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16 ANALYZING ALASKAN GAS DISTRIBUTION OPTIONS

Harvey J. Greenberg*

This paper reports the use of the Project Independence Evaluation System (PIES) to analyze U.S. options to distribute natural gas from the Alaskan North Slope. Scenario descriptions include reasons for the particular choices and how the analysis has affected the policy debates.

16.1 INTRODUCTION

For several years the United States has considered when and how to bring natural gas from the North Slope of Alaska to the lower forty-eight states. In 1976 the Federal Power Commission (FPC) asked the Federal Energy Administration (FEA) to help evaluate three pipeline proposals: Arctic, El Paso, and Alcan. John Adger was FEA's responsible analyst, and he requested the use of the Project Independence Evaluation System (PIES), which was under the general direction of David Nissen. My division, which

*The results described here comprise the labors of many people. The modeling system used (PIES) was built initially under the direction of William Hogan. The use of the model for this analysis was conducted by Richard Thrasher. Thanks are also due to Bill Ziemba for his help in editing this paper.

managed PIES, entered the project, and I assigned Richard Thrasher to be the team's PIES expert.

In this paper I describe how PIES was used, including scenario specifications and associated analyses. An overview of PIES is given in section 16.2. The reader may wish to consult FEA (1976) for a comprehensive description of PIES and Thrasher (1977) for details of this study.

An important limitation of PIES is its inability to distinguish usefully the three proposals, due to its level of aggregation. This was apparent in the FPC's (1977) report, where results from PIES were quoted.

The question PIES was able to address is: "What is the marketability of Alaskan gas?" This has many facets: When? At what price? What does it displace? Further, the study must consider uncertainties in at least three categories: (1) states of *nature,* such as the extent of the U.S. resource base; (2) states of *economy,* such as industrial growth; and (3) states of *policy,* such a natural gas pricing.

Of particular importance are the estimated impacts of the Administration's proposed National Energy Plan. This not only contains a major change in gas pricing, but also it contains a coal conversion program, designed to reduce the natural gas market, where coal could be substituted, such as fuel for large combustors.

A brief overview of PIES is presented in section 16.2. The scenario specification process is then reported in section 16.3. The orientation is to convey the chronological interrelations among modeling, analysis, policy formation and decision making. For technical presentation of the study, along with quantitative results and inferred conclusions, see Thrasher (1977).

16.2. OVERVIEW OF PIES

The underlying modeling philosophy of PIES is that energy production and consumption are determined by economic incentives; that is, the amount of supply a producer will sell is a function of price, as is the amount a consumer will buy. Federal/state policies and regulations influence the energy market, but they do not determine final prices and quantities. PIES takes into consideration several key regulatory structures, such as price controls of utilities.

Figure 16-1 illustrates generic supply and demand functions in PIES. As the price is increased, there will be more supplied and less demanded. The equilibrium price, denoted P^* in Figure 16-1, is called the "clearing price."

From the simple unidimensional case of Figure 16-1 to the more general situation of multiproduct, multiregion, multieconomic sector is a big step.

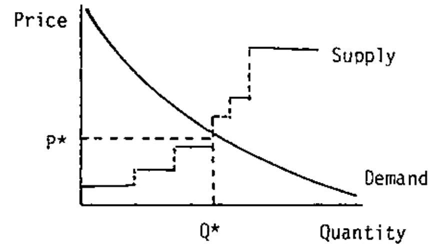

FIGURE 16-1. Generic supply and demand functions yielding equilibrium price (P^*) and quantity (Q^*)

In fact, the methodology of PIES is not on firm mathematical ground at present, and its eclectic form introduced a new approach to economic modeling for policy analysis. The salient feature of the PIES methodology is that it incorporates many modeling techniques into one integrated system. It uses the following four approaches: (1) econometrics to related demands to prices; (2) linear programming to represent physical flows, conversion processes, and supply competition; (3) simulation to equilibrate supply and demand in the presence of regulatory structures; and (4) judgmental modeling to represent supplies of some of the primary resources.

