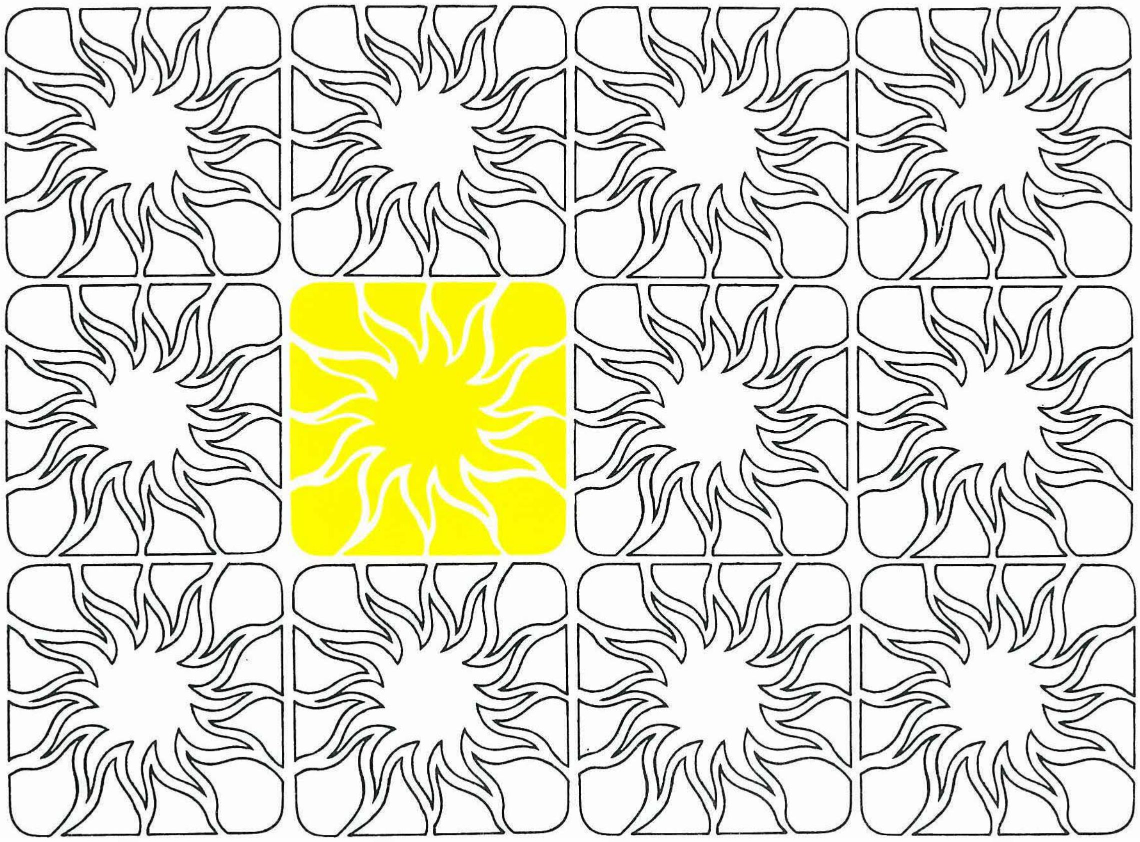

# U.S. Energy Outlook

## Gas Demand

National Petroleum Council

# U.S. Energy Outlook

# Gas Demand

A Report by the
Gas Demand Task Group
of the Gas Subcommittee of the
National Petroleum Council's Committee
on U. S. Energy Outlook

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National Petroleum Council

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# PREFACE

On January 20, 1970, the National Petroleum Council, an officially established industry advisory board to the Secretary of the Interior, was asked to undertake a comprehensive study of the Nation's energy outlook. This request came from the Assistant Secretary-Mineral Resources, Department of the Interior, who asked the Council to project the energy outlook in the Western Hemisphere into the future as near to the end of the century as feasible, with particular reference to the evaluation of future trends and their implications for the United States.

In response to this request, the National Petroleum Council's Committee on U.S. Energy Outlook was established, with a coordinating subcommittee, four supporting subcommittees for oil, gas, other energy forms and government policy, and 14 task groups. An organization chart appears as Appendix 2. In July 1971, the Council issued an interim report entitled *U.S. Energy Outlook: An Initial Appraisal 1971-1985* which, along with associated task group reports, provided the groundwork for subsequent investigation of the U.S. energy situation.

Continuing investigation by the Committee and component subcommittees and task groups resulted in the publication in December 1972 of the NPC's summary report, *U.S. Energy Outlook*, as well as an expanded full report of the Committee. Individual task group reports have been prepared to include methodology, data, illustrations and computer program descriptions for the particular area studied by the task group. This report is one of ten such detailed studies. Other fuel task group reports are available as listed on the order form included at the back of this volume.

The findings and recommendations of this report represent the best judgment of the experts from the energy industries. However, it should be noted that the political, economic, social and technological factors bearing upon the long-term U.S. energy outlook are subject to substantial change with the passage of time. Thus future developments will undoubtedly provide additional insights and amend the conclusions to some degree.

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# FOREWORD

This report has been prepared by the Gas Demand Task Group of the National Petroleum Council's Committee on the U.S. Energy Outlook as part of its final report.*

*U.S. Energy Outlook--Gas Demand* updates the information presented in the Initial Appraisal and discusses further the many factors influencing the demand for utility pipeline gas in the United States during the 1970-1985 period.

During the preparation of the report, the task group made every effort to relate gas demand to various economic parameters in a quantitative way. However, the inability to predict such related parameters as fuel prices, regulatory changes, import policies, fuel distribution policies and research and development efforts frustrated that effort. The task group was therefore forced to rely upon more generalized discussions of these factors, relating them wherever possible to available data prepared by the Future Requirements Committee.†

This difficulty serves to emphasize the need for definitive policies on matters affecting the administration of the energy industries. Until these uncertainties are removed, it will be difficult to plan and finance the facilities needed to serve the energy needs of the Nation.

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* NPC, *U.S. Energy Outlook--A Report of the National Petroleum Council's Committee on U.S. Energy Outlook* (December 1972).

† Future Requirements Agency, *Future Natural Gas Requirements of the United States*, Vol. No. 4, prepared by the Future Requirements Committee for the Gas Industry Committee, Future Requirements Agency (October 1971).

## Chapter One

## GAS DEMAND SUMMARY

The demand for gas, or any other commodity, is established by its comparative value to the consumer in relation to other alternatives and is tempered by the relative costs of choosing each alternative. In this case, the value of gas to the user is being increased by the demand for clean fuels necessary to comply with increasingly severe air pollution control regulations. The price of gas in relation to other clean fuels is generally low and it does not appear that this relative low price will be increased sufficiently to bring gas supply and demand into balance before 1985.

The shortage of available gas alone does not decrease the demand for gas. An obvious inability to obtain gas may reduce the number of visible requests for gas service and cause potential users to accept some other alternative, but the potential demand remains, unless the alternative chosen precludes conversion to gas at some future date when additional supply may become available.

It has been customary within the oil and gas industries to regard the amount of fuel produced in a given year as the *supply* and the total amount of fuel purchased by customers as the market *demand*. In this limited sense, the total supply and demand are equal, except for inventory changes which occur from year to year.

The oil and gas industries have traditionally sought to provide adequate supplies of fuel to meet the demands of their customers that it is sometimes assumed that supply must in fact equal demand. However, there have been at least two occasions when this was not the case. During World Was II, the demands of the military left insufficient gasoline for domestic motor fuel use, and it was necessary to ration gasoline. During the 1950's, the natural gas pipeline network could not be expanded rapidly enough to serve all of the new customers who wanted gas, and there were waiting lists of prospective customers who could not obtain gas service. Thus, demand and supply have not always been equal. Currently, the supply of gas in inadequate to meet the demands of customers who desire gas service. For some time to come, it is expected that the total potential demand for gas will remain only partially satisfied, and efforts are being made to allocate available supply on some acceptable basis.

Gas demand is established by the nature of gas and its competitive fuels and the prices at which each are offered. Since the gas industry is regulated, the price of gas is set by regulatory authorities. The cumbersome regulatory process makes price responses to market conditions too slow for price to be used effectively as a device to control demand. Furthermore, since regulatory and legislative activity cannot be projected, the impact on demand cannot be predicted.

