A SIMULATED INVESTMENT ANALYSIS FOR A GAS PIPELINE COMPANY

Hal Miller

Colorado Interstate Gas Company

Abstract

The supply and demand schedules for gas pipeline companies are probabilistic in form and dynamistic in nature. These factors, along with the other uncertainties associated with gas supply investment decisions, must be considered in order to properly evaluate decision alternatives. These dynamic, uncertain and interrelated decision elements can be properly evaluated through computer based simulation, where each element not known precisely is considered as a random variate, to be simulated. The manifestation of the resulting simulation model is the expected profit and loss (variance from the perfect decision) of each investment alternative, evaluated over its anticipated life.

INTRODUCTION

The populace of the world appears to have an insatiable desire for energy, for as people become more appreciative of what energy can do for them they utilize ever-increasing quantities of it. Each child demands more energy in his lifetime than did his parents and in this quest for an energy-rich Utopia in which he will be free from limitations prescribed by his physical capabilities mankind is creating an energy explosion that is far more staggering than the infamous population explosion. By the turn of the century, less than thirty years time, the world's population is expected to be almost double what it is now, but world's annual consumption of energy is expected to be almost six times the present consumption level. Energy consumption in the United States is expected to be over three times its present level.[1]

[1]William T. Reid, "The Melchett Lecture, 1969 - The Energy Explosion," Journal of the Institute of Fuel, February, 1970.

The sheer magnitude of the investment necessary to meet this tremendous growth in demand is going to require a great deal of innovation on the part of energy companies in the formulation of investment strategies. It is going to compel managers to become more cognizant of market reaction to higher prices (which are inevitable) and to more effectively evaluate the risks and uncertainties inherent in these types of investments.

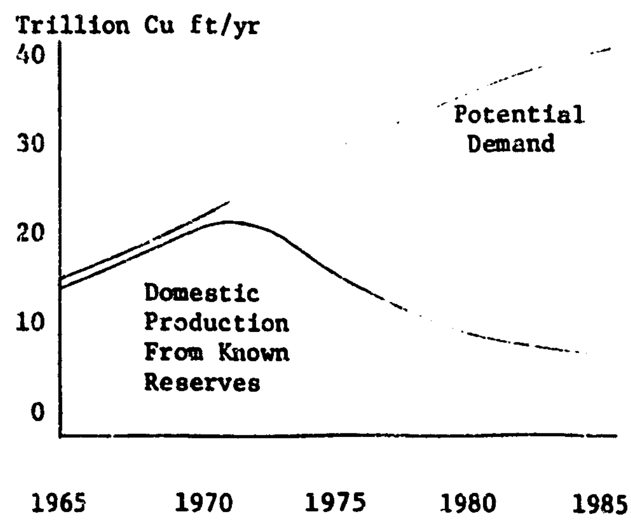
This paper concerns a simulation approach in evaluating energy supply investment strategies. More specifically, it addresses itself to the investment problems currently facing gas pipeline companies.

BACKGROUND

Currently, the natural gas industry is providing about one-third of the energy consumed in the United States. The industry has a current investment in plant and equipment of over $40 billion, or about sixteen percent of the $250 billion currently invested in the U.S. energy industry as a whole.[2] To meet the growing energy demands it has been estimated that $500 billion will be needed to finance investments by energy companies over the next fifteen years.[3] It becomes readily apparent from the graph in Figure 1, which represents an estimation, for the U.S., of the future production capability of the existing gas supply and the potential demand for gas, that the gas industry will probably require a considerable portion of that $500 billion if it is to remain a viable element in the energy industry.

Figure 1

U.S. GAS SUPPLY AND DEMAND



Source: Humble Oil and Refining Company

In the past, gas companies have not been greatly concerned with the uncertainties associated with supply related investments, because most of the risk was carried by gas exploration and production companies and the pipeline company simply made its investment after a gas supply was discovered. Likewise, these companies have not been overly concerned with market reaction

[2]"Statistics of Privately Owned Electric Utilities in the United States," Federal Power Commission, Washington, D.C., December 1971. "1971 Gas Facts," American Gas Association, Arlington, Va., 1971. "Annual Financial Analysis of the Petroleum Industry," The Chase Manhattan Bank, New York, N.Y., August, 1971.

[3]Hollis Dole, Assistant Secretary of Interior, during speech to Financial Analysts Federation, New York, N. Y., May 1972.

to price, because the price of gas has historically been low relative to competing fuels and the increase in price resulting from a particular investment would not have harmed gas' competitive position in the market place. The traditional method used by such a company in formulating supply related investment plans generally assumed that, given no production constraint, the company would continue to maintain its market share. A comparison of the future production capability of the company's present facilities to the demand resulting from the continued market share would provide a forecast of the company's future supply- demand gap, and a determination would, then, be made of the investment necessary to fill this gap.

Because pipeline companies are most often regulated by some form of governmental agency, they are protected (by either dictate or economics) from invasion by another gas company into their geographic market area. Also, their rates are set to provide for a specific return on investment. Considering only this, it appears that a gas company would have few reservations about making whatever investment deemed necessary to fill the gap mentioned above.

