Chapter II

CURRENT AND PROJECTED FUEL COSTS

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Chapter II

Current and Projected Fuel Costs

Anticipating the future cost of energy in the United States is an extremely uncertain undertaking. The complex industry is in rapid flux, and the past is an unreliable guide to the future. Prices will depend on:

- the cost of developing and producing domestic fuel resources;
- the price of imported fuels;
- the cost of producing synthetic fuel substitutes;
- externalities such as environmental regulations; and
- regulatory impact, both explicit and implicit.

Confident estimates in these areas simply are not possible, although a large number of the estimates can be supported. The predicted future price of fuel can have a strong influence on both private and public decisions about solar energy. Investments in solar and other conservation equipment will appear more attractive if energy prices are expected to rise sharply instead of remaining constant or increasing gradually. Public perception of future energy prices may be guided, to a large degree, by the Government's behavior on this issue. As long as the Government insists that energy prices will not rise, the public almost certainly will make decisions on this basis.

CURRENT ENERGY PRICES

The prices charged during 1976 for residential and utility fuels in the four regions examined in this study are illustrated in table II-1. It should be noted that there is a significant difference between prices paid for residential natural gas in different parts of the country ($3.18 per million Btu (MMBtu) in Boston and $1.10 per MMBtu in Kansas City in 1975), and the prices charged for utility coal ($5 per ton in Albuquerque, where access to mines is direct, and $25 per ton in Boston, where transportation costs are significant). In general, energy prices demonstrate a greater geographic variation than the total amount of sunlight available for solar installations, and the two effects may cancel each other out. In New England, for example, insolation rates are relatively low, but fuel prices are high.

The prices charged for electricity are more difficult to summarize, since most utilities charge different rates in summer and winter and use "declining block rates" to define costs in each season. The actual residential rate schedules used in each of the four cities in 1976 are plotted as a function of monthly consumption in figure I 1-1, As can be seen, electric prices vary greatly around the country.

The rates used in evaluating the cost of electricity consumed by different customers are simplified approximations of the actual prices charged. The assumed rate schedules are summarized in table 11-2, and residential rates are illustrated in figure 11-2. The schedules were prepared from the actual rates, using procedures outlined in table II-3. Different schedules were applied, as appropriate, to residences, apartments, shopping centers, and industries. Where different summer and winter rates applied, the rates were averaged by weighting each seasonal rate according to the number of months in the season. Complex rate schedules were simplified with linear approximations in some instances.

Table II-1.—1976 Fuel Prices

Location	Residential consumer prices incl. applicable taxes[a] (mils/kWht)		Average delivered contract price at utility electric plants, January 1976[b] (mils/kWht)		
	Natural gas	No. 2 heating oil	Natural gas	Residual fuel oil (No. 6)	Coal
Albuquerque	4.980 (Dallas)	9.893[c] (Mountain)	2.696 (New Mexico)	6.335 (New Mexico)	0.8601 (New Mexico)
Boston	10.87 (Boston)	10.40 (Boston)	5.669 (Vermont)	6.171 (Massachusetts)	4.239
Fort Worth	4.980 (Dallas)	Not Available (West South Central)	2.966 (Texas)	6.010 (Texas)	0.9010 (Texas)
Omaha	3.747 (Kansas City)	9.573[c] (West North Central)	2.365 (Nebraska)	5.474 (Nebraska)	3.276 (Nebraska)

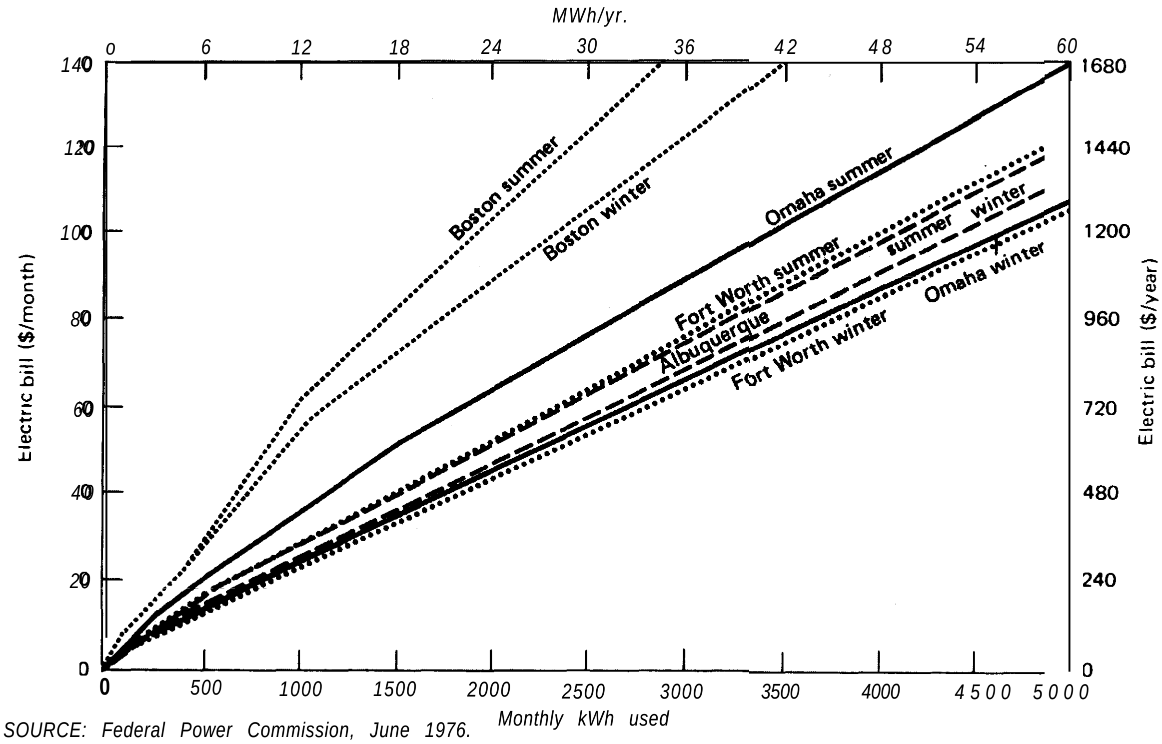
(Note The following conversion factors were used. 1 therm = 2930 kWht; 1 gallon No 2 oil = 40.64 kWht; 1 kWht = 3413 Btu)

[a] *Retail Prices and Indexes of Fuels and Utilities Residential Use*, Bureau of Labor Statistics, US Dept of Labor, March 1976

[b] Federal power Commission *News Release No.* 22363, May 19, 1976.