## INITIAL APPRAISAL

Under the conditions assumed for the Initial Appraisal, the Gas Demand Task Group projected the demand for gas as it appeared likely to develop without supply limitations.* It was recognized that gas consumption would be severely restricted by supply conditions and that the demand would be a potential demand which could not be fulfilled by the available supply. A comparison of the projected gas supply and demand is presented in Table 1.

**TABLE 1**

**GAS SUPPLY/DEMAND COMPARISON**
**(Trillion BTU's)**

| | 1975 | 1980 | 1985 |
|---|---|---|---|
| Potential Demand | 30,268 | 34,700 | 40,119 |
| Anticipated Supply | 22,420 | 22,480 | 22,180 |
| Indicated Shortfall | 7,848 | 12,220 | 17,939 |

The data presented in Table 1 for potential demand were derived from 1969 projections of gas requirements compiled by the Future Requirements Committee (FRC).† These data reflect no consideration of gas supply limitations or relative changes in the energy pricing structure during the projection period.

Total requirements were projected to increase from 24.9 quadrillion BTU's in 1970 to 40.1 quadrillion BTU's in 1985--an increase of 61 percent during the 15-year period. These projected gas requirements were broken down by categories of use for each Petroleum Administration for Defense (PAD) district, and data were presented for 5-year intervals.

In addition, the field uses of natural gas were estimated within each PAD district for each year through 1975 and for 5-year intervals through 1985. These data included gas plant shrinkage, gas used and vented at leases and gas plant fuel. Data was also tabulated for gas used to manufacture chemicals.

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* NPC, *U.S. Energy Outlook: An Initial Appraisal 1971-1985*, Vol. II (November 1971), pp. 99-112.

† FRC, *Future Natural Gas Requirements of the United States*, Vol. No. 3, prepared by FRC for the Gas Industry Committee, Future Requirements Agency (September 1969).

## FINAL REPORT

Under the conditions assumed for the final report on U.S. Energy Outlook, the Gas Demand Task Group has reviewed the gas requirements projected in the Initial Appraisal in light of factors which may influence natural gas demand, such as air pollution control regulations, changes in relative prices of fuels, improvements in energy utilization efficiency, and changing technology. This was done by first updating and revising the demand projection used in the Initial Appraisal to serve as a base case for the comparison of the various factors considered.

Since the Initial Appraisal was completed, the FRC issued Volume No. 4 of its gas requirements report.* This supersedes the projections made by FRC in 1969 which provided the basis of the demand projection used in the Initial Appraisal.† Data developed and compiled by the FRC include actual data on gas requirements in the United States for the years 1964 through 1970; estimated data for the 1971-1975 period; and projected data for 1980, 1985 and 1995. The 1971 report follows the pattern of the 1969 report and increases its estimate of gas required in most categories and geographical regions.

The methodology employed by the FRC in the assembly and projection of these data is described in considerable detail in Volume No. 4. It is referred to here only to the extent necessary to interpret the findings of the Gas Demand Task Group. Two important assumptions made by the FRC should be mentioned, however:

- The FRC assumed that "there will be an adequate supply of gas for all estimated requirements for all periods covered by the survey."‡
- The FRC further assumed that "the present day price relationship of gas to the competing fuels will remain essentially the same in the future. However, individual companies were asked to consider 'known' changes in these relationships in their market area."‡

The FRC's 1971 report is used in the U.S. Energy Outlook report as the basis for projecting future gas demand. *However, in this study it is considered as a base case only.* Considerable discussion is presented by the Gas Demand Task Group of the effects

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* FRC, *Future Natural Gas Requirements of the United States*, Vol. No. 4 (October 1971).

† FRC, *Future Natural Gas Requirements of the United States*, Vol. No. 3 (September 1969).

‡ FRC, *Future Natural Gas Requirements of the United States*, Vol. No. 4 (October 1971).

of price changes, environmental considerations, gross national product (GNP) and population trends, efficiency of fuel use, technological developments, and changes in utilization efficiencies on the base case projection.

The FRC data were not in a form suitable for use in the NPC study and had to be rearranged. First, the data had to be rearranged from the state projections developed by the FRC into projections for the PAD districts. Maps showing the PAD districts, FRC regions, and census divisions are shown as Figures 1, 2 and 3. In addition to grouping the actual and projected gas requirements into the five basic districts, breakdowns were required of PAD District I into the New England, Middle Atlantic and South Atlantic Census Divisions, and of PAD District II into the East North Central Census Division and a section covering the remainder of District II. Further, it was necessary to modify the classes of gas requirements reported by the FRC to conform to the use categories used in the NPC study.

The following procedure was used to regroup the FRC data into the categories employed in the NPC study:

- *Firm residential* plus *firm commercial* were equated to *residential/commercial*.

- *Firm industrial* plus *interruptible* were equated to *industrial*.

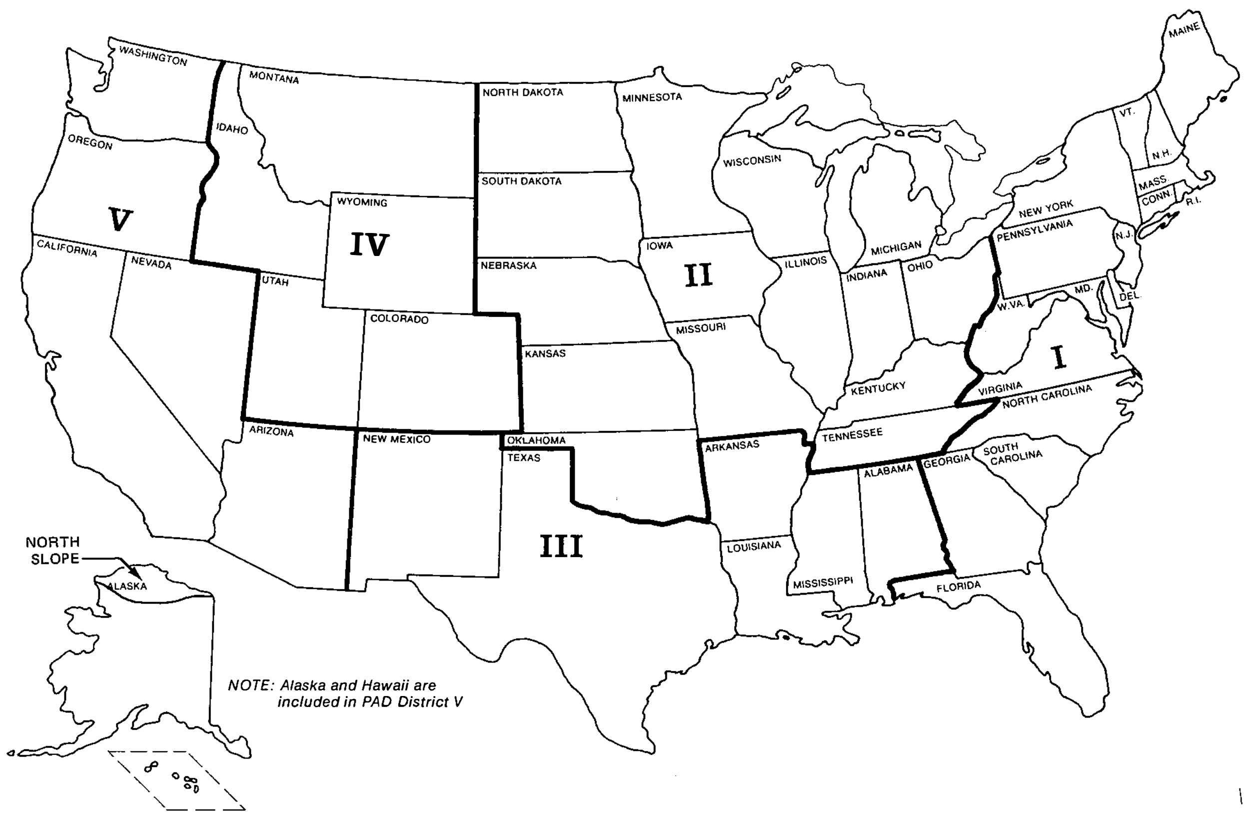


Figure 1. Petroleum Administration for Defense (PAD) Districts.