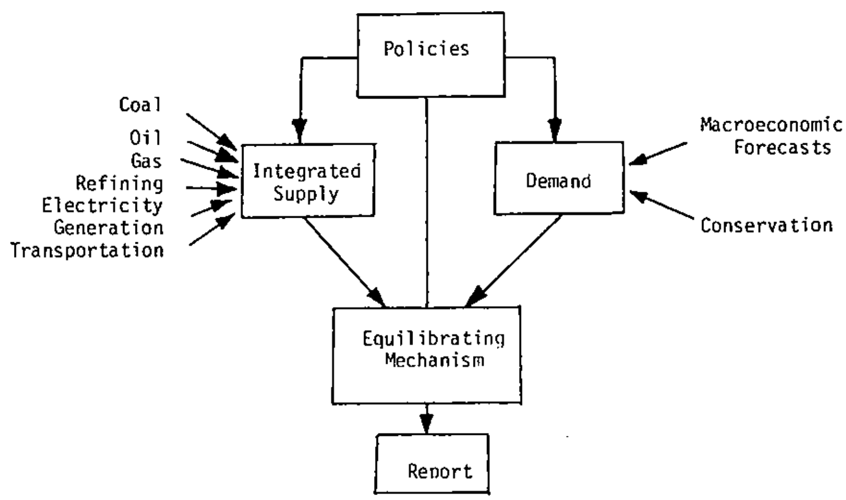

FIGURE 16-2. PIES modeling framework

16.2.1 The Supply Side

The energy supply system is modularized into the following components

- Production
  - coal
  - oil
  - natural gas
  - uranium
  - new technologies, e.g., geothermal, solar, and hydroelectric power
- Conversion
  - oil refining
  - electricity generation
- Distribution/transportation.

In addition, a companion model, the International Energy Evaluation System (IEES), provides data on crude oil and petroleum product imports.

In general, supply of primary energy sources in PIES is developed by analytical models which respond to price levels and develop resources dynamically, explicitly accounting for the resource base. The supplies are characterized by incremental quantities available at some minimum acceptable price which includes production costs as well as a "fair" rate of return on capital investment. The lowest steps of a supply function represent production levels which require little or no new capital investment. Higher priced steps correspond, for example, to production from new coal mines or oil fields.

The regional structure in PIES is consistent with definitions used by primary data sources, such as the Bureau of Mines or the National Petroleum Council.

The coal supply model recognizes that coal is produced from either existing or new mines. For each coal type and in each region the price required to induce production from existing mines is based only on variable costs. The price must be high enough to provide a fair rate of return on capital to induce production from new mines. Several coal types are distinguished by their heat contents, measured in Btu's, and sulfur levels. The coal model includes the distinction between surface and deep mined coal with associated reclamation costs, depending upon assumed policies for the particular scenario. Since both production and transportation costs are based on tonnage, the energy from low Btu coal is proportionately more expensive than energy from higher Btu coal. Environmental regulations require sulfur removal from coal types having significant sulfur content, making the low sulfur coals more valuable.

Projections of domestic oil and gas supplies, as functions of prices, are based upon engineering and economic factors which affect production decisions. Exploration and development activities leading to new supplies are assumed to be justified on the basis of a discounted cash flow analysis and estimates of reserves. Unlike coal, oil and gas production both involve a mix of co-products, such as associated gas from oil wells or natural gas liquids. Estimates of supplies in unexplored areas, such as North Alaska, are more speculative and rest on expert judgment.

The model maintains a distinction among recovery methods: primary, secondary, and tertiary, with the differing associated costs. The integrating methodology of PIES distinguishes between interstate and intrastate sales of natural gas in order to represent the federally controlled price and distribution of interstate sales.

The key inputs, which may be varied for a particular scenario, are as follows:

resource base	estimates of extent and location
finding rates	rate of new discoveries as a function of drilling
recovery factors	ultimate production of new discoveries for each recovery method
decline rates	rates of production from proven reserves
costs	investment, operation, and maintenance
prices	pattern of market prices over time, affected by world oil prices and federal regulations.

A strong determinant of new supply is the expected future prices of oil and gas. Other variables, of course, can serve to determine future supplies — an example is in the off-shore regions, where production is constrained by federal leasing schedules. The underlying methodology insures the rule that more oil would be produced at higher prices.