This statement may have been appropriate a few years ago, but the environment acting on this type of decision has become so complex as to completely negate its validity at the present time. The statement neglects two fundamental points. One is that a pipeline company's market, although protected from another gas company, is not protected from invasion from another energy form. Another is that, if the investment were not a prudent one, the regulatory agencies would not allow full return on that investment. These two factors are interrelated, for if a company made an investment to fill the projected supply-demand gap and it turned out that gap had narrowed because of a negative shift in the market share, the company would find that it had over-invested. The consequences, in theory at least, would be a dilution in the company's overall rate of return.

DISCUSSION

Uncertainty is pervasive in the environment of this decision, for investment decisions of a pipeline company are, by nature, very long in term. The ramifications of such a decision can hardly be known precisely. Also, the energy situation is changing very rapidly from both technological and consumption standpoints and this dynamism further augments the uncertainty.

In the analytical approach to this problem the first place uncertainty arises is in the market place. Demand cannot be estimated on a deterministic basis and probabilistic confidence limits should be used to envelop any demand forecast. Directly related to these market uncertainties is the financial risk that the regulators will not allow a return on an "over-investment." The financial risks, however, are not limited to that of the market place or the rate makers. For example, the new supply environment requires that a portion of a pipeline company's future capital expenditures be channeled into exploration of natural gas (traditionally a high risk investment). In addition, a large part of a typical company's future expenditures will be for nonconventional gas supplies. This includes such things as nuclear stimulated gas reserves and coal or oil gasification plants to produce synthetic gas. The political problems associated with coal and oil gasification present risks for these types of investments.

The manifestation of all of these interrelating elements is that a gas pipeline company has dynamic probabilistic supply and demand schedules and in order to properly evaluate supply related investment alternatives these dynamic probabilities have to be considered.

Theoretical Constructs

The basic decision variable is, of course, investment. It is a discrete variable for there is a limited number of investment alternatives available. Two other variables are considered to be directly dependent upon the investment variable -- supply and price. Supply could be said to be functionally related to the investment parameter through the following expression:

$$(1)\quad S_t = S_o + K_1\ (I)$$

where:

S_t = supply for some period (t)

S_o = supply for some period (t) if no additional investment were made

K_1 = constant, dependent upon investment alternative and vary overtime

I = additional investment

Because of the regulated nature of the company with its rates based upon return on investment, price could be said to be functionally related to the investment parameter through the following expression:

$$(2)\quad P_t = \begin{cases} (I_o + I)\ K_2/S_t\ , & S_t \leq D_t \\ (I_o + I)\ K_3/D_t\ , & S_t > D_t \end{cases}$$

where:

P_t = price per unit volume for some period (t)

I_o = initial investment

K_2, K_3 = constants which reflect rate of return and cost of service

D_t = demand for some period (t)

S_t = supply for some period (t)

The demand (D_t) is functionally related to price, which is, in turn, related to investment, as indicated in expression (2). The demand variable can be shown to be functionally related to the other variables as follows:

$$(3)\quad D_t = \begin{cases} S_t - K_4(P_t - P_z) & , P_t > P_z \\ S_t & , P_t = P_z \\ S_t - K_5(P_t - P_z) & , P_t < P_z \end{cases}$$

where:

D_t, S_t and P_t are as before

K_4, K_5 = constants reflecting elasticity of demand

P_z = optimum price where supply and demand are at the equilibrium point on the supply-demand schedule

The prime objective of management in selecting specific investment alternatives is, of course, to maximize profits. It can be intuitively shown that profit, in this instance, is maximized when supply is precisely equal to demand. When supply is less than demand there exists an opportunity loss, for the firm is not realizing the sales volume and the subsequent profit, in the form of return on investment, that it could be realizing. When supply exceeds demand, however, the firm has apparently drifted, in theory at least, into the situation where it has made "imprudent" investments and the regulatory agency will not allow the firm to earn on that "unnecessary" investment. Thus, a real loss occurs, which I term a risk loss. Loss, then, is variance from the perfect decision - when supply and demand are equal. In analyzing an investment alternative both profit and loss have to be considered. The goal would then be to select the alternative that optimizes the combination of expected profits and expected losses.

The profit level of investment alternatives for a pipeline company is the resultant return on investment. An indication of the loss level can be determined through the following function:

$$(4) \quad L = \begin{cases} (S_t - D_t)\ K_6, & P_t > P_z \\ 0, & P_t = P_z \\ (S_t - D_t)\ K_7, & P_t < P_z \end{cases}$$

where:

S_t, D_t, P_t, and P_z are as before

K_6, K_7 = constants reflecting unit losses

The expected loss for any particular time (t) can be determined, for each investment alternative, as follows:

$$(5) \quad EL_t = \int\int_{-\infty}^{+\infty} L \cdot f(S_t) \cdot f(D_t) \cdot dS_t dD_t$$

A present value determination of the expected loss of an alternative over the life of the investment can be conducted as follows:

$$(6) \quad EL = \sum_{t=1}^{n} \left[EL_t \left(\frac{1}{1+i} \right)^t \right]$$

where:

EL_t is as before

i = annual capital discount factor

n = life of the investment in years

The integral in expression (5) can be evaluated by Monte Carlo methods using a normal random number generator on the distributions of supply and demand.