[c] *Monthly Energy Review* FEA, May 1976, p. 60.

Figure II.1.—Actual 1976 Residential Declining Block-Rate Structure Including Fuel Adjustment



SOURCE: Federal Power Commission, June 1976.

Table II-2.—Model's Assumed 1976 Electric Rate Structures

City	Loads (see previous table)		
Albuquerque			
SFH	Bill =	1.60 + .02928 X kWh	kWh<650
		6.41 + .021876 X kWh	kWh>650
TNH, LR, HR, SC	Bill =	102.50 + .011043 X kWh	D<50
		10 + 3.85 X .011043 X kWh	D>50
Boston			
SFH, TNH	Bill =	2.23 + .0558 X kWh	kWh61000
		22.027 + .03603 X kWh	kWh>1000
LR, HR	Bill =	1.60 x No. units + .29 x D + .0629 x kWh	kWh<200 x D, and kWh<12,000
		1.60 x No. units + .41 x D + .0623 x kWh	kWh>200 x D, and kWh<12,000
		1.60 x No. units + .29 x D + .0625 X kWh	kWh<120 x D, and kWh>12,000
		1.60 x No. units + 1.838 x D + .0472 X kWh	kWh>120 X D, and kWh>12,000
SC	Bill =	82 + 3.664 X D + .03707 X kWh	D<8O0, and kWh<300
		84.44 + 3.664 X D + .02893 X kWh	D<800, and kWh>300
		3013.50 + 3.433 x D + .03707 X kWh	D>800 and kWh<300
		3015.94 + 3.433 X D + .02893 X kWh	D>800, and kWh>300
Fort Worth			
SFH	Bill =	1.69 + .0368 X kWh	kWh<200
		3.95 + .02548 X kWh	kWh>200
	D Bill =	1.65	D<8
		1.65 + 1.85 X (D-8)	D>8
	"D-500" =	0	D<500
		D – 500	D>500
TNH, LR, HR, SC	Bill =	D Bill + 92.40 + .01703 x kWh	kWh<50,000 + 100 X ("0-500")
		D Bill + 943.90 + 01313 x kWh + 1.703 X ("D-500")	kWh>50,000 + 100 X ("D-600") kWh<100,000 + 200 X ("D-500")
		D Bill + 1600.44 + .01043 x kWh + 3.016 X ("D-500")	kWh>100,000 + 200 x ("D-500")
Omaha			
SFH	Bill =	3.91 + .0289 X kWh	kWh<800
		9.65 + .02174 X kWh	kwh>800
TNH, LR, SC	Bill =	93.88 + .0218 X kWh	kWH<7,500+ 300 x D
		147.21 + 2.13 X D + .0147 X. kWh	kWh>7,500 + 300 X D

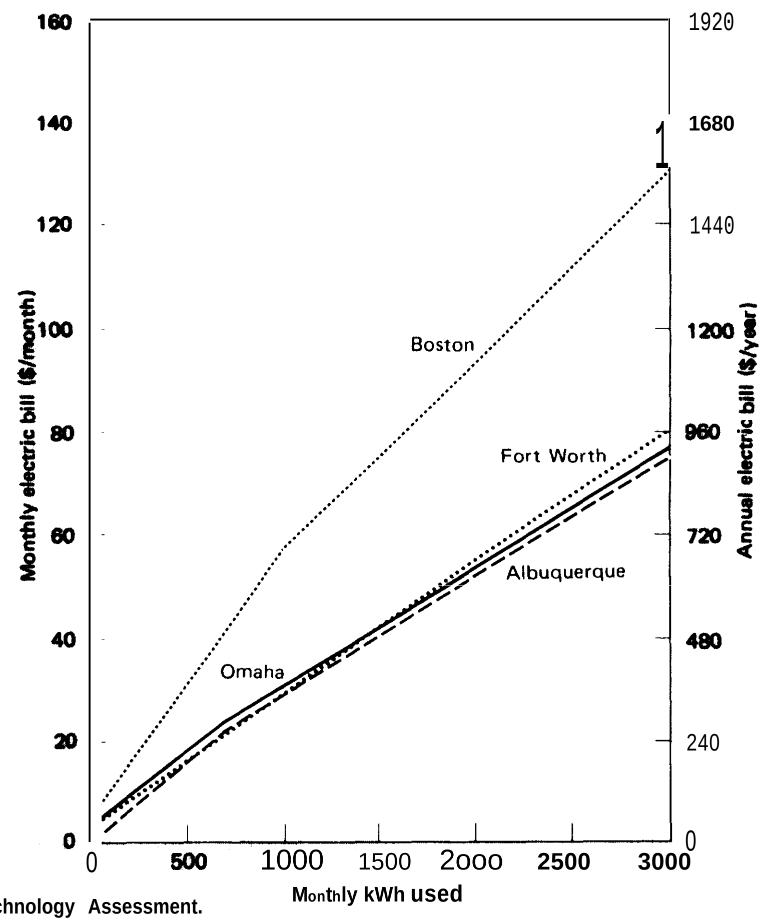
Source Off Ice of Technology Assessment

Table n-3.-Simplified Electric Rate Schedules

City (electrlc utility)	Fuel adjustment (mils/kWh)	Actual electric rate schedules from which simplified schedules are developed for each case modeled (Effective date)				
		Single family house (SFH)	8 Unit townhouse (TNH)	36 Unit low rise (LR)	196 Unit high rise (HR)	Shopping center (Se)
Albuquerque (Publicc Service Company of New Mexico)	3.043	Schedule #l residential service (May 23, 1975)	Schedule #3 general power service (May 23, 1975)	No. 3	No. 3	No. 3
Boston (Boston Edison Company)	19.1	Residence rate B (Oct. 17, 1975)	Rate B	Apartment house rate C (Oct. 17, 1975)	Rate C	General service rate (Oct. 17 1975)
Fort Worth (Texas Electric Service Co.)	2.13	Rate R residential service (Dec. 3, 1975)	Rate G general service	Rate G	Rate G	Rate G
Omaha (Omaha Public Power District)	2.07	Schedule #10 residential service (March 1, 1976)	Schedule #30 general service (March 1, 1976)	No. 30	No. 30	No 30