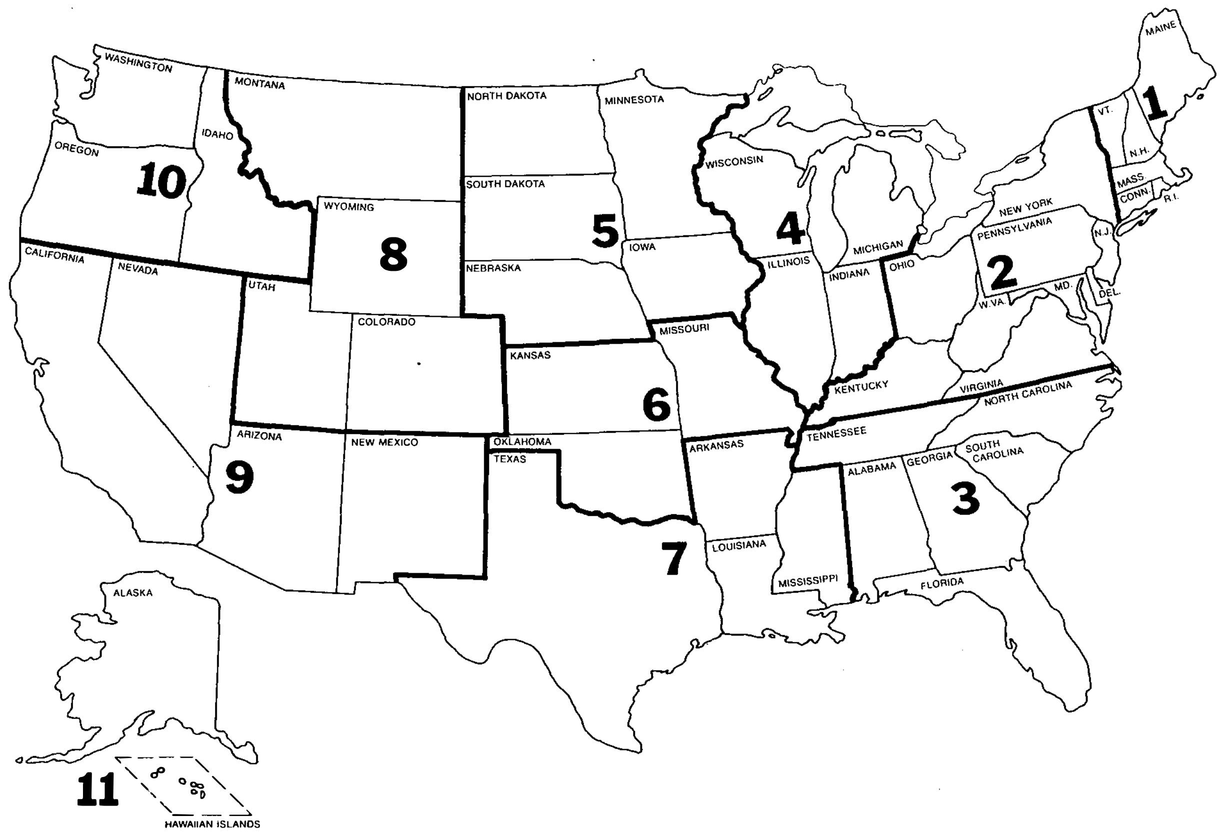


Figure 2. Map of Regions Used in Future Requirements Committee Reports.

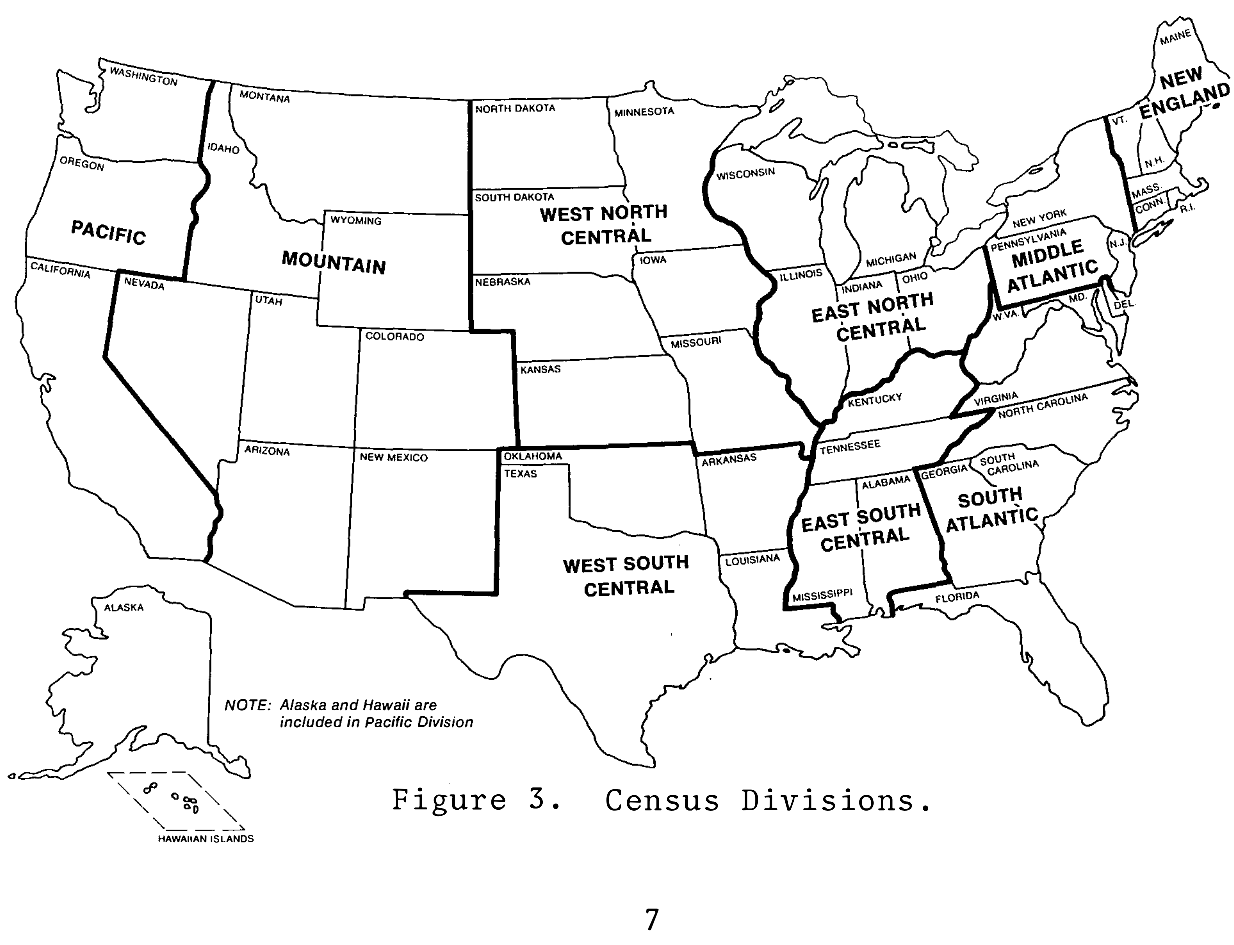


Figure 3. Census Divisions.

- *Firm utility power generation* plus *interruptible utility power generation* were equated to *electric utilities*.

- The *transportation* category required for the NPC study was estimated from 1969 data reported by the Bureau of Mines on the use of gas for transportation (primarily pipeline compressor station fuel).* The use for this purpose for each PAD district computed as a percentage of the total gas requirements, exclusive of field use, is as follows: PAD District I--1.7 percent; PAD District II--3.5 percent; PAD District III--4.3 percent; PAD District IV--2.7 percent; and PAD District V--2.1 percent. Within Districts I and II, these amounts were allocated to the appropriate subregions. It was assumed that these percentages remained constant through 1985.

- The quantities of gas in the residential/commercial, industrial, electric utilities, and transportation categories were then subtracted from the total requirements, excluding field use, for each PAD district computed from the FRC data. The remaining gas requirements were identified as "raw material and other," excluding field use. Field use as defined by the FRC is that gas consumed as fuel on leases for pumping, drilling and other field facilities; fuel and losses and extraction loss (shrinkage) at gas processing plants; and quantities vented and flared on producing properties. For consistency with other task group reports, field use, except for the shrinkage due to the extraction of natural gas liquids, has been added to the raw material and other category. The field use data reported by the FRC does include these liquids and would result in double counting unless removed for use in this report.