Because of the real-world dynamism and uncertainty, the model developed in this paper is stochastic in nature and uses simulation techniques to evaluate the system's stochastic properties. The basis for the simulation is that each relevant variable that is being estimated, or for some other reason is not known precisely, is considered to be a random variate. A known, or assumed, probability density function is applied to each of these variables to "simulate" its degree of unknownness (for want of a better word). The model enables the user to utilize both subjectively defined density functions and quantitatively determined functions.

As an example of a subjective function, suppose the value of a particular parameter is estimated to be 100 units and the estimator feels that there is a 50-50 chance the real value will fall within ± 10 units of that estimate (and the associated density function is assumed to be normal). Since the 90-110 unit interval contains half the total probability, the probability of the true value lying above 110 is 25 percent. This means that $\sigma(\mu)$ must have a value such that:

$$(7) \quad P(\mu > 110) = P\left[\mu > \frac{110-100}{\sigma(\mu)}\right] = P\,\frac{10}{\sigma(\mu)} = .25$$

From the normal tables,

$$\frac{10}{\sigma(\mu)} = .67$$

$$\sigma(\mu) = 15 \text{ units}$$

The $\sigma(\mu)$ is the standard error (or deviation) and μ is a random variable analogous to the true value of the parameter. The density function for this particular variable would be normal with a mean of 100 units and a standard deviation of 15 units.

The quantitatively determined density functions are simply determined analytically or empirically. An example of a quantitatively determined density function is that of regression equation where the confidence interval is based on the following:

$$(8) \quad \mathrm{Var}(Y) = \hat{\sigma}^2\left[1 + \frac{1}{n} + \frac{(x - \bar{x})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right]$$

where:

$\hat{\sigma}$ = variance of the regression or the estimate of the variance of the errors of observation

n = number of observations

x = independent variable

x_i = observation of independent variable

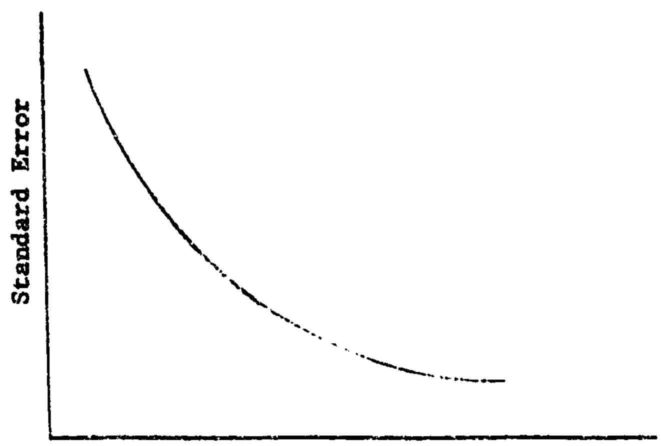
$\bar{x}$ = mean of independent variable

Var Y = variance of the estimated dependent variable

The density function in this case would be normal with the mean being the estimate of Y from the regression equation and the standard deviation being the square root of Var(Y).

In the model, each random variable is simulated through random number generation with each variable's simulation being conducted independently (for those variables whose density functions are independent of each other). The optimum number of simulations has been determined through analysis of the standard error of the estimate. The graph in Figure 2 shows the typical relationship between the error and the number of simulations.

Figure 2



As the number of simulations increases the standard error more closely approximates the theoretical value. In most cases 100 simulations proved to be adequate, for any additional incremental shift in standard error could not justify the incremental cost of additional simulation.

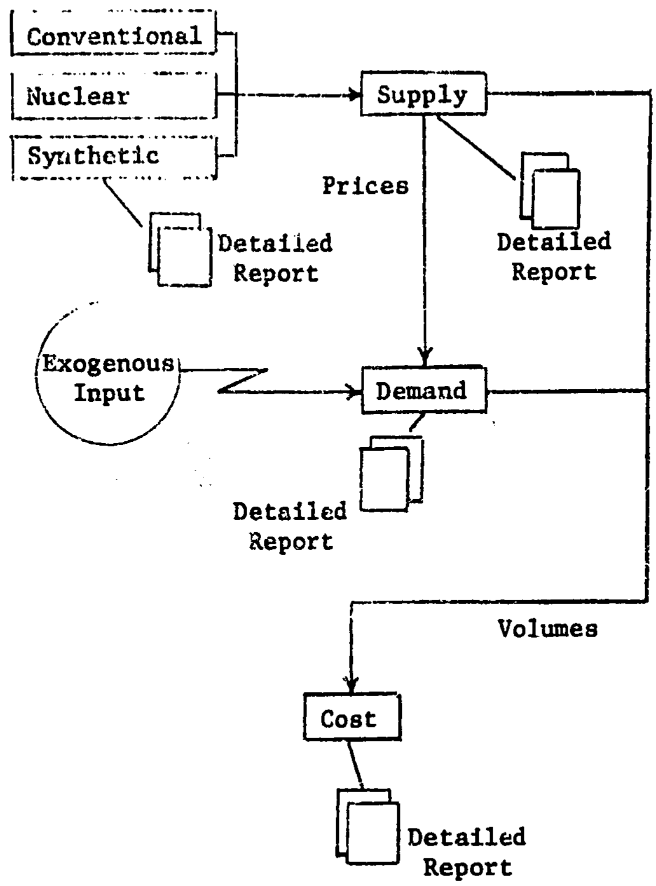
General Model Description

A sub-model has been developed for each major decision variable, such as supply, demand, or expected profit and loss. The desired output from each model is an aggregate forecast of the particular decision element and its standard error of estimate for each forecast period.