RawDataSuFport by FPC Burrau f Pwr June 1976

Figure II-2.—1976 Residential Electric Rate Structure Used in Model



SOURCE: Office of Technology Assessment.

ESTIMATES OF FUTURE ENERGY PRICES

As indicated, methods to project future energy prices are quite inexact. A variety of organizations have published estimates of the future prices of energy and, as may be expected, the results vary greatly. As a result, rather than relying on a simple projection to provide a set of energy prices for comparison, a range of estimates has been used. These include:

1. no increase in energy prices in constant dollars;
2. residential energy price projections generated by Brookhaven National Laboratory (BNL); and
3. a projection chosen arbitrarily higher than the BNL forecast.

The results of these estimates are illustrated in figures II-3 through II-10 for the four cities examined. This set is used to demonstrate the sensitivity of price in the analysis. It is intended not to represent most probable future energy prices, but a set of projections representing several plausible forecasts of future energy prices. The choice of these bounds is explained below, along with a description of how the curves were obtained.

The Brook haven National Laboratory (BNL) is responsible for preparing the Department of Energy's (DOE) projections of future energy prices. However, because the Federal Energy Administration (FEA) had responsibility for setting "near-term" energy policy, the Brook haven modelers were required to use FEA's energy price projections through the year 1985. The BNL projections used here were received in July 1976, and at the time were BNL's "baseline" (high nuclear power) residential energy price projections.[1] There is no single "standard" set of BNL energy price projections, as a number of scenarios with different assumptions about the future have been run and have yielded differing results. Furthermore, BNL is constantly updating its energy price projections as new data become available.[3]

Even DOE's energy price forecasters admit that al I forecasts are necessarily speculative. However, the more sophisticated forecasters, such as BNL, take their initial guesses and run them in supply/demand models to see if the resulting mix of fuels looks "reason able." If the initial guess results in an unlikely mix of fuels being burned (all natural gas and no oil or coal, for example), the future energy price guesses are revised and the model is run again. This process is repeated until they have a "reason able-looking" set of future energy price guesses which result in a "reasonable-looking" future energy use mix.[1] The result of these analyses is a set of energy price ratios indicating the growth in energy prices as a function of the current price of energy.

BNL concurred that:

1, The exponential curve fit (described below) is an acceptable way of extrapolating their energy price ratios to beyond the year 2000.
2. Applying these price ratios to actual 1976 prices of energy in various regions of the country is an acceptable way of projecting future energy prices in each location.
3. Applying the corresponding residential price ratio to 1976 prices of commercial and utility fuels is an acceptable way of projecting these energy prices.[5]

Figures II-3 through II-10 illustrate the BNL energy price projections through the year 2000 for residential natural gas, residential heating oil, and residential electricity in Albuquerque, N. Mex., Boston, Mass., Fort Worth, Tex., and Omaha, Nebr.

PROJECTIONS

High Projection.—The BNL projections indicate a relatively modest increase in energy prices over the next few decades. It is possible, however, that the price of energy may reach levels higher than those shown in the BNL projections as a result of shortages and the higher cost of producing new sources. Given the large number of uncertainties surrounding estimates, it is impossible to accurately quantify either of these effects. In addition, a tax on energy could also raise the price. A high price ceiling for energy, was chosen and it was assumed for this scenario that current prices rise gradually to stable prices at these high levels.

This price behavior is determined by assuming that energy prices rise to the stable level PRICE (∞) according to the following formula:

$$\text{PRICE}(t) = \text{PRICE}(\infty) \times \left(1 - \exp \frac{t_o - t}{T_r}\right) \quad (1)$$

where PRICE(t) is the energy price in year t, and T_r is a time constant* indicating the speed with which the price approaches the final threshold. The BNL data were fitted to

[1] Residential energy price projections from BNL supplied by Eric Hirst, Oak Ridge National Laboratory, July 1976

[2] D Behling (BNL), private communication, July 19, 1976

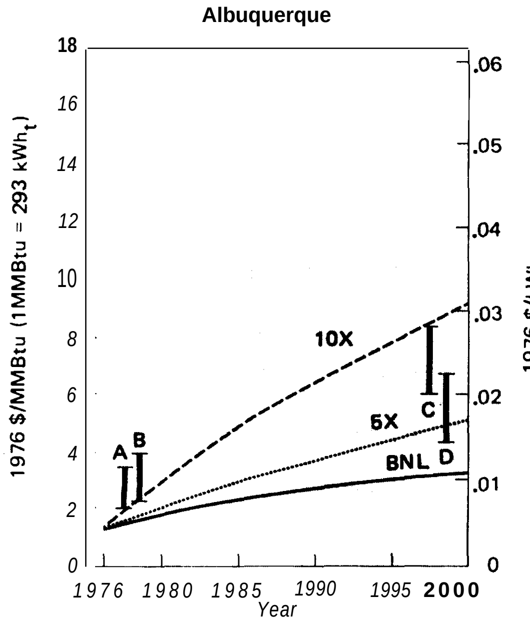
[3] Ibid

[4] M Beller (BNL), private communication, July 19, 1976

[5] D Behling (BNL), op cit

*The time constant (T_r) of 283 years for the three high projections, is a reasonable choice since it is close to the typical lifetime of generating plants, mines, oil- pumping rigs, etc

