropped to 33 percent of the total world production. However, in 2014 OPEC nations will account for more than 50 percent of total U.S. petroleum imports. By 2020, OPEC once again will produce 50 percent of the world's petroleum.

NUCLEAR POWER

In 1998 nuclear power produced 674 billion killowatthours of electricity in the U.S. Replacing that generation with natural-gas combined-cycle gas-turbine generators will increase U.S. CO_2 emissions by 277 million tons per year, which is 21 percent more CO_2 emissions to remove in the year 2010. Using coal-fired generation results in 633 million tons per year of CO_2 emissions or 48 percent more emissions to be removed in 2010.

Because of disasters such as the Chernobyl accident in 1986, nuclear power is not a politically popular energy source. However, eliminating nuclear power as an energy source fuel will make the goals of the Kyoto Protocol even more difficult. If we allow our nuclear plants to die off in the U.S., it will take 21-percent additional natural gas to produce the same amount of electricity. Using coal-fired generation to replace nuclear would result in a 30 percent increase in coal consumption.

Nuclear plants produce electricity without emitting greenhouse gases. Nuclear power could also reduce our dependence on imported energy. Two countries that seem to support nuclear power are China and Russia. China plans to increase its nuclear generation from 1.1 percent of its total to 18 percent by 2020. Russia plans to more than double its current 14 percent to 31 percent by 2030.

WORLD FUEL RESOURCES

Table 4 is the author's attempt to look at the world resources of our three primary fuels and their usages. It is important to note that coal constitutes almost 48 percent of the world fossil fuel reserves. Also, at the current rate of petroleum usage, some analysts think that demand will begin to exceed supply in 25 years.

CONCLUSION

The Greenhouse effect, caused by rising rates of CO_2 and other gases, still is debated by the experts. One central concern is what fraction of the increase in atmospheric CO_2 levels is attributable to humans and what fraction is attributable to natural sources. Another concern is the lack of conclusive correlation between human-made emissions and global warming. It's likely that the U.S. Senate may have to vote on the Kyoto Protocol before the experts reach more conclusive results.

The primary aim of this article was to raise the level of understanding of energy, technology, the environment, resource availability, and the economy. The intent was to provide the reader with an appreciation of all these issues so that we as a society can make equitable decisions in the years ahead. The author's advice to designers, installers and maintenance people is to stay informed on the issues of environmental legislation in particular the Kyoto Protocol, and to choose more efficient equipment, which not only saves on annual fuel costs, but also reduces our air emissions and our dependence on imported energy. One easy way to do this would be to consider renewable energy systems or to purchase electricity made from renewable energy sources. There is no single answer to the questions about energy in the years ahead, but you can be sure that there will be environmental challenges and probably be energy crises as well. ■

TABLE 4. World fuel reserves and fuel consumption

	Crude Oil	Natural Gas	Coal
BTU/Unit	138,000 Btu/gal	1000 Btu/ft^3	10,300 Btu/lb
World Reserves	2 x 10^{12} barrels 11.592 x 10^{18} Btu 36.56 percent	5.0 10^{15} ft^3 5 x 10^{18} Btu 15.81 percent	730 x 10^9 tons 15.038 x 10^{18} Btu 47.54 percent
World Annual Usage	27,375,000,000 barrels/yr 15.867 x 10^{16} Btu/yr	82 x 10^{12} ft^3/yr 8.2 x 10^{16} Btu/yr	4,502,912.620 tons/yr 9.276 x 10^{16} Btu/yr
Years (World reserves/annual use)	73 years	61 years	162 years

REFERENCES

1. "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity." Energy Information Administration, 1998.

2. "Annual Energy Outlook, 2000." Energy Information Administration.

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