The general logic for the system of sub-models is shown on the diagram in Figure 3. Each box can be considered as being a sub-model. There are three sources of data for the supply model -- the conventional, nuclear and synthetic sub-models. The output of these models is the estimated supply parameters resulting from conventional natural gas production, nuclear stimulated production and coal or oil gasification, respectively. Each of these outputs contains volumetric forecasts, price forecasts, and estimated volume and price variances for each year of the forecast horizon. One of the three supply sub-models is computerized and that is the synthetic model, which contains a simulation of coal hydrogenation variables. The other two models are based on analytic estimation of the parameters. The simulated price and its deviation from the supply model is used as input for the demand model, which uses other exogenous factors to simulate demand. The simulated demand and its deviation, and the simulated supply and its deviation are used as input for the cost model which, when provided the investment dollars, return criteria and other relevant data, simulates income and opportunity cost for each year. The present value of those future incomes and opportunity costs are also calculated by this sub-model.[4] The computerized models were developed over a period of time and both FORTRAN and Time Sharing BASIC languages were used.

[4]A more detailed discussion of each of the sub-models is exhibited in the Appendix.

Figure 3



RESULTS

This model could be used for various types of comparative investment analyses for a pipeline company, ranging from analysis of a detailed and intricate investment strategy to that of comparing the ramifications of two simple investment alternatives. To illustrate the use of the model three hypothetical investment strategies for a typical pipeline company have been analyzed. The only investment decision that varies from one strategy to the next in this example concerns the type of coal hydrogenation process to be employed. All other decision elements are assumed to remain constant.

At the present time a dozen hydrogenation processes are being promoted by various manufacturing and engineering firms. These processes are all at various stages of development, but none have been used commercially. Each process is unique from a financial viewpoint. For instance, some processes require a lower level of investment than others but, consequently, have higher operating costs. Also, the level of risk is different for each process so that one process might result in a gas price considerably below the others, but it has a smaller chance of becoming a commercial reality in time to do any good.

In view of all these uncertainties and variabilities, the most logical thing to do would be to wait for the processes to become commercially available before making the selection. That would take the guess work out of the decision, but that is not feasible, for the promoters of these processes are demanding development capital and, in order to receive the benefit of early use of one of these plants, commitments have to be made now. These commitments are extremely large, for the cost of building one of these plants is on the order of $250-$300 million.

The three types of processes presented in this paper are termed A, B and C. Process A is closest to being commercially available in that a portion of the process has been in use for quite some time. There is the smallest risk associated with this process, but is has a low efficiency so its estimated gas price will be greater than the others. It is anticipated that this process will be the first to be available for use - possibly by 1977. It is estimated that process B will result in the cheapest gas price and will require less investment than the others. At the same time, however, it will probably have higher operating costs. It is estimated that this process could be used by late 1978. The program to develop this process is of a crash type. Consequently, the risks associated with it are greater than for the others. Process C won't be available until about 1982 and its estimated resultant price will be somewhere between the other two processes. This process is being developed over a longer period of time so the risks associated with it are less than with process B.

The first illustrative hypothetical alternative is that of investing in one plant of each of the processes and bringing them on stream at their earliest possible dates. The A plant is to be on stream in 1977, the B plant in 1978 and the C plant in 1982. The second investment alternative is that of investing in one A plant and two B plants. The A plant is to be on stream in 1977 and the two B plants in 1982. The third alternative is to invest in a B plant to be on stream in 1978, and a C plant to be on stream in 1982.

The results of the investment alternatives are shown on Table 1 through Table 3.[5] For the first alternative, the present value of the income (return) and opportunity costs are $451 million and $81 million, respectively. For the second alternative, those values are $411 million and $76 million, respectively, and for the third alternative, they are $414 million and $49 million, respectively. Alternative one maximizes return and alternative three minimizes the opportunity costs. The annual income or return figures, shown on the tables should also be of interest for these values can be used to approximate the net investment of an alternative for any particular point in time. For instance, the 1991 net investment for the three alternative strategies is about $1,050 million, $850 million, and $950 million, respectively.[6]

[5] All figures are hypothetical

[6] These values are calculated by dividing the annual income figures by 8-1/2 percent, which is the assumed hypothetical rate of return.