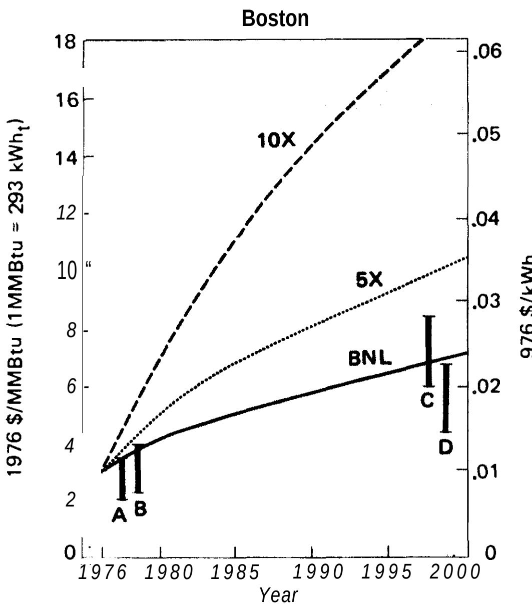
Figure II-3.—Assumed Future Residential Natural Gas Prices



A. Unregulated natural gas in 1976
B. LNG in 1976
C. Synthetic gas from coal @ $40/ton
D. Synthetic gas from coal @ $20/ton

SOURCE: Office of Technology Assessment.

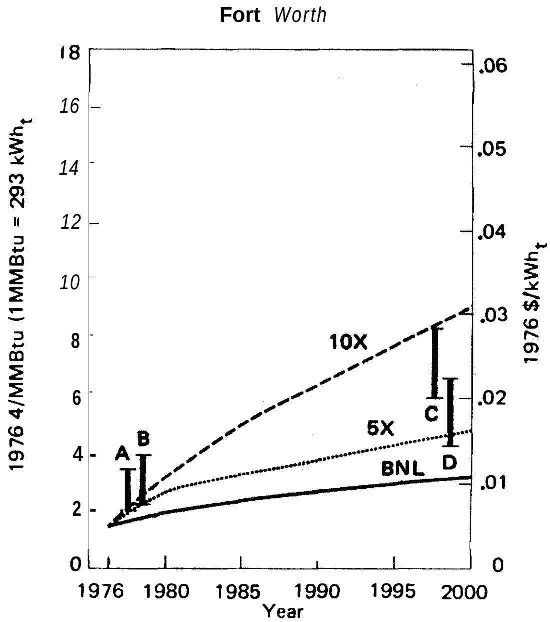
Figure n-4.-Assumed Future Residential Natural Gas Prices



A. Unregulated natural gas in 1976
B. LNG in 1976
C. Synthetic gas from coal @ $40/ton
D. Synthetic gas from coal @ $20/ton

SOURCE: Office of Technology Assessment.

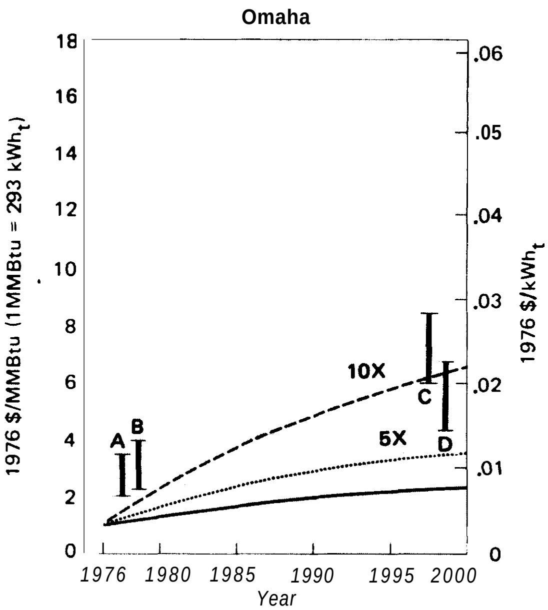
Figure II-5.—Assumed Future Residential Natural Gas Prices



A. Unregulated natural gas in 1976
B. LNG in 1976
C. Synthetic gas from coal @ $40/ton
D. Synthetic gas from coal @ $20/ton

SOURCE: Office of Technology Assessment.

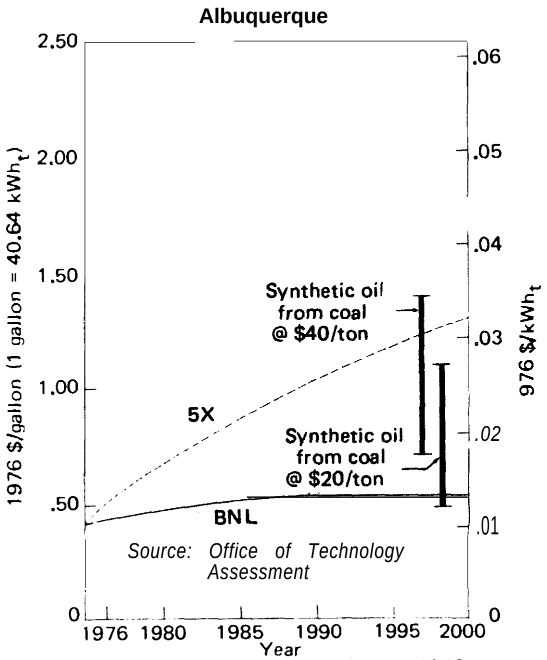
Figure II-6.—Assumed Future Residential Natural Gas Prices



A. Unregulated natural gas in 1976
B. LNG in 1976
C. Synthetic gas from coal @ $40/ton
D. Synthetic gas from coal @ $20/ton

SOURCE: Office of Technology Assessment.