Refineries convert crude oils into a multitude of products to be used as fuels and petrochemicals. The primary processes in a refinery are designed to separate, change, or combine the constituents of oil. The refiner may choose a collection of processes from existing or new plants, so as to vary the mix and quality of products produced, with associated costs varying. PIES has an embedded process model to simulate the refiners' decisions in seven regions of the United States.

In order to determine prices and quantities of refined petroleum products as a function of crude oil acquisition costs, PIES employs two methodologies: (1) represents refining processes with associated costs, and (2) maintains price relationships that account for differences not reflected by processing costs.

Refiners have used linear programming for more than twenty-five years to determine optimal product mixes, so it is consistent for PIES to emulate their decision process in a like manner. However, unlike the refiners' models, both quantities and prices are endogenous to PIES, so special activities are present to increase the model's flexibility to reconfigure its slate. These special activities are equivalent to price relations among pairs of products. For example, based upon projected demands and refining costs, it may appear in the model that a heavy oil used in large boilers to generate steam should be priced higher than a lighter oil used to heat homes. This anomoly may come about as a result of perceived market pressure to produce unusually large volumes of the heavy oil, thus reflecting an opportunity cost rather than an out-of-pocket cost. The presence of a price relationship that maintains, for example, heavy oil costs less than light oil, has been included.

The embedded electric utilities dispatching model in PIES is designed to determine the mix of plant types to generate electricity and the associated costs of generation. Since electricity cannot be stored in significant quantity, it is necessary to account for daily and seasonal variation in the demand; this is done by accounting for load as a function of time. Demand for electricity is split into load levels: seasonal peak, daily peak, cycling, and base. Peak loads, such as those occurring on a hot summer afternoon, require the greatest generation capacity. Base load is, essentially, the continual demand that occurs, even through mild weather. Between these extremes is cycling load, connoting a wave of variation.

In general, base load is satisfied by equipment that has low fuel, operation and maintenance costs per unit of electricity generated, such as a boiler burning coal to generate steam or a nuclear plant, whereas the infrequent peak loads are satisfied by equipment having low capital costs, such as diesel oil or natural gas fired turbines. The dispatching of plants depends largely upon fuel costs; acquisition of new plants depends both upon dispatching economics and the capital charges, which are based on discounted cash flows analyses.

The pricing of electricity to consumers is based upon the average, rather than the marginal, cost of generation. This is consistent with regulations that limit utilities' rate of return on investment. This price regulation is implemented in the equilibrating mechanism of PIES when determining consumer prices.

The supply side of PIES is linked together by distribution networks that account for transportation of primary resources to their destination for consumption, either by fulfilling demand or as input to a conversion process, and another collection of networks to account for flow from conversion processes to final consumption.

Coal may be transported by rail or barge; oil and petroleum products may flow by pipeline or tanker; natural gas moves by pipeline. The transportation tariffs depend upon predicted throughput, maintaining rate-of-return controls where appropriate.

16.2.2 The Demand Side

The demand side of PIES is composed of a set of econometrically based regional models. For each of the ten demand regions they provide the final demand for refined petroleum products, natural gas, electricity, and coal as a function of prices. The demand models have four major modules as indicated in Figure 16-3.

Many energy demands can be satisfied by a variety of fuels, and modeling fuel substitution choices in response to relative price changes is the central issue on the demand side of PIES. The demand for a given fuel is assumed to depend on its price, the prices of substitutes, the general level of economic activity, and a time-lag effect depending on the rate of change of demand. In Figure 16-3 the boxes labeled "Total Energy Demand Index" represent economic models forecasting total energy demand in that sector as a function of a fuel price index and levels of macroeconomic variables. The boxes labeled "Specific Fuel Demand Indices" are the economic equations that apportion the total demand to the various fuels consumed in the sector. In the industrial sector, demand for raw materials, such as petrochemicals and coking coal, is accounted for separately.

The structure of the model for the transportation sector is quite different from the other sectors and focuses on road vehicles. This sector, as composed, accounts for about half of the nation's demand for petroleum and over 20 percent of all energy demand. The Automobile Simulation model produces forecasts of vehicle miles, new car purchases, total fleet size, average new car efficiency, and average fleet efficiency. Based on these forecasts, it then produces estimates of the level of gasoline and diesel fuel consumption. Inputs into this simulation are price paths for vehicle fuels and factors used to model laws and policies affecting transportation such as giving greater support to public transit or a tax on "gas guzzling" cars.