The 1971 FRC report does not provide a breakdown of field use by region or use. However, the total quantities estimated for shrinkage were provided by the FRC from unpublished data, and a regional breakdown was made based on the regional estimate of shrinkage presented in the Initial Appraisal. The field use values presented in the 1971 FRC report are substantially higher than those reported in the 1969 FRC report because of a revision in the heating values used. These are presented in Table 2, together with the estimated breakdown by PAD district. The portion of field use labeled "Other" in Table 2 has been included in the "Raw Material and Other" category in Table 3.

Table 3 shows a summary of gas requirements by PAD districts, subdivided in accordance with the NPC categories. Since only the "Other" field use category shown in Table 2 is incorporated with

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* U.S. Bureau of Mines, "Natural Gas Production and Consumption: 1969," *Mineral Industry Surveys* (September 3, 1970).

## TABLE 2

### ESTIMATED BREAKDOWN OF FRC FIELD USE PROJECTION BY PAD DISTRICT
(Trillion BTU's)

| | | PAD District I | | | | PAD District II | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Use Category | New England | Middle Atlantic | South Atlantic | Total | East North Central | All Other | Total | PAD District III | PAD District IV | PAD District V | Total U.S.* |
| 1965 | Shrinkage | – | – | 32 | 32 | 45 | 242 | 287 | 1,516 | 50 | 107 | 1,992 |
| | Other | – | 10 | 4 | 14 | 89 | 34 | 123 | 1,250 | 57 | 191 | 1,635 |
| | **Total Field Use** | **–** | **10** | **36** | **46** | **134** | **276** | **410** | **2,766** | **107** | **298** | **2,627** |
| 1970 | Shrinkage | 0 | 0 | 25 | 25 | 41 | 300 | 341 | 1,954 | 66 | 99 | 2,485 |
| | Other | 1 | 19 | 3 | 23 | 230 | 181 | 411 | 1,554 | 94 | 143 | 2,225 |
| | **Total Field Use** | **1** | **19** | **28** | **48** | **271** | **481** | **752** | **3,508** | **160** | **242** | **4,710** |
| 1975 | Shrinkage | 0 | 0 | 6 | 6 | 56 | 389 | 445 | 2,285 | 82 | 103 | 2,921 |
| | Other | 1 | 10 | 5 | 16 | 295 | 187 | 482 | 1,799 | 104 | 105 | 2,506 |
| | **Total Field Use** | **1** | **10** | **11** | **22** | **351** | **576** | **927** | **4,084** | **186** | **208** | **5,427** |
| 1980 | Shrinkage | 0 | 0 | 7 | 7 | 53 | 366 | 419 | 2,039 | 76 | 81 | 2,622 |
| | Other | 2 | 9 | 6 | 17 | 268 | 190 | 458 | 1,688 | 112 | 103 | 2,378 |
| | **Total Field Use** | **2** | **9** | **13** | **24** | **321** | **556** | **877** | **3,727** | **188** | **184** | **5,000** |
| 1985 | Shrinkage | 0 | 0 | 6 | 6 | 46 | 318 | 364 | 1,772 | 66 | 71 | 2,279 |
| | Other | 2 | 9 | 5 | 16 | 233 | 167 | 400 | 1,465 | 110 | 87 | 2,078 |
| | **Total Field Use** | **2** | **9** | **11** | **22** | **279** | **485** | **764** | **3,237** | **176** | **158** | **4,357** |

* Total U.S. data are provided by FRC for 1975, 1980 and 1985. Regional breakdown and earlier years estimated from shrinkage and field use data presented in the NPC's Initial Appraisal.

## TABLE 3

### ACTUAL AND PROJECTED ANNUAL GAS REQUIREMENTS BY USE CATEGORY AND PAD DISTRICT FOR SELECTED YEARS 1965 THROUGH 1985
(Trillion BTU's)

| | | PAD District I | | | | PAD District II | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Use Category | New England | Middle Atlantic | South Atlantic | Total | East North Central | All Other | Total | PAD District III | PAD District IV | PAD District V | Total U.S. |
| 1965 | Residential/Commercial | 130 | 868 | 379 | 1,377 | 1,597 | 916 | 2,513 | 526 | 208 | 773 | 5,397 |
| | Industrial | 30 | 452 | 428 | 910 | 1,030 | 717 | 1,747 | 2,595 | 177 | 657 | 6,086 |
| | Electric Utilities | 14 | 102 | 120 | 236 | 69 | 456 | 525 | 1,040 | 36 | 586 | 2,423 |
| | Transportation | 3 | 26 | 17 | 46 | 104 | 78 | 182 | 198 | 8 | 44 | 478 |
| | Raw Material & Other | 8 | 70 | 53 | 131 | 111 | 78 | 189 | 451 | 22 | 159 | 963 |
| | **Total Inc. Field Use** | **185** | **1,518** | **997** | **2,700** | **2,911** | **2,245** | **5,156** | **4,810** | **462** | **2,219** | **15,347** |
| 1970 | Residential/Commercial | 177 | 1,106 | 517 | 1,800 | 2,138 | 1,059 | 3,197 | 734 | 260 | 910 | 6,901 |
| | Industrial | 52 | 578 | 654 | 1,284 | 1,494 | 984 | 2,478 | 4,140 | 238 | 897 | 9,037 |
| | Electric Utilities | 9 | 172 | 324 | 505 | 272 | 699 | 971 | 1,617 | 63 | 759 | 3,915 |
| | Transportation | 5 | 33 | 27 | 65 | 144 | 108 | 252 | 305 | 10 | 57 | 689 |
| | Raw Material & Other | 8 | 91 | 110 | 209 | 265 | 445 | 710 | 1,831 | 104 | 262 | 3,116 |
| | **Total Inc. Field Use** | **251** | **1,980** | **1,632** | **3,863** | **4,313** | **3,295** | **7,608** | **8,627** | **675** | **2,885** | **23,658** |
| 1975 | Residential/Commercial | 231 | 1,347 | 682 | 2,260 | 2,664 | 1,232 | 3,896 | 848 | 310 | 1,125 | 8,439 |
| | Industrial | 77 | 862 | 1,132 | 2,071 | 2,377 | 1,322 | 3,699 | 5,284 | 298 | 1,289 | 12,641 |
| | Electric Utilities | 17 | 210 | 339 | 566 | 578 | 870 | 1,448 | 2,298 | 83 | 1,068 | 5,463 |
| | Transportation | 6 | 43 | 39 | 88 | 205 | 137 | 342 | 393 | 12 | 74 | 909 |
| | Raw Material & Other | 6 | 106 | 139 | 251 | 346 | 522 | 868 | 2,079 | 115 | 220 | 3,533 |
| | **Total Inc. Field Use** | **337** | **2,568** | **2,331** | **5,236** | **6,170** | **4,083** | **10,253** | **10,902** | **818** | **3,776** | **30,985** |
| 1980 | Residential/Commercial | 287 | 1,576 | 860 | 2,723 | 3,173 | 1,424 | 4,597 | 1,011 | 349 | 1,327 | 10,007 |
| | Industrial | 97 | 1,063 | 1,506 | 2,666 | 3,085 | 1,588 | 4,673 | 6,038 | 327 | 1,457 | 15,161 |
| | Electric Utilities | 16 | 183 | 393 | 592 | 597 | 1,058 | 1,655 | 2,965 | 95 | 885 | 6,192 |
| | Transportation | 7 | 50 | 50 | 107 | 250 | 161 | 411 | 465 | 14 | 80 | 1,077 |
| | Raw Material & Other | 9 | 116 | 159 | 284 | 266 | 553 | 819 | 1,990 | 122 | 242 | 3,457 |
| | **Total Inc. Field Use** | **416** | **2,988** | **2,968** | **6,372** | **7,371** | **4,784** | **12,155** | **12,469** | **907** | **3,991** | **35,894** |
| 1985 | Residential/Commercial | 352 | 1,830 | 1,060 | 3,242 | 3,778 | 1,625 | 5,403 | 1,182 | 394 | 1,548 | 11,769 |
| | Industrial | 124 | 1,276 | 1,940 | 3,340 | 3,802 | 1,804 | 5,606 | 6,872 | 361 | 1,626 | 17,805 |
| | Electric Utilities | 14 | 185 | 483 | 682 | 672 | 1,121 | 1,793 | 3,852 | 116 | 829 | 7,272 |
| | Transportation | 8 | 59 | 63 | 130 | 300 | 180 | 480 | 551 | 16 | 87 | 1,264 |
| | Raw Material & Other | 9 | 130 | 181 | 320 | 217 | 565 | 782 | 1,774 | 119 | 241 | 3,236 |
| | **Total Inc. Field Use** | **507** | **3,480** | **3,727** | **7,714** | **8,769** | **5,295** | **14,064** | **14,231** | **1,006** | **4,331** | **41,346** |

the NPC use category "Raw Materials and Other," the totals are smaller than the FRC report totals by the amount of shrinkage due to removal of gas liquids. Table 3 more closely represents the requirements for dry pipeline quality gas. All data are reported in units of trillion ($10^{12}$) BTU's. (One trillion BTU's is the equivalent of 1 billion cubic feet [BCF] of natural gas having a heating value of 1,000 BTU's per cubic foot [CF].)