Figure II-7.—Assumed Future Residential Heating Oil Prices



A. Unregulated natural gas in 1976
B. LNG in 1976
C. Synthetic gas from coal @ $40/ton
D. Synthetic gas from coal @ $20/ton

Figure II-9.—Assumed Future Residential Heating Oil Prices

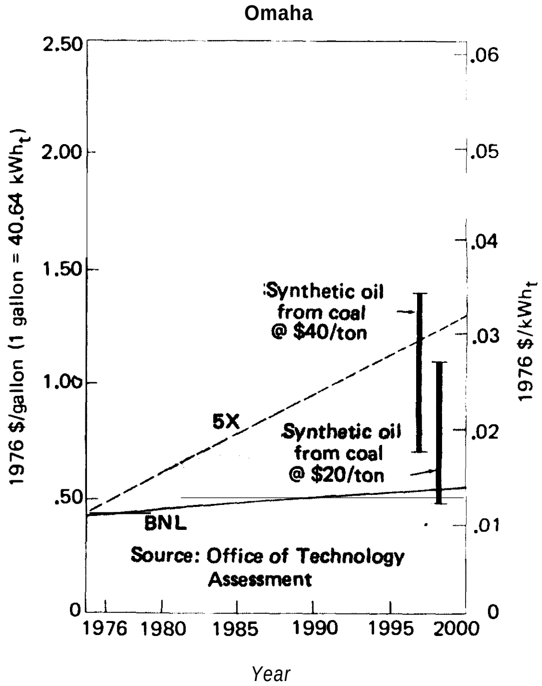


Figure II-8.—Assumed Future Residential Heating Oil Prices

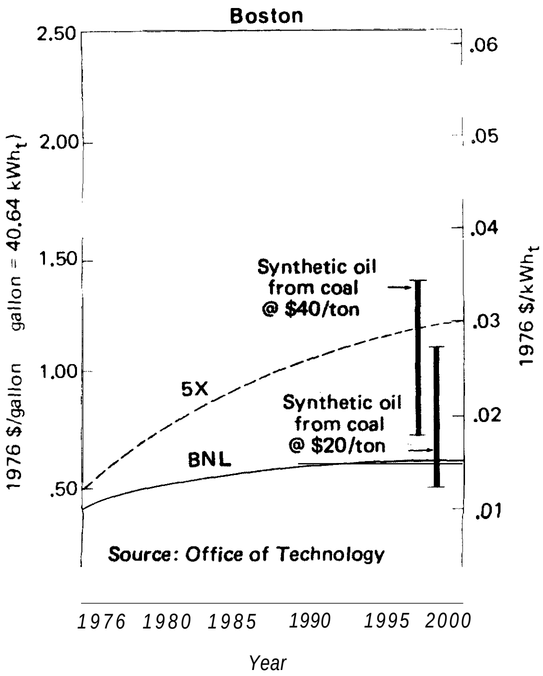
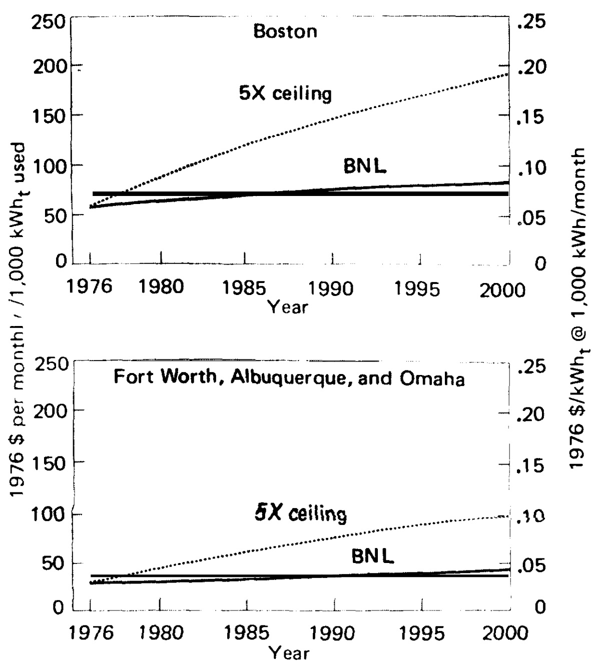


Figure II-10.—Assumed Residential Electricity Rate Increases



SOURCE: Office of Technology Assessment

this curve, and the results shown in table II-4. The table also shows constants chosen to yield prices higher than the BNL projections.

Table II-4.-Constants for Brookhaven National Laboratory Price Increase Projections*

PRICE (m) / PRICE (1976)		t_o	T_r
BNL electricity	1.62	1952.8	28.334
BNL gas	2.89	1965.7	24.334
BNL oil	1.71	1951.2	28.334
2x cost projection	2.00	1956.4	28.334
5x cost projection	5.00	1979.7	28.334
10x cost projection	10.00	1973.0	28.334

*These constants are defined in equation (1) in the text. The price ratio shown in the first column is the constant dollar ratio between an assumed future "stable" price of energy of the type shown and the price paid in 1976

For the purposes of this study, the five-times-cost (5 x) projection was chosen. A discussion of the factors making up the cost of the principal energy sources follows this section to demonstrate the plausibility at the 5 x projection.

FOSSIL FUEL PRICES

Natural Gas

Current natural gas prices in most of the country are a result of Federal and State regulatory actions, which control the price from the wellhead to the ultimate user. The large cost variations between localities, as evidenced by comparing Boston and Omaha, result from the differences in transportation costs and the volume of supplemental gas resources (propane-air mixture, synthetic natural gas from petroleum products, and liquefied natural gas) that must be used to meet demand. These latter supplies are only partially price regulated, and their costs to the gas distributor more nearly reflect the real incremental costs of new supplies. However, these costs are averaged with that of flowing gas so the ultimate user does not see this incremental price. Current regulated gas prices range from about $0.20 to $1.49 per million Btu (MMBtu) at the wellhead and from about $1.85 to $4.70 per MMBtu (1976 prices) delivered to residences, depending on when the gas was dedicated to the interstate market.[6] In some parts of the country (the intrastate market), natural gas prices are not regulated and new contract gas sells for about $1.00 to $2.00 per MMBtu at the wellhead.[7] The average price of natural gas to residences in the intrastate market area is about $2.35 per MMBtu.[8] Future gas prices will be determined by the costs of bringing in new reserves as existing fields are depleted, developing synthetic natural gas from coal and liquids, and providing imported liquefied natural gas. Although precise estimates for 1985 and 2000 are not possible at present, arguments can be made which show that the range chosen is reasonable.