As Figure 16-3 portrays, fuel prices and macroeconomic measures are exogenous to the demand model. More specifically the exogenous inputs are: (1) the path of fuel prices by sector from the present until 1990; (2) forecasts of population, income, and industrial activity through 1990; (3) details of conservation programs; and (4) forecasts of solar and geothermal con-

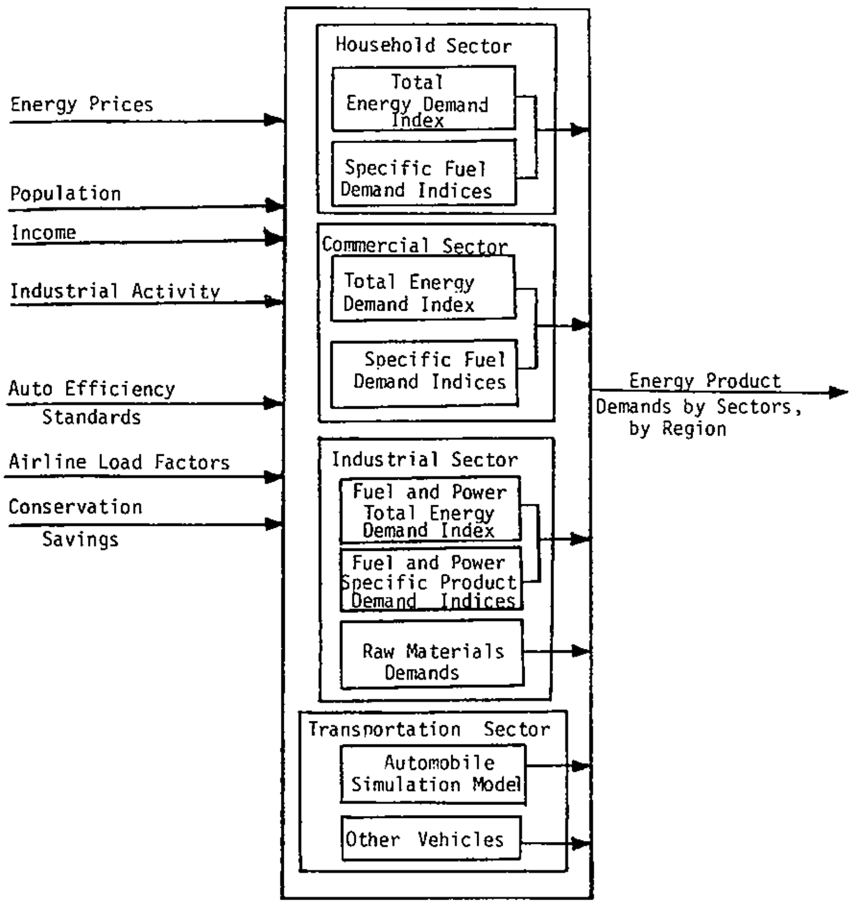

FIGURE 16-3. Demand model: basic configuration

sumption. The form of the inputs combined with lag-term equations results in a demand model containing intertemporal price effects.

The output of the family of demand models is a set of coefficients for a system of log-linear equations used by the equilibrating mechanism to represent the consumers' fuel demand responses to prices. This demand function is an approximation of the family of regional and sectoral demand models in a given, future year. It accounts for both own-price and cross-price elasticity effects in the final demand for energy materials.

16.3 SCENARIO SPECIFICATIONS

To deal with uncertainties in nature, economic activity, and national policy, scenarios were defined to answer the question of marketability *conditionally.* It is not difficult to imagine at least a dozen variables which are candidates for variation in the experimental design. However, when considering the multiplicative growth in the number of interesting cases, it becomes apparent that the team of analysts had to delineate key factors and proceed with frugality in order to maintain manageability. Therefore, the first series of experiments, performed for the early FPC study, considered only two variables: natural gas pricing policy and wellhead price of Alaskan gas. Table 16-1 shows the thirty-nine experiments that account for the effects of pipeline proposals by 1985 and 1990, and the case of no entrance of North Slope gas for 1980, 1985 and 1990.