Table 1
INVESTMENT ALTERNATIVE I

Year	Supply BCF	Supply Std Dev	Demand BCF	Demand Std Dev	Income $Million	Cost $Million
1972	443	17	426	13	17.21	0.71
1973	463	23	426	16	17.95	1.73
1974	476	27	448	17	19.75	1.25
1975	494	32	473	17	21.74	0.93
1976	511	37	476	20	24.64	1.56
1977	556	42	467	25	35.00	6.78
1978	586	48	470	25	42.98	10.64
1979	550	53	431	24	42.69	11.28
1980	567	60	409	22	42.33	16.42
1981	535	67	485	26	52.07	4.59
1982	584	73	447	29	62.99	18.03
1983	617	81	437	24	73.75	29.80
1984	590	90	458	20	79.60	22.93
1985	580	100	447	23	80.41	21.74
1986	562	112	472	26	86.00	13.55
1987	543	122	517	24	91.60	7.08
1988	527	134	574	33	100.69	4.16
1989	508	144	493	39	89.88	8.53
1990	505	158	481	29	87.90	9.64
1991	517	171	490	40	89.59	10.70

PRESENT VALUE INCOME	PRESENT VALUE COST
$ 451.33	$ 81.32

Table 2
INVESTMENT ALTERNATIVE II

Year	Supply BCF	Supply Std Dev	Demand BCF	Demand Std Dev	Income $Million	Cost $Million
1972	443	17	426	13	17.21	0.71
1973	463	23	426	16	17.95	1.73
1974	476	27	448	17	19.75	1.25
1975	494	32	473	17	21.74	0.93
1976	511	37	476	20	24.64	1.56
1977	556	42	466	25	35.00	6.78
1978	586	48	470	25	42.98	10.64
1979	550	53	431	24	42.69	11.28
1980	567	60	409	22	42.36	16.42
1981	535	67	485	26	52.07	4.59
1982	634	75	444	30	59.15	24.72
1983	617	85	441	27	60.73	23.39
1984	599	96	471	25	65.45	16.57
1985	580	107	451	29	65.88	16.68
1986	562	120	476	32	70.00	10.52
1987	543	131	529	29	74.86	5.40
1988	527	142	601	42	82.60	4.80
1989	508	154	499	49	72.22	7.58
1990	505	167	485	34	87.38	9.92
1991	517	181	493	48	72.25	9.24

PRESENT VALUE INCOME	PRESENT VALUE COST
$ [illegible]11.64	$ 75.82

Table 3
INVESTMENT ALTERNATIVE III

Year	Supply BCF	Supply Std Dev	Demand BCF	Demand Std Dev	Income $Million	Cost $Million
1972	443	17	426	13	17.21	0.71
1973	463	23	426	16	17.95	1.73
1974	476	27	448	17	19.75	1.25
1975	494	32	473	17	21.74	0.93
1976	511	37	476	20	24.64	1.56
1977	526	42	475	24	26.85	2.98
1978	566	48	484	25	35.96	5.35
1979	520	53	449	25	36.22	5.25
1980	537	60	431	24	37.08	8.77
1981	505	67	511	30	43.81	1.22
1982	564	73	469	31	58.25	9.24
1983	587	81	461	29	71.43	18.71
1984	569	89	481	25	75.93	12.22
1985	560	100	457	27	75.03	13.09
1986	532	112	479	29	78.72	8.15
1987	513	122	527	26	83.24	4.46
1988	497	133	590	37	89.98	6.27
1989	478	144	490	43	80.41	7.21
1990	505	158	485	31	88.41	9.35
1991	487	171	495	43	80.61	8.45

PRESENT VALUE INCOME	PRESENT VALUE COST
$ 414.21	$ 49.36

The objective has to include the present values of both income and opportunity costs. The income figure represents the expected payoff or monetary value of the particular strategy employed and the cost figure represents the risk of monetary loss that could occur through employment of that strategy. Members of Management who are responsible for selecting the investment strategy have to weigh the profit potential against the risk. All the model can do is provide data for consideration by Management. The important ingredient in this decision process which now becomes prevalent is the relative degree of risk aversion of the members of Management. This factor is combined with the simulation results to form the utility of each investment alternative and it is hoped that through this process of combining the quantitative and qualitative elements of the decision-making process, the result is the best solution to the problem.

REFERENCES

American Gas Association, "1971 Gas Facts," Arlington, Va., 1971

Bierman, Harold, Jr., Bonini, Charles P., et al., "Quantitative Analysis for Business Decisions," Homewood, Illinois, Richard D. Irwin, Inc., 1965

Chase Manhattan Bank, "Annual Financial Analysis of the Petroleum Industry," New York, New York, August, 1971.

Federal Power Commission, "Statistics of Privately Owned Electric Utilities in the United States," Washington, D. C., December, 1971.

Frederick, Donald G., "Industrial Pricing Decision Using Bayesian Multivariate Analysis," Journal of Marketing Research, May, 1971.

Reid, William T., "The Melchett Lecture, 1969 - The Energy Explosion," Journal of the Institute of Fuel, February, 1970.

Schlaifer, Robert, "Analysis of Decisions Under Uncertainty," New York, New York, McGraw-Hill, 1967.

Schlaifer, Robert, "Probability and Statistics for Business Decisions," McGraw-Hill, New York, New York, 1959.