Gas from new reserves in the interstate market was priced by the Federal Energy Regulatory Commission (formerly the Federal Power Commission) at $1.45 per MCF at the wellhead in 1977. However, as previously stated, new gas at the wellhead is selling for up to $2.00 per MMBtu where not regulated. Synthetic natural gas (SNG) from petroleum products (naphtha and propane) is currently priced at anywhere from $3.00 to $4.20 per MMBtu at the plant gate. Although no plants to produce synthetic gas from coal have been built, estimates are that gas from such plants will cost from $4.00 to $6.00 per MMBtu ($4.50 to $7.50 per MMBtu delivered to residences) if coal costs $20.00 per ton.[9,10] If the cost of coal doubled to $40.00 per ton, SNG prices would increase by approximately $1.50 per MMBtu resulting in a delivered residential price of

[6] Quarterly Report of Gas Industry Operations, American Gas Association, Third Quarter, 1977.

[7] Federal Energy Regulatory Commission, News Release FE-69, Nov. 24,1977.

[8] *Quarterly Report of Gas Industry Operations*, op cit

[9] *Gas Supply Review*, American Gas Association, vol. 5, January 1977, pp 9-10.

[10] Richard A. Tybout, *Public Utilities Fortnightly*, *Vol 99, Mar.* 31, 1977, p 17.

$6.00 to $9.00 per MMBtu. The current price of gas imported as a liquid in cryogenic tankers (liquefied natural gas or LNG) ranges from about $1.75 to $2.90 per MMBtu delivered to the pipeline. [11] Although the above prices, which are indicative of the marginal costs of new supplies, are presently rolled into the cost of flowing gas from existing wells, the total price will more nearly equal the marginal cost as the latter depletes.

When transportation and distribution costs (about $0.50 to $1.50 per MMBtu) are added to the above prices, the result is a range of marginal prices from $2.25 to $9.00 per MMBtu. Although these are current prices, the upper end of the range already reaches or exceeds the 5 x ceiling prices in the year 2000 for all cities except Boston (see figure II-4). As stated earlier, a considerable portion of Boston's gas is made up of supplemental supplies, and current prices there are much closer to marginal cost of new supplies. However, if synthetic natural gas (SNG) from coal is included, an upper price of $9.00 per MMBtu (delivered) is obtainable, which approximates the 5 x ceiling price in Boston in the year 2000. It appears that the set of 5 x ceiling curves for natural gas is at least plausible.

Oil

A similar analysis can be developed for oil. The present average price of domestic oil is about $1.50 per MMBtu ($8.75 per barrel) at the well head. [12] Uncontrolled oil is about $2.40 per MMBtu and imported oil costs about $2.25 to $2.60 per MMBtu. [13] Residential heating oil currently costs about $3.35 per MMBtu delivered ($0.46 per gallon), This is about 30 percent above the price of crude oil, reflecting the costs of refining, transporting, and distributing the fuel oil.

Future oil and gas prices will depend on the cost of producing and transporting hydrocarbons from new sources and decisions made by petroleum exporting nations. The present price charged for oil from domestic sources can be approximated by the price of uncontrolled oil, $2.35 per mill ion Btu, [t has been estimated that oil produced from advanced recovery techniques at existing sites may cost as much as $4.30 per million Btu ($25 per barrel) before the supply of oil from these resources begins to fall rapidly. [14] The cost of imported oil will probably be the largest factor in determining oil price over the next 10 to 15 years. Although there is no way to be certain that these prices will continue to increase from their present levels of $2.25 per MMBtu, the continuing growth of world demand and the likely peak in production around 1990 make it improbable that prices will fall. Prices for oil produced from coal and oil shale can only be approximated, as no operating plants exist. As with SNG, these prices are subject to considerable uncertainty. In an analysis performed by ERDA (now DOE) in March 1976, shale oil prices of $2.50 per MMBtu were obtained. However, this study indicated that estimates of $3.25 per MMBtu had been made by others. The report also noted that their calculation could range as high as $4.00 per MMBtu, depending on financing assumptions. [15] Oil from coal was not estimated in the study, but the similarity between these processes and production of SNG from coal allows the same price range ($4.00 to $6.00 per MMBtu) to apply.

The price of delivered residential heating oil is presently about 30 percent higher than crude oil. The range of costs quoted above, $2.25 to $6.00 per MMBtu, is therefore equivalent to $3.15 to $8.00 per MM Btu, or $0,45 to $1.10 per gallon for delivered residential heating oil. These prices bracket the 5 x ceiling price in the year 2000 for all of the cities (see figures I I-7 through 11-9) in

[11] *Gas Supply Review,* American Gas Association, VOl 5, February 1977, pp 10-11

[12] Monthly *Energy Review,* DOE, November 1977, p 72

[13] Ibid , pp 72, 76

[14] *Enhanced Oil Recovery in the United States,* Office of Technology Assessment, U S Congress, Washington, D C., January 1978.

[15] *Proposed Synthetic Fuels* Corn mere *ial Demonstration Program: Fact Book,* ERDA, Washington, D C , March 1976

question, even before any real increase between now and 2000 is taken into account. The plausibility of this 5 x ceiling again appears justified.