Natural gas liquids have been excluded entirely from this report in order to avoid confusion with other task group reports. They are deleted from the future gas requirements in order to make them comparable with gas supply projections. No projections of other natural gas liquid requirements have been included.

# Chapter Two

## ECONOMETRIC ANALYSIS

A number of econometric studies have been made of natural gas demand in recent years. Most of them have attempted to relate gas demand to price in some meaningful way that would permit the prediction of future gas demand in relation to changing price. Several such studies were reviewed in an effort to develop some basis for relating gas demand to price or to other significant parameters.*

Each study analyzed historical data in an effort to relate gas demand to price. However, factors other than price have an influence upon demand. Some of these factors, as well as price, are discussed below in order to provide some understanding of the number and complexity of the variables involved.

- *Price:* Fuel price is, of course, one obvious parameter affecting demand. However, the market price of fuel is less significant than the "as burned" price, which includes related costs, such as storage equipment, combustion equipment and inventory costs, that are not readily identifiable and may vary among users. There are few statistical sources that report "as burned" fuel costs. Furthermore, it is not only the price itself, but also the price relative to other fuels that influences selection. The situation can become very complex when three fuels such as coal, oil and gas are all competitive in a given market.

- *Interruptible Gas Rates:* Substantial amounts of gas are sold to industrial users during the summertime when it can offer more attractive rates, with the understanding that the gas supply will be interrupted when and if the supplier needs the gas to serve the heavy winter loads of firm contract customers.

  Since this gas is sold at the convenience of the seller, the quantities that are offered are more closely related to the needs of the utility than to the demands of the industrial customers. Factors such as summer gas storage capacity, system load factors, winter heating load demands, and gas supply contract terms all enter the picture. Any attempt to analyze industrial gas market statistics in order to show price/demand relationships must take into consideration these indirect influences, wherever interruptible sales contracts are involved.

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* These studies included the work of Balestra, Villanueva, Vermetten and Plantinga, P. W. MacAvoy, E. W. Erickson, Kazzoom and others.

- *Availability:* Demand is influenced by current and future availability of fuels. Even when there has been an abundance of supply nationwide, regional and seasonal variations in energy demand have required the storage or transportation of certain fuels to balance supply and demand. The costs associated with this activity are reflected in local and seasonal price fluctuations that can distort statistical data. For example, average annual sales and price data may adequately represent a steady year-round industrial fuel demand but would distort the price/demand relationship of a heating load that occurs only during cold weather when prices are higher. Thus, monthly and regional data on fuel prices must be related to particular fuel uses region-by-region in order to begin to correlate demand and price in a manner that can be used for future projection of fuel demand.

  As the availability of various fuels becomes restricted, the premiums paid for storage and transport of desirable fuels will increase. This has already begun, but the historical records, which lag behind current activities, are only beginning to reflect the changing picture. Past historical data do not indicate what to expect in the future as fuel availability changes.

- *In-Place Consumption Facilities:* The demand for gas is related to the number of appliances and gas-burning devices of various kinds of in-place consumption facilities. Future gas demand can be predicted by estimating future inventory of gas-burning equipment. However, historical data must be corrected for the changing inventory in order to be applicable to future time periods. This can be done, but it entails a complex forecast of future appliance sales that introduces additional uncertainties. A mathematical model of gas demand might properly include a model of future appliance and industrial equipment inventory. Since the future inventory is influenced by the current outlook for fuel supplies and prices, there is a feedback effect that must be considered in building such a model.

- *Relationship to Productivity:* A major concern of the industrial user is not the cost of fuel itself but its effects upon production rates, product quality, scrap rates, etc. Thus, dependability of supply, simplicity of control, consistency of fuel quality, and flexibility of operation may have greater value than the difference between various fuel prices. These factors must be considered when historical data are examined to determine price/demand relationships.

- *Intangible Factors:* There are also intangible factors that influence gas demand which cannot be quantified or related to demand in meaningful numbers. Personal tastes, habits, selling influences, provincialism, mistaken impressions, etc., all have recognized influences, although they cannot be related to demand in mathematical terms. Their effect is to scatter data points and to obscure correlations of reported statistics that might otherwise provide useful information.

All of these variables are interacting with each other at the same time. Historical data only records the overall net effect, and it becomes difficult if not impossible to identify the influence of each factor. Without this knowledge, it becomes impossible to predict the net result of specific changes in the governing factors.

Unfortunately, there are no economics laboratories in which to experiment by changing each of these variables one at a time in order to observe their influence upon the overall situation. It is a rare occurrence to find any instance in historical records in which one variable has changed while all others are known to have remained constant. Only then can the influence of that parameter be identified.

Researchers hope to build mathematical models that can serve as economic laboratories in which individual parameters may be changed to observe their effects. However, there is presently no way to determine when such a model properly simulates the complex interrelationships of the real world that it represents. This goal may be reached in time by a series of successive approximations. As such models are built and used, their defects will be identified and corrected. In time, they will be refined to such a degree that they can reproduce historical trends. As confidence in their use increases, it will become possible to utilize them to predict future trends.

At the present time, however, the state of the art does not permit quantitative prediction of the future trends of gas demand on the basis of historical performances. It is therefore necessary to rely upon judgmental techniques in assessing the future demand for gas. Consequently, the major factors in the economy that may influence gas demand are discussed in narrative style, making such judgments as can be made.

The gas requirements presented as the base case have been reviewed as related to changes in GNP, changes in population growth, implementation of increasingly severe environmental controls, changes in relative prices of fuels, and technical advances in improved utilization efficiency. Discussion of each of these items as related to gas demand are presented in the following chapters.

## Chapter Three

## FUTURE GAS DEMAND AND THE GENERAL ECONOMY

### HISTORICAL GROWTH RATE

Before discussing future gas demand in relation to the general economy, it may be beneficial to briefly review the historical growth of the gas industry.

In 1950, the total annual consumption of natural gas in the United States amounted to 6,150 trillion BTU's. By 1970, consumption had increased to 22,029 trillion BTU's, amounting to an average annual increase of about 6.5 percent. During this same period, the consumption of all forms of energy increased only about 3.5 percent per year. Although gas accounted for only 18 percent of the total energy consumed in the United States in 1950, it supplied 32 percent of the total in 1970. Thus, the gas industry must be regarded as one of the major growth industries in the country during the past 20 years. Some of these statistics are presented in Table 4, along with reported GNP and total population.

During the 1950's, when the gas industry was expanding as rapidly as it could finance and build new pipelines, it grew at a rate generally less than 15 percent annually, even though there were ample reserves of gas available. Since 1960, its growth rate has not exceeded 8 percent in any one year. The 5-year averages presented in Table 4 show that in recent years the growth rate has generally been less than the average of 6.5 percent per year for the 20-year period 1950-1970. The most rapid growth occurred prior to 1960, and during the 1960's, gas consumption increased at only a slightly higher rate than the total energy market.

The decade of the 1960's represented a stable period of continued growth in the gas industry. The regulated utilities and their supporting industries, such as the pipeline construction industry and the pipe manufacturing industry, have been sized to fit the steady growth rate that prevailed.