APPENDIX

Conventional Supply - An estimation of a typical company's supply of conventional natural gas can be determined analytically through statistical analysis with the use of Gompertz curvefitting techniques. Using this technique, the density function of the conventional natural gas supply is determined through the regression confidence interval calculation exhibited in the DISCUSSION portion of the paper. The density function can be revised by the company's supply personnel to reflect their subjective estimation of the potential supply to be discovered and their evaluation of the company's ability to compete for that supply. The result of this analysis is estimated supply, prices, return and respective variances for each year in the forecast. The prices are the wholesale prices necessary to provide a specified return on the investment required to market the gas. The return indicates that proportion of the price which is necessary to provide the required return.

Nuclear Supply - The supply, prices, return, and respective variances for nuclear stimulated gas production are estimated on a subjective basis with consideration being given to various political and technological problems which might be encountered. The prices and return are as discussed in the Conventional Supply section, above. The subjective density function associated with this "sub-model" is defined according to the procedure outline in the paper.

Coal Supply - Prices, return, and their respective variances for coal hydrogenated gas is determined through a computerized simulation model. This model considers the level of investment required for a particular hydrogenation process and calculates a gas price that would be required to earn a specified rate of return.[1] The variables that are being estimated (and therefore treated as random variables) are:

[1] depreciation
[2] interest rates
[3] debt/equity ratio
[4] tax rates
[5] labor costs
[6] material costs
[7] equity return
[8] coal costs

The output of this model includes a detailed breakdown of various factors relevant to an economic analysis of a hydrogenation plant, a sample of which is shown in Table 1. The general logic of the simulation aspect of this model is similar to that of the demand model which is discussed later.

The supply of hydrogenated gas and its related variance is subjectively estimated, with consideration being given to the reliability of the technology involved and the degree to which that technology has been proved through actual application. One of the biggest factors in this consideration is the variability associated with the estimation of the earliest "on stream" date for one of these plants.

TABLE 1
COST OF SERVICE (MANUFACTURED COST OF GAS)
(AMOUNTS IN THOUSANDS OF DOLLARS)

Particulars	1973
Total Facilities Investment	$ 76,898
Working Capital	5,383
Total Capital Investment	$ 82,281
Cost of Service	
Operation and Maintenance	
Direct Labor	1,669
Maintenance	2,568
Supplies	385
Administrative and General	
Supervision	167
Payroll	184
General	2,395
Insurance	369
Coal Cost	17,082
Water Cost	147
Other Direct Materials	811
Depreciation	3,845
Return	7,558
Federal Income Tax	4,001
State Income Tax	288
Other Local Tax	1,153
Subtotal	$ 42,622
Contingencies	767
Subtotal	$ 43,389
Byproduct Credit (Char, Sulfur, Power)	11,454
Total Cost of Service/Year	$ 31,935
Cost of Gas Determination	
Annual Gas Production, MMBTU	51,903
Basic Gas Prices, Cents/MMBTU	61.53
Royalty Cost, Cents/MMBTU	2.50
Final Gas Price, Cents/MMBTU	64.03
Mean Value of Basic Gas Price	61.50
Standard Deviation of Gas Price	2.20

[1] It might be well to point out that the same type of simulation model could be developed for the conventional and nuclear supply cases. It is felt at this time, however, that the subjective aspects of these analyses negate the need for such sophistication.

Total Supply Model - The total supply schedule is estimated through a computerized simulation model which takes, as input, all of the supply, price and variance estimates of the previously mentioned sub-models and independently generates random numbers representing each of these variables. Since retail prices are required to determine market demand and the prices determined thus far are wholesale prices, an estimation is needed for the retail mark-up in each consumption category. This in itself is a considerable task for utility pricing strategies vary substantially from one sales category to another. In addition, an estimation is needed of the retailers' revenue requirements. To account for the uncertainties involved in this procedure, these mark-ups are also simulated. The results from this model are used as input for two other models. The retail prices for each consumption category and their respective standard errors are transmitted to the demand model and the aggregate total supply and its standard error are transmitted to the cost model. An example of the information generated by this model is shown in Table 2.

Demand Model - The total demand schedule is estimated through a computerized econometric and simulation model which takes, as input, the retail prices of each sales category generated in the total supply model discussed above and their respective standard errors. Other exogenous factors used in this model include population, per capita income, competing energy prices and household formations. As in all the models discussed thus far, each estimated variable is treated as a random variable and is simulated through random number generation. These estimated variables, which are treated as random statistics, include both exogenous and endogenous variables. In addition, a confidence interval has been established for each of the fifteen regression equations in the model. The regression equations represent market share elasticity or sensitivity to price, income, or various other factors. These interval calculations have been based on the equation exhibited in the Theoretical Constructs section of the paper. Random numbers analogous to each dependent variable are generated, based on the confidence intervals. These random numbers can be thought of as simulating the degree to which the regression equation does not statistically explain the behavior of that dependent variable.

A flow diagram of the basic logic of this model is shown on Figure 1. The output of the model includes a breakdown of various factors relevant to a market analysis, an example of which is shown in Table 3. The total demand and its standard error are transmitted to the cost model for further use.