Coal

The price of coal varies enormously around the country depending on the distance over which the coal must be shipped, heat content, and sulfur content (which determines the amount of pollution which will be released by burning), and a variety of other factors which determine its burning properties. Contract prices paid for coal by utilities vary from about $4.00 per ton in North Dakota to nearly $40.00 per ton in New Jersey. ”

Future prices will depend both on the extent to which the price of coal rises to meet the increasing price of competing fuels, and the extent to which environmental restrictions are imposed. If utilities are allowed to use western coal without flue gas desulfurization (FGD) technologies to meet air quality standards, the average price of coal would be lower than if they used eastern coal and FGD devices. Estimates are that sulfur cleanup will add as much as $0.60 per MMBtu to the price of coal.[17]

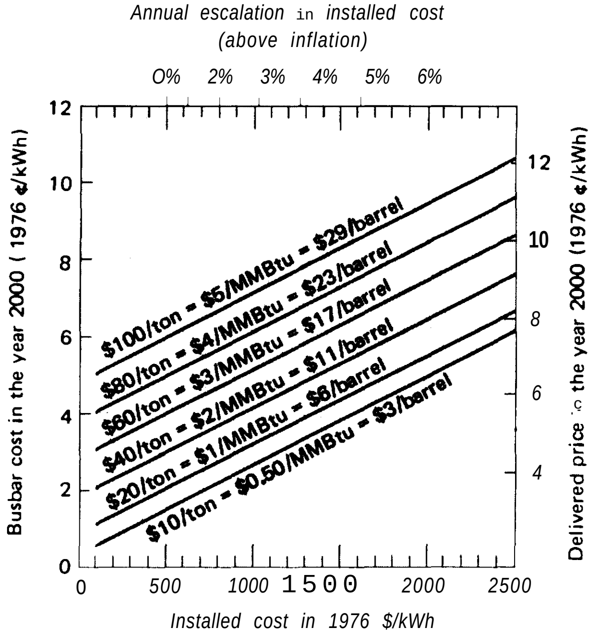
Based on this and on current coal prices, a range of $1.00 to $2.50 per MMBtu is not unreasonable. It should be noted that no coal prices as such are included in the price projections in figures II-3 through II-10. Coal will show up in the price of electricity as it has already appeared with respect to synthetic gas and oil. The sensitivity of electricity prices to coal prices will be discussed in more detail below.

ELECTRICITY PRICES

The two major components of electricity prices are the cost of fuel and the capital cost of the powerplant. The relative significance of either depends on the fuel used. Fuel costs are much more significant for oil-fired plants than that for coal or nuclear, since oil is two to five times more expensive on a Btu basis. The interaction between these two factors is shown in figures II-11 and II-12 which show the cost of electricity sold at the generating plant (busbar cost) and the average electricity sales price, delivered to the customer, as a function of the following variables:

- the installed cost of the generating facility in dollars per kw;
- the cost of fuel burned in the facility (coal, oil, or gas); and
- the "capacity factor, " defined as the average percentage use of the facility's capacity.

Figure II.11 .—Potential Marginal Costs of Baseload Electricity in the Year 2000 (75 Percent Load Factor)



Assumptions
–75% load factor –1976 Installed cost $500/kWh
–35% efficiency in generation and transmission
–Transmission and distribution cost $300 to $400/kWh
–Operating costs (exclusive of fuel) = $0.01/kWh
–Capital cost 0.15

SOURCE: Office of Technology Assessment,

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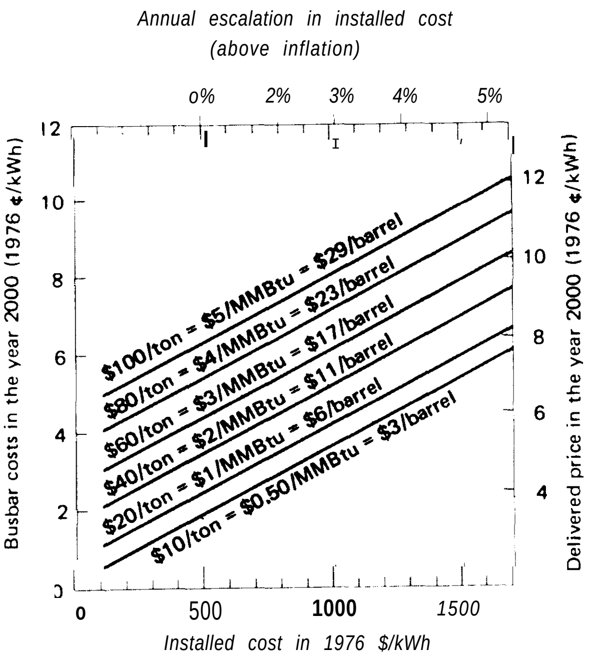
[16] *Annual Summary of Cost and Quality of Steam-Electric Plant Fuels, 1976,* Staff Report by the Bureau of Power, Federal Power Commission, May 1977

[17] National *Energy Outlook,* Federal Energy Administration, February 1976, p F-6

Figure II-12.— Potential Marginal Costs of Baseload Electricity in the Year 2000
(50 Percent Load Factor)



Assumptions
- *–50% load factor –1976 installed cost $500/kWh*
- *- 35% efficiency in generation and transmission*
- *–Transmission and distribution cost $300 to $400/kWh*
- *–Operation*
- *–Operation*
- *–Operating costs (exclusive of fuel) = $0.01/kwh*
- *–Capital cost 0.15*

SOURCE: *Office of Technology Assessment.*

In all cases it has been assumed that the plant is 35 percent efficient (including all losses in transmission and distribution). The delivered electricity costs includes, among other factors, the cost of building and operating a network of transmission and distribution lines

Coal Powerplants

Coal-fired plants presently on order cost about $500 per kW, including flue gas desulfurization devices. [18] Using present utility coal prices of about $1.00 per MMBtu ($20.00 per ton) and a capacity factor of 75 percent, a delivered electricity price of about $0.035 per kWh results from figure 11-11. It must be noted that this is the cost of baseload electric power, i.e., that produced by a large plant operating at a capacity factor of about 75 percent.