A sudden increase in demand for natural gas for pollution control purposes would create major problems in these industries even if adequate supplies of gas were available. Other factors would soon limit the ability of the industry to respond to the demand. The need for additional capital to expand facilities and the physical limitations of the construction and equipment manufacturing industries would soon limit expansion. The time required to obtain regulatory approval of new projects, as well as to plan and justify new projects to financing interests, environmentalists and state and federal agencies, may also govern the pace of expansion.

Because of these factors, it would be difficult for the gas industry to expand rapidly enough to satisfy a sudden large demand

TABLE 4

NATURAL GAS CONSUMPTION AND SELECTED ECONOMIC FACTORS

| Year | Natural Gas Consumption* (Trillion BTU's) | | | Average Growth Rate—Total Consumption Past 5 Years (Percent)† | Total U.S. Energy Consumption (Trillion BTU's)‡ | Gas Consumption to Total Energy (Percent) | GNP (Billions of $)§ | U.S. Resident Population (Millions) |
|---|---|---|---|---|---|---|---|---|
| | Residential/ Commercial | All Other | Total | | | | | |
| 1950 | 1,586 | 4,564 | 6,150 | 9.0 | 34,153 | 18 | 481 | 151.2 |
| 1955 | 2,753 | 6,479 | 9,232 | 8.4 | 39,956 | 23 | 593 | 164.3 |
| 1960 | 4,123 | 8,576 | 12,699 | 6.5 | 44,816 | 28 | 660 | 180.0 |
| 1965 | 5,396 | 10,702 | 16,098 | 4.8 | 53,969 | 30 | 836 | 193.8 |
| 1966 | 5,605 | 11,788 | 17,393 | 5.6 | 57,130 | 30 | 890 | 195.9 |
| 1967 | 5,911 | 12,339 | 18,250 | 5.2 | 59,156 | 31 | 913 | 197.9 |
| 1968 | 6,249 | 13,331 | 19,580 | 5.7 | 62,463 | 31 | 957 | 199.8 |
| 1969 | 6,710 | 14,310 | 21,020 | 6.0 | 65,809 | 32 | 980 | 201.4 |
| 1970 | 6,901 | 15,128 | 22,029 | 6.4 | 68,757 | 32 | 974 | 203.2 |
| Average Annual Compound Growth Rate from 1950 to 1970 | 7.7% | 6.2% | 6.6% | | 3.6% | | 3.6% | 1.5% |

* For the 1950-1970 period, total figure represents gross consumption reported by the Bureau of Mines, March 31, 1972, with residential/commercial consumption reported by the American Gas Association, *Statistical Abstract of the United States* (1971).

† Percentages represent rolling average growth rate over preceding 5 years.

‡ American Gas Association, *Gas Facts* (1971), p. 24.

§ GNP in constant 1970 dollars.

for gas even if an adequate supply were available. This lack of flexibility in responding to rapid change is characteristic of capital-intensive industries, particularly those subject to close regulation by governmental agencies.

## RELATIONSHIP TO GNP

Although total energy consumption has grown at a rate that is comparable with GNP, the consumption of gas has grown more rapidly during the past two decades. It is interesting to compare the growth in gas consumption per unit of GNP with the growth in energy consumption per unit of GNP which was presented in the Initial Appraisal.*

The trend of gas consumption per unit of GNP is shown graphically in Figure 4, using data presented in Table 5 which tabulates the estimated future gas requirements per dollar of GNP,

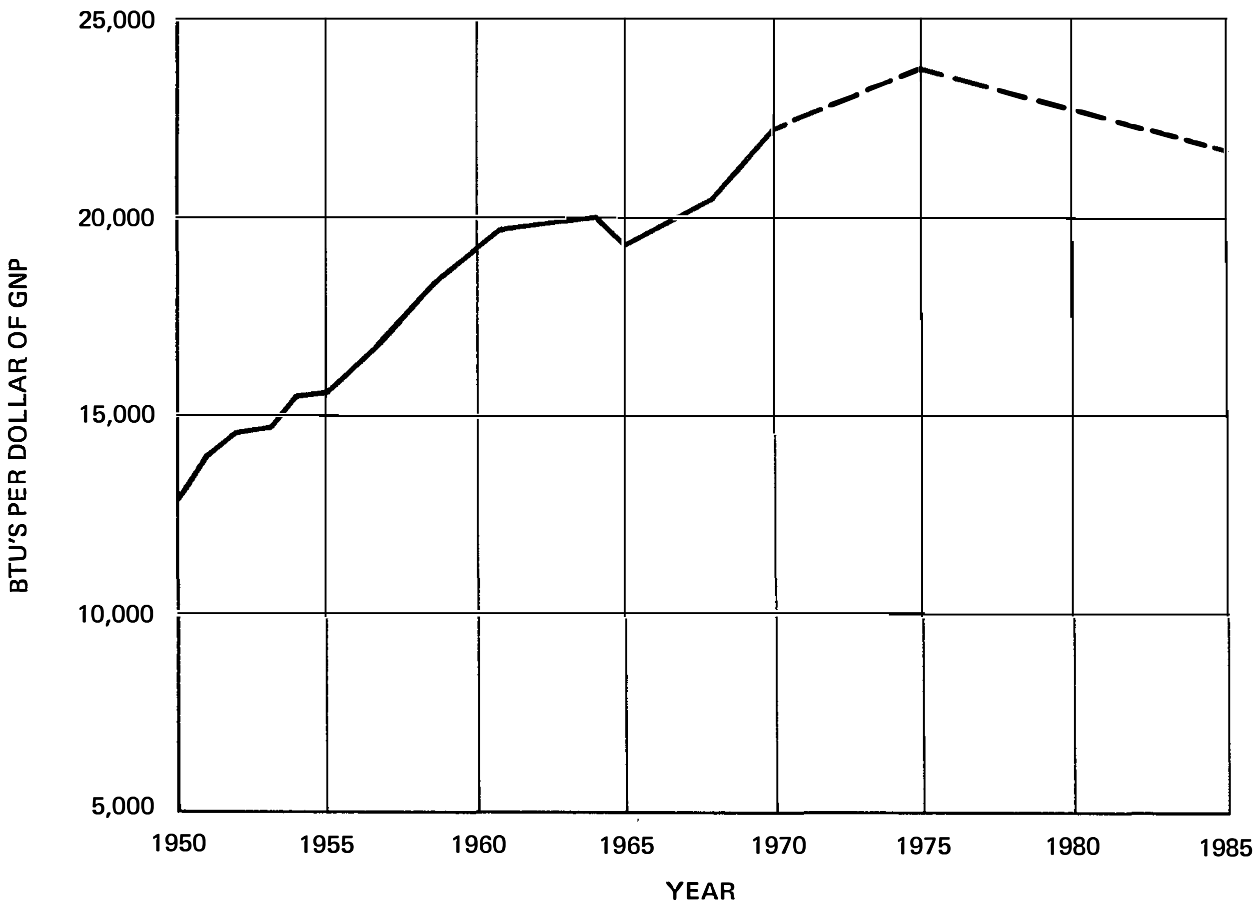


Figure 4. Natural Gas Consumption per Dollar of Gross National Product.

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*NPC, *U.S. Energy Outlook: An Initial Appraisal 1971-1985*, Volume II (November 1971), p. 4.