Cost Model - The term cost model is somewhat misleading for the model's function is to summarize the results of all the previous models and simulate the financial ramifications of the entire process. The model takes, as input, the total

TABLE 2

Year	SUPPLY BCF	SUPPLY STD DEV	CITY GATE PRICE	CITY GATE STD DEV	RESIDENTIAL PRICE	RESIDENTIAL STD DEV	COMMERCIAL PRICE	COMMERCIAL STD DEV	INDUSTRIAL PRICE	INDUSTRIAL STD DEV	ELECTRIC GEN PRICE	ELECTRIC GEN STD DEV
1972	443	17	0.27	0.03	0.73	0.06	0.61	0.05	0.30	0.03	0.30	0.03
1973	463	23	0.28	0.05	0.76	0.08	0.64	0.07	0.31	0.05	0.31	0.05
1974	476	27	0.29	0.07	0.80	0.11	0.67	0.09	0.33	0.07	0.36	0.07
1975	494	32	0.31	0.08	0.83	0.13	0.69	0.11	0.34	0.08	0.34	0.08
1976	511	37	0.34	0.09	0.89	0.14	0.75	0.13	0.38	0.09	0.38	0.09
1977	556	42	0.43	0.10	1.00	0.16	0.85	0.14	0.47	0.10	0.47	0.11
1978	586	48	0.52	0.12	1.11	0.19	0.95	0.16	0.56	0.12	0.56	0.12
1979	580	53	0.56	0.13	1.17	0.20	1.01	0.18	0.60	0.13	0.60	0.13
1980	567	60	0.60	0.15	1.24	0.22	1.07	0.19	0.64	0.15	0.64	0.15
1981	536	67	0.64	0.16	1.30	0.24	1.13	0.21	0.68	0.16	0.68	0.16
1982	584	73	0.74	0.18	1.43	0.26	1.25	0.23	0.78	0.18	0.78	0.18
1983	617	81	0.82	0.20	1.54	0.28	1.35	0.25	0.87	0.20	0.87	0.20
1984	590	90	0.85	0.21	1.60	0.31	1.41	0.27	0.90	0.21	0.90	0.21
1985	500	100	0.86	0.23	1.66	0.35	1.46	0.29	0.93	0.23	0.93	0.23
1986	562	112	0.91	0.26	1.72	0.35	1.51	0.31	0.96	0.26	0.96	0.26
1987	543	122	0.95	0.28	1.79	0.38	1.57	0.34	1.01	0.28	1.01	0.28
1988	527	136	0.98	0.31	1.85	0.40	1.63	0.36	1.04	0.31	1.04	0.31
1989	508	147	1.02	0.35	1.93	0.44	1.69	0.40	1.08	0.35	1.06	0.35
1990	505	158	1.04	0.38	1.98	0.48	1.74	0.43	1.10	0.38	1.10	0.38
1991	517	171	1.05	0.42	2.03	0.51	1.78	0.47	1.12	0.42	1.12	0.42

supply estimate and its standard error, the total demand estimate and its standard error, and the various prices, returns and their respective standard errors, and simulates the resultant income and opportunity cost. Income, in this instance, is before taxes and financial costs.[2] Opportunity costs are basically measures of variance from the perfect decision and, as mentioned before, arise in two instances - when demand exceeds supply, in which case profit opportunities are not fully utilized, and when supply exceeds demand, in which case an over-investment has been made and the utility regulators will disallow a return on that "imprudent" investment. These income and opportunity cost estimates for each year of the forecast are discounted to the present to arrive at a present value figure so that comparative analyses can be conducted for the various investment alternatives. The general logic in this model is exhibited on Figure 2 and a sample output is exhibited as Tables 1-3 in the Results section of the paper.

[2]This is the manner in which return on investment is calculated for a utility.