The three gas pricing policies pertain to base rate formation before sectoral markups, discounts, taxes, etc. To illustrate, consider a distributor with two classes of customers: residential/commercial and industrial. Let us suppose they each demand 150 mcf. Further suppose the distributor buys 100 mcf from each of three producers at $1.00, $2.00 and $3.00 per mcf. Under rolled-in pricing, which is the current law, the base rate is the average price of $2.00. Under incremental pricing to industrial users, which is in the proposed National Energy Plan, the residential and commercial sectors pay the lowest price of $1.00 per mcf for the first 100 mcf; then, the next price step of $2.00 per mcf is rolled in for the remaining amount of 50 mcf. This yields a residential/commercial base rate of $1.33 per mcf. Now the industrial user must begin with the $2.00 per mcf price step, which is depleted at 50 mcf. The remaining 100 mcf of industrial demand brings in the last price step of $3.00 per mcf; this is rolled into the industrial base rate to yield $2.67 per mcf. Finally, if natural gas prices are deregulated, then the base rate for all sectors uses the marginal price of $3.00 for new gas sales.

Table 16-1. First series of PIES scenarios

Gas pricing	*Wellhead price**	*No north slope gas*	*Three proposals*	*Total*
Rolled-in	1.00	80,85,90	85,90	9
Incremental	1.00	80,85,90	85,90	9
Incremental	1.50		85,90	6
Deregulated	1.00	80,85,90	85,90	9
Deregulated	1.50		85,90	6
Total		9	30	39

*1975 U.S. dollars per thousand cubic feet (mcf).

It became evident from the first series of experiments that PIES could not contribute usefully to the evaluation of one proposal over another. Therefore, subsequent experiments addressed the marketability issue of bifurcating entrance, versus no entrance, of Alaskan gas.

Early in the current Administration, President Carter established an interagency task force, led by FPC, and expended the project's scope. When the Department of Energy was formed, this project came under the Federal Energy Regulatory Commission (FERC). Due to certain developments, three new variables were introduced: world price of crude oil, availability of supplemental supplies, and limited distribution of Alaskan gas.

New scenarios were specified to analyze associated effects. The first variable, world oil price, was stimulated by a report from the Central Intelligence Agency (1977) which held implications that OPEC is likely to increase their price, in real terms, during the early 1980s. This was modeled in PIES by assuming a real increase at 2 percent per annum between 1980 and 1990.

The second variable, availability of supplemental supplies, was prompted by recent negotiations for additional sales from Canada (1888 bcf by 1990) and new sales from Mexico (500 bcf in 1985 and 700 bcf in 1990). The third variable is concerned with effects of limiting distribution of Alaskan gas to the West Coast, such as in the El Paso proposal. Table 16-2 shows the ten additional experiments that comprise the second series. This series was later extended to consider effects of an extra U.S. off-shore lease sale per year, resulting in additional domestic supply by 1990.

At this point the analysis suggested two important conclusions: (1) by 1990 Alaskan gas is fully marketable under all conditions considered; and (2) by 1985 Alaskan gas is marketable, but marginally so if supplemental supplies are available.

However, the National Energy Plan then emerged, and PIES was used to estimate its effects (See my earlier article in this volume and Greenberg (1978).) It was obvious that we had to re-analyze Alaskan gas marketability

Table 16-2. Second series of PIES scenarios (1985 and 1990)

World crude oil price	*Alaskan gas distribution*	*Supplemental supplies*
Constant	West Coast	No
Constant	West Coast	Yes
Increasing*	West Coast	No
Increasing*	West Coast	Yes
Increasing*	Nationwide	No

*At 2 percent per annum, real.

if policies were changed in accordance with the Plan. We did so, and we concluded that Alaskan gas would *not* be marketable by 1985; it would be marketable by 1990 only if no supplemental supply became available. Three primary reasons for this are: (1) *reduction* of demand, due to increased consumer prices resulting from a higher price ceiling to producers and an end use tax to industrial users; (2) *displacement* by coal by fueling large combustors; and (3) *balanced distribution* between supply and demand, resulting from the elimination of the gas market dichotomy: interstate vs. intrastate sales.