TABLE 5

RELATIONSHIP BETWEEN GNP AND NATURAL GAS CONSUMPTION

| | GNP (Billion 1970 Dollars) | Natural Gas Consumption (Trillion BTU's)* | Natural Gas/ GNP Ratio (BTU's/$) |
|---|---|---|---|
| 1950 | 480.7 | 6,150 | 12,800 |
| 1951 | 528.7 | 7,248 | 14,000 |
| 1952 | 534.5 | 7,760 | 14,500 |
| 1953 | 558.5 | 8,156 | 14,600 |
| 1954 | 550.6 | 8,548 | 15,500 |
| 1955 | 592.6 | 9,232 | 15,600 |
| 1956 | 603.5 | 9,834 | 16,300 |
| 1957 | 612.2 | 10,416 | 17,000 |
| 1958 | 605.2 | 10,995 | 18,200 |
| 1959 | 643.8 | 11,990 | 18,600 |
| 1960 | 659.8 | 12,699 | 19,200 |
| 1961 | 672.7 | 13,228 | 19,700 |
| 1962 | 716.8 | 14,121 | 19,700 |
| 1963 | 745.4 | 14,843 | 19,900 |
| 1964 | 786.2 | 15,688 | 20,000 |
| 1965 | 835.8 | 16,098 | 19,300 |
| 1966 | 890.3 | 17,393 | 19,500 |
| 1967 | 912.7 | 18,250 | 20,000 |
| 1968 | 957.3 | 19,580 | 20,500 |
| 1969 | 980.4 | 21,020 | 21,400 |
| 1970 | 974.1 | 22,029 | 22,600 |
| 1975 (est.) | 1,196.6† | 28,479 | 23,800 |
| 1980 (est.) | 1,469.9† | 33,516 | 21,700 |
| 1985 (est.) | 1,805.6† | 39,268 | 21,700 |

* 1950 to 1970 data from Department of the Interior, Bureau of Mines News Release, "U.S. Energy Use at New High in 1971," March 31, 1972, Supplement Table A and Table B; 1975, 1980 and 1985 data FRC requirements less field use (FRC, *Future Natural Gas Requirements of the United States,* Vol. No. 4 [October 1971]); Data are not strictly comparable since Bureau of Mines data includes some field use.

† GNP growth at 4.2 percent in constant 1970 dollars.

using constant 1970 dollars and a GNP growth rate of 4.2 percent, along with the historical trend of the same parameter. Historically, the consumption of natural gas per dollar of GNP (using constant 1970 dollars) has increased steadily from about 12,800 BTU's per dollar of GNP in 1950 to about 19,700 BTU's per dollar of GNP in 1961. It then remained nearly constant until 1966 when it resumed an increasing pattern similar to that experienced with total energy consumption during the late 1960's, reaching 22,600 BTU's per dollar of GNP in 1970. The projection into the future using the base case data indicates a gradual decline in the 1975-1985 period, since the projected overall rate of growth in gas use is less than the 4.2 percent used for the GNP growth rate. This is consistent with the total energy projections presented in the Initial Appraisal which indicate that the sharp rise in energy use per unit of GNP in the past 5 years is temporary and may soon revert to a more stable relationship.

There is no way of knowing what GNP growth rate was assumed in preparing the FRC estimate, and it is probable that each group involved used its own rate (or some other device) in preparing its estimates. This comparison simply relates the FRC estimate totals to a specific GNP growth rate and suggests that the steadily increasing consumption of gas per unit of GNP that has occurred over the past 20 years may soon reach a peak and begin to decline after 1975.

No attempt has been made to correlate individual segments of gas consumption with specific elements of the GNP, even though it is recognized that industrial gas uses can be related to particular segments of the GNP while residential/commercial uses may correlate better with population trends. There are no available projections of future elements of GNP that would permit better estimates of gas demand. It was the general opinion of the task group that estimating future GNP by its various elements was beyond the scope of this study.

It should be emphasized again that the historical portion of Figure 4 reflects a time period in which demand, or consumption, was in fact not limited by supply. Conversely, the forward period is one in which demand is *assumed* not to be supply limited.

## RELATIONSHIP TO POPULATION GROWTH

The base case projections of gas requirements are not conditioned on a specific population growth rate. Therefore, we have no basis on which to convert the projections from one growth rate to another. We can, however, compare the base case projections to a particular population growth rate.

Historically, on a national basis, per capita gas consumption grew from 70.1 million BTU's per capita in 1960 to 109 million BTU's per capita between 1960 and 1970. The future trend is for further increases, although at a somewhat slower rate. Using the FRC total gas requirements excluding field uses, the per capita gas demand estimates are shown in Table 6 for the Series D population projections of the Bureau of the Census.

The figures shown in Table 6 indicate that, for example, an increase in the total population of 1 million people over the Series D forecast for 1980 would result in an increase in gas requirements of about 147 trillion BTU's annually.

Population can be projected more precisely than many other indices of future growth. The difference between the Series D

TABLE 6

ESTIMATED ANNUAL PER CAPITA GAS REQUIREMENTS

| | Million BTU's per Capita |
|---|---|
| 1960* | 70.1 |
| 1965* | 83.3 |
| 1970* | 108.8 |
| 1975 | 132 |
| 1980 | 147 |
| 1985 | 163 |

* Using Bureau of Census Data and gas consumption reported by Bureau of Mines.

and Series E forecasts of the Bureau of the Census, for example, amounts to only about 2 million people in 1980, or less than 1 percent of the total population. If per capita gas demand remained nearly constant, it would be possible to predict future gas demand quite accurately. Unfortunately, this is not the case Per capita gas demand has been steadily increasing as shown in Table 6. Furthermore, this quantity varies considerably in different regions of the country.

The historical per capita consumption of natural gas was calculated for each PAD district, including breakdowns within certain districts such as District I where patterns vary markedly within the district. The data show wide variations ranging from 20 million BTU's per capita in New England to 340 million BTU's per capita in PAD District III primarily due to variations in industrial trends, which are in turn related to such factors as availability and relative economics of gas and alternative fuels as industrial fuels. It is recommended that only residential/commercial demand be correlated with regional population trends.

These regional population trends have been related to residential/commercial gas consumption and are presented in Table 7 and Figure 5. It can be seen that in each region the residential/commercial use of gas per capita generally follows the same upward trend as the national data. In PAD Districts IV and V, however, the projected rate of increase falls off somewhat compared to other regions. An examination of the growth rates of both population and gas requirements reveals that this is due more to a lower rate of increase in gas consumption than to a higher rate of population growth in both of these PAD districts.

This increasing trend in per capita gas use is due to both the increasing market share of gas and the spread to suburbia and can be expected to continue as long as the trend toward increased living space per person continues. The annual rates of increase in total residential/commercial per capita gas use are given in Table 8. The regional data follow a similar pattern. It should be noted, however, that the rate of increase is gradually diminishing. These data suggest that the sharpest increases have already occurred. Nevertheless, because of the large base that has developed, the actual quantities added remain large.