Figure 1

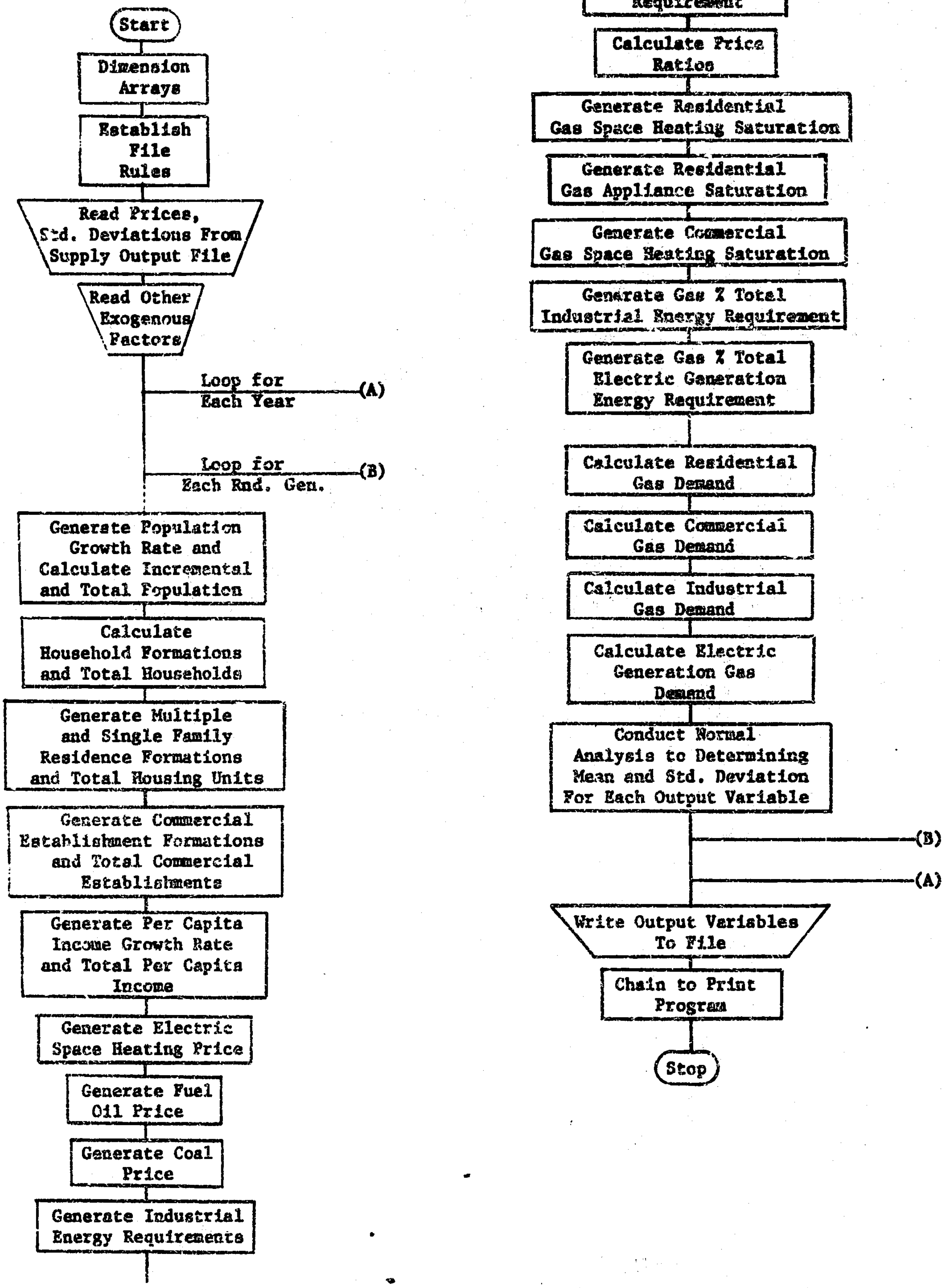

Start
Dimension Arrays
Establish File Rules
Read Prices, Std. Deviations From Supply Output File
Read Other Exogenous Factors
Loop for Each Year
(A)
Loop for Each Rnd. Gen.
(B)
Generate Population Growth Rate and Calculate Incremental and Total Population
Calculate Household Formations and Total Households
Generate Multiple and Single Family Residence Formations and Total Housing Units
Generate Commercial Establishment Formations and Total Commercial Establishments
Generate Per Capita Income Growth Rate and Total Per Capita Income
Generate Electric Space Heating Price
Generate Fuel Oil Price
Generate Coal Price
Generate Industrial Energy Requirements
Generate Electric Generation Energy Requirement
Calculate Price Ratios
Generate Residential Gas Space Heating Saturation
Generate Residential Gas Appliance Saturation
Generate Commercial Gas Space Heating Saturation
Generate Gas % Total Industrial Energy Requirement
Generate Gas % Total Electric Generation Energy Requirement
Calculate Residential Gas Demand
Calculate Commercial Gas Demand
Calculate Industrial Gas Demand
Calculate Electric Generation Gas Demand
Conduct Normal Analysis to Determining Mean and Std. Deviation For Each Output Variable
(B)
(A)
Write Output Variables To File
Chain to Print Program
Stop

TABLE 3

NATURAL GAS MARKETS
TYPICAL GAS COMPANY

1972

Population	2,285,370
Number Households	724,128
Single Residences	543,320
Commercial Establishments	71,298
Per Capita Income	$ 3,578.69

Gas Price	Per MMBtu
Residential	$ .735
Commercial	.615
Industrial	.301
Electric Generation	.301
Electric Price	4.903
Residential Fuel Oil Price	1.079
Commercial Fuel Oil Price	1.079
Industrial Fuel Oil Price	.549
Electric Generation Fuel Oil Price. .	.457
Industrial Coal Price	.421
Electric Generation Coal Price . . .	.312

Residential Saturations	
Central Heating	95.0 %
Ranges	38.6 %
Water Heaters	90.0 %
Clothes Dryers	11.6 %
Commercial Saturation	95.0 %
Industrial Percentage	64.0 %
Electric Generation Percentage . . .	46.1 %

GAS CONSUMPTION REQUIREMENTS

	MMCF	STD. DEV.
Residential	80,378.0	1,085.0
Commercial	50,266.4	2,230.2
Industrial	86,732.5	6,748.0
Electric Generation . .	52,324.1	8,060.8
Total	269,701.0	12,484.9
Other Sales	134,250.0	-
Lost & Unaccounted For	22,217.3	686.7
Total Requirements	426,168.0	13,171.5

Figure 2