Utility loads fluctuate, however, and about 30 percent of the total electricity generated will need to come from facilities which can adjust their output rapidly (on the order of minutes to hours) to meet these fluctuations. These are typically smaller steam turbines (less than 100kW), combustion turbines, diesel engines, or hydroelectric storage systems, and are relatively expensive to operate. The cost of this intermediate and peak load electricity is about 1.35 to 3 times that of baseload electricity. [19] The total cost of electricity is the weighted average of the base, intermediate, and peak-load electricity, and is about 40 percent higher than the baseload price. Therefore, $0.035 per kwh for baseload must be adjusted for a total cost to the customer of about $0.049 per kWh. A further adjustment is needed, since the rates to different classes of customers are not the same. In 1975, residential customers paid about 15 percent more per kWh than the average to all customers. [20]

The future price of electricity will depend on the escalation rate of powerplant capital costs and fuel. For example, it can be seen from figure 11-11 that a 3-percent-per-year escalation rate, above inflation, will cause a $500 per kw plant to cost $1,000 per kW by the year 2000. If this is coupled with a real price rise in coal from $1.00 to $2.00 per MMBtu, the delivered cost of baseload electricity becomes $0.057 per kWh.

Applying these adjustments produces a total marginal cost in the year 2000 of $0.092 per kwh delivered to a residential customer. Previous discussion has already shown this coal price to be plausible (it is

[18] *The Economic and Social Costs of Coal and Nuclear Electric Generation,* National Science Foundation, Washington, D C , March 1976, p 12

[19] 1977 *National* Energy Outlook, (Draft), Federal Energy Administration, Washington, D C , *January* 1977, Appendix C, p. 19.

[20] *Statistical Yearbook of the Electric Utility Industry,* Edison Electric Institute, New York, N Y., October 1976, p. 54.

being paid by some utilities today). There are no generally accepted estimates at this time for the projected capital cost increase. The actual rate will have a substantial effect on electricity prices from coal-fired plants and is, therefore, one of the major uncertainties in assessing the relative economics of alternative energy systems.

Nuclear Powerplants

Another major uncertainty is associated with the cost of nuclear-generated electricity. The possible changes in plant capital costs are even more crucial in this instance because fuel costs do not contribute as significantly as in the case of coal. The many studies on the relative marginal costs of new nuclear and coal-fired electricity have reached no definitive conclusion. It is likely that percentage changes in capital costs will be similar for both coal-fired and nuclear plants, since the largest component is the construction cost, which is relatively independent of the type of plant built. As a result, nuclear costs will be more affected by capital cost escalations because nuclear power is more capital-intensive.

Another controlling item in the relative costs is the relative fuel costs and the associated environmental and safety features peculiar to each fuel cycle. This means that if nuclear electricity prices are to be significantly lower than the $0.092 per kWh previously calculated, assuming a 3-percent real increase in capital costs, the price of nuclear fuel must not increase significantly. However, present knowledge about moderately priced U_3O_8 resources and serious problems in developing a breeder reactor make it likely that nuclear fuel prices will continue to climb.

With regard to electricity, the 5 *x* ceiling curve loses plausibility only if electricity prices remain near their present marginal costs. This means either no significant real increase in capital costs (below 3 percent) or the continuation or decrease (to compensate for any rise in capital costs above 3 percent) of present fuel costs Again, it is not known what will occur in this context, but the fact that there are major uncertainties means that the 5 *x* ceiling cannot be precluded.

OTHER PROJECTIONS

InterTechnology Corporation.–Several other price projections have appeared recently, in addition to those quoted above. To complete this discussion, a review of these are given for comparison. In a report on the economic potential of solar thermal energy to provide industrial process heat, InterTechnology Corporation assumed a series of real escalation rates to obtain price estimates for the year 2000 of $2. I 4 per MMBtu for coal, $9.20 per MMBtu for oil (approximately $1.25 per gallon for delivered fuel oil), and $8.02 per MMBtu for natural gas, all in 1976 dollars. [21] The latter two are equal to or greater than the 5 *x* ceiling price used in this study. The coal costs correspond to coal at $43 per ton which, if coupled with plant capital costs of $1,000 per kW, produce residential electricity of about $0.093 per kWh.

Battelle Columbus Laboratories.–In a similar study, Battelle Columbus Laboratories came up with estimates for the year 2000 of $4.00 to $6.00 per MMBtu for natural gas, $5.00 to $6,50 per MMBtu ($0.70 to $0.90 per gallon) for residential home heating oil, and $1.50 to $2.50 per MMBtu ($30 to $50 per ton) for coal delivered to utilities. " Except for natural gas in Boston, these prices also bracket the estimated oil and natural gas prices in the year 2000 from the 5 *x* ceiling.

Federal Power Commission (FPC).-In a report by the Bureau of Natural Gas of the FPC (now the Federal Energy Regulatory Commission (FE RC)), energy prices delivered to residences of $4.16 per MMBtu for natural gas, $3.58 per MMBtu for fuel oil

[21] *Analysis of the Economic Potential of Solar Therma/ Energy to Provide Industrial Process t/eat,* InterTechnology Corporation, Warrenton, Va , February 1977

[22] *Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat,* Battelle Columbus Laboratories, Columbus, Ohio, January 1977

($0.050 per gallon) and $0.035 per kWh for electricity (all in 1976 dollars) were projected for the year 2000.[23] These are national averages, and no means to allocate them by region was given. It is not likely however, that regional adjustments would bring the prices near the 5 x ceiling in any of the four cities under consideration. These projections assume that all crude oil prices will remain at the present level of imported crude, $2.32 per MM Btu. Any increase in this price will cause a corresponding increase in the other prices.

[23] The Future of Natural Gas" Economic Myths, Regu/a tory Rea lities, Federa l Power Corn m ission, Bureau of Natural Gas, November 1976

Federal Energy Administration (FEA).–A final set of price projections is that developed by FEA (now DOE) in the draft of the 7977 National Energy Outlook.[24] Although only estimated to 1985, they can still be used for comparison to that date. Their results (in 1976 dollars) are $3.72 per MM Btu for fuel oil ($0.52 per gallon), $2.78 per MMBtu for natural gas, and $0.049 per kWh for electricity. These prices are based on imported crude oil prices of $2.25 per MMBtu, and are those delivered to residential customers. In nearly all cases these are close to the 5 x ceiling curve.

[24] 1977 National Energy Outlook, (Draft), Federal Energy Administration, Washington, D C , January 1977, Appendix C, p 19,