While PIES was used to quantify these three effects, the less visible, but perhaps more valuable, contribution was the qualitative one. For example, the distribution property, stated in the last of the three conclusions just given, may seem tautological now, but during earlier stages of analysis it was less than obvious. In fact, to digress for a moment, the swapping phenomenon in the marketplace is not well understood, and PIES surfaced some interesting distribution effects, particularly with regard to imported liquid natural gas (LNG).

Indeed, the process of scenario specification and iterative analyses contributed credible wisdom. Of course, numbers were reported and formed the quantitative basis of the conclusions and recommendations sent to the President. However, the analysis is distinct from model results, and the main value of PIES was that of a catharsis which kept the focus on the key factors and spared us debates over empirics.

As a rule, model results are of three classes: (1) *agrees with prior intuition,* providing quantification of the analysis; (2) *erroneous,* causing us to repair the faulty data or structure in a component; and (3) *counter-intuitive,* helping us to revise our intuition. After the first several attempts to use PIES, class 2 disappeared, but erroneous results *impacted* our analyses by sharpening our collected wisdom. Later stages of analysis generally found model results to be in class 1, but we frequently saw counter-intuitive results. This is certainly a productive class of model results. For example, important market phenomena, such as surprising displacements or subtle effects of gas pricing, came into clearer focus, thus improving the quality of analysis.

In closing, let me offer a retrospection. An important question is, "How did the use of PIES help the Administration decide upon its options?" It is at least difficult to answer this question, particularly since no final decision has been made, but even a speculative attempt seems appropriate.

If new U.S. gas pricing policies are changed, which now seems probable, we know the legislatures are informed about the interdependencies among supply options, particularly the nature and extent of competition among North Slope gas, Mexican gas, additional LNG, additional synthetic gas, etc. Therefore, at least one answer is that the decisions are currently being deliberated by an informed Administration and Congress. Perhaps one, slightly visible, impact of our analyses pertains to the issue of timing. It was generally felt, but not known, that Alaskan gas would be marketable by the mid-1980s, becoming increasingly important to the U.S. economy, especially in the Midwest, and perhaps critical by the early 1990s. Our analyses essentially confirmed this, but, more importantly, it identified the factors that are key to that feeling. Moreover, it helped to understand how several issues facing the United States relate to each other — in particular, how the supply issues, such as Alaskan gas distribution options, relate to gas pricing, coal conversion, etc. Thus, we can now explicate *how* one decision depends upon the others.

REFERENCES

Central Intelligence Agency. April 1977. *The international energy situation: Outlook to 1985.* Washington, D.C.

Eynon, R. T.; Greenberg, H. J.; Murphy, F. H.; and Mylander, W. C. May 1978. Using PIES to answer questions about the U.S. energy future. *AIDS Proc.* Washington, D.C.

Federal Energy Administration. 1976. *Project independence evaluation system (PIES) documentation,* vol. I–XV. National Tech. Info. Service. Springfield, Virginia.

Federal Power Commission. May 1, 1977. *Recommendation to the president, Alaska natural gas transportation systems.* Washington, D.C.

Greenberg, H. J., and Murphy, F. H. 1978. Modeling the national energy plan. *Proc. Institute of Gas Technology* (to appear).

Greenberg, H. J., and O'Neill, R. P. 1977. A computational perspective of PIES. *SHARE Proc.* Washington, D.C.

Hogan, W. W. 1975. Energy policy models for project independence. *Comp. and Oper. Res.* 2:251–271.

Murphy, F. H. 1978. The structure and solution techniques of the project independence evaluation system. *Comp. and Math. Prog.,* NBS Pub. 502, Washington, D.C.

Murphy, F. H. July 1978. Modeling natural gas regulation in the project independence evaluation system. EIA Tech. Rept. No. TM/AOA/7815.

Nissen, D., and Knapp, D. 1976. A regional model of interfuel substitution. *Energy: Mathematics & models.* Philadelphia: SIAM, pp. 121–131.

Thrasher, R. L. December 5, 1977. PIES analysis of Alaskan distribution options. Discussion paper, Energy Information Administration, Department of Energy, Washington, D.C.

Wagner, M. 1976. Project independence evaluation system integrating model. *Energy: Mathematics & models.* Philadelphia: SIAM, pp. 36–47.