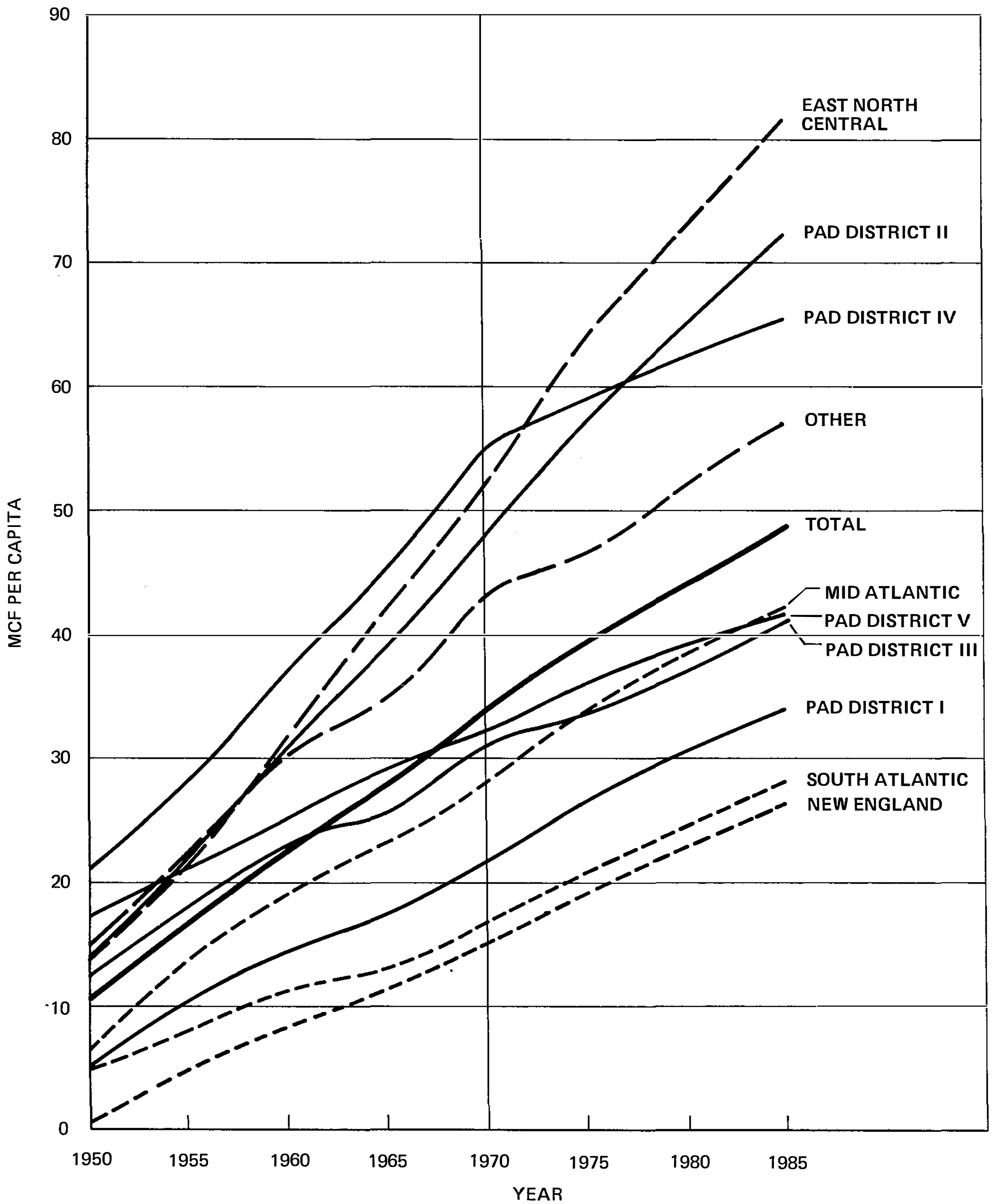


Figure 5. Residential/Commercial per Capital Gas Consumption for PAD Districts.

## TABLE 7

### RESIDENTIAL/COMMERCIAL PER CAPITA GAS CONSUMPTION BY PAD DISTRICT*
(Thousand Cubic Feet [MCF] per Capita)

| | 1950 | 1955 | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|---|---|---|
| PAD District I | 4.7 | 10.2 | 14.7 | 17.3 | 21.8 | 26.8 | 30.7 | 34.6 |
| New England | 0 | 4.7 | 8.1 | 11.0 | 15.1 | 19.2 | 22.7 | 26.4 |
| Middle Atlantic | 6.3 | 13.7 | 19.4 | 23.0 | 28.0 | 34.2 | 38.3 | 42.5 |
| South Atlantic | 4.5 | 7.6 | 11.2 | 12.6 | 16.8 | 20.8 | 24.6 | 28.4 |
| PAD District II | 13.9 | 21.8 | 31.1 | 39.3 | 48.8 | 57.7 | 65.3 | 72.9 |
| East North Central | 13.4 | 21.4 | 31.7 | 42.3 | 52.7 | 64.8 | 73.6 | 82.7 |
| All Other | 14.6 | 22.3 | 30.2 | 34.6 | 43.5 | 46.6 | 52.1 | 57.2 |
| PAD District III | 12.2 | 17.8 | 23.2 | 25.1 | 31.5 | 33.3 | 37.5 | 41.3 |
| PAD District IV | 20.9 | 27.6 | 37.3 | 45.4 | 55.7 | 59.4 | 62.7 | 66.0 |
| PAD District V | 17.0 | 21.1 | 25.2 | 29.3 | 32.3 | 36.4 | 39.2 | 41.7 |
| **Total** | **10.5** | **16.8** | **23.1** | **27.8** | **34.0** | **39.6** | **44.4** | **49.1** |

* Data through 1970 are based on population growth reported by AGA, *Statistical Abstracts*, and gas consumption reported by the Bureau of Mines. Data from 1975 are based on Base Case Projection and Series II-D population forecast.

## TABLE 8

### RESIDENTIAL/COMMERCIAL GAS CONSUMPTION AND SPACE HEATING GROWTH

| | Per Capita Gas Consumption (Million BTU's) | 5-Year Increase (Percent) Consumption | 5-Year Increase (Percent) Space Heating Customers |
|---|---|---|---|
| 1950 | 10.8 | — | — |
| 1955 | 17.3 | 60.2 | 69.0 |
| 1960 | 23.6 | 36.4 | 40.8 |
| 1965 | 28.6 | 21.1 | 26.1 |
| 1970 | 35.1 | 22.7 | 15.3 |
| 1975 | 40.6 | 15.6 | n.a. |
| 1980 | 45.5 | 12.1 | n.a. |
| 1985 | 50.8 | 11.6 | n.a. |

# Chapter Four

# ENVIRONMENTAL FACTORS

The impact of environmental control factors varies with each market segment and in some cases with geographical regions as well. Therefore, we have presented the discussion of environmental factors by market segment and, where necessary, by region.

## RESIDENTIAL/COMMERCIAL

Since relatively clean fuels are already being used almost universally in the residential/commercial market, compliance with air pollution control regulations will have very little impact upon the demand for fuel in this market segment unless environmental controls go to extreme levels such as requiring heating oil with sulfur content below 0.2 percent. Thus, fuel selection will depend largely upon the same factors that have governed the market in past years.

There is ample evidence that price is not the only factor governing the selection of fuels in this market. Such factors as convenience, dependability of supply, characteristics of fuel burning equipment and service requirements probably will continue to govern fuel selection in spite of some shift in relative fuel prices.

It appears that the assumption of adequate gas supply may apply to the residential/commercial market throughout the projected period.

Those gas utilities that have been forced to curtail gas sales have generally restricted industrial and other customers in order to ensure adequate supplies for their residential/commercial heating customers.

It is likely that reduced promotional efforts by the industry will result in a slightly reduced gas demand during the projected period. However, the present thrust of energy conservation appears to be directed by both industry and government toward the continued use of gas for residential/commercial uses at the expense, if necessary, of other uses. This serves to ensure the continued use of natural gas in these markets both for environmental protection and for consumer convenience.

## TRANSPORTATION

Virtually all of the gas used for transportation purposes is pipeline compressor fuel. These quantities have been reported in the base case and are not expected to change because of environmental considerations.

However, there is one development currently underway that is worthy of comment. An increasing number of gas pipeline compressor stations are operating on gas turbines which can be readily converted to the use of other fuels such as diesel fuel, naphtha or other light hydrocarbon oils. In these compressor stations, it is possible to substitute light oils for natural gas as a turbine fuel during periods of high gas demand. This has the effect of increasing the delivery of natural gas to urban load centers when pipeline capacity limits throughput by using these alternate fuels to drive the turbines. In effect, this permits more natural gas fuel to be burned in urban load areas while a corresponding amount of substitute fuel such as diesel oil is burned in the more remote compressor station. The overall effect of this development will be minor, although it may have significance in local areas.

The use of natural gas for motor fuel purposes is not expected to grow to significant proportions during the projected period. This is discussed in more detail in Chapter Six.

## ELECTRIC UTILITY

In contrast to the residential/commercial market, the electric utilities industry is perhaps the most price-sensitive fuel market. Many steam-electric power plant boilers are designed to burn more than one type of fuel and can readily switch from one to another as shifting prices favor their selection.

The recent enactment of air pollution control regulations has forced changes in the selection of fuels because of their emission products and also has drastically affected the cost of using the various competing fuels. It has placed a premium on the value of clean fuels which is reflected in the price of those unregulated forms that are free to respond to market demands. In 1970, the wholesale price indices of residual oil and coal jumped over 50 percent, an increase far greater than that of any other industrial commodity reported by the Department of Labor. This increase is shown in Figure 6, which compares the wholesale price indices of coal, oil and natural gas during the past several years. It should be noted that these are indices of current prices and not average prices paid for the quantities of fuel sold. Average fuel prices have only begun to show the effects of these new prices because of existing purchase contracts, but they can be expected to escalate toward the index prices. These price increases reflect the premium being paid for low-sulfur varieties of oil and coal and the increased cost of transporting them from more remote sources. It is not believed that they are temporary increases caused by a sudden disruption of the energy market. All of the long-range alternatives to current practices adopted to comply with pollution control laws appear to entail significant price increases.

These sharp increases in the price of residual oil and coal must quickly result in large increases in the demand for natural gas in the electric utility market if we assume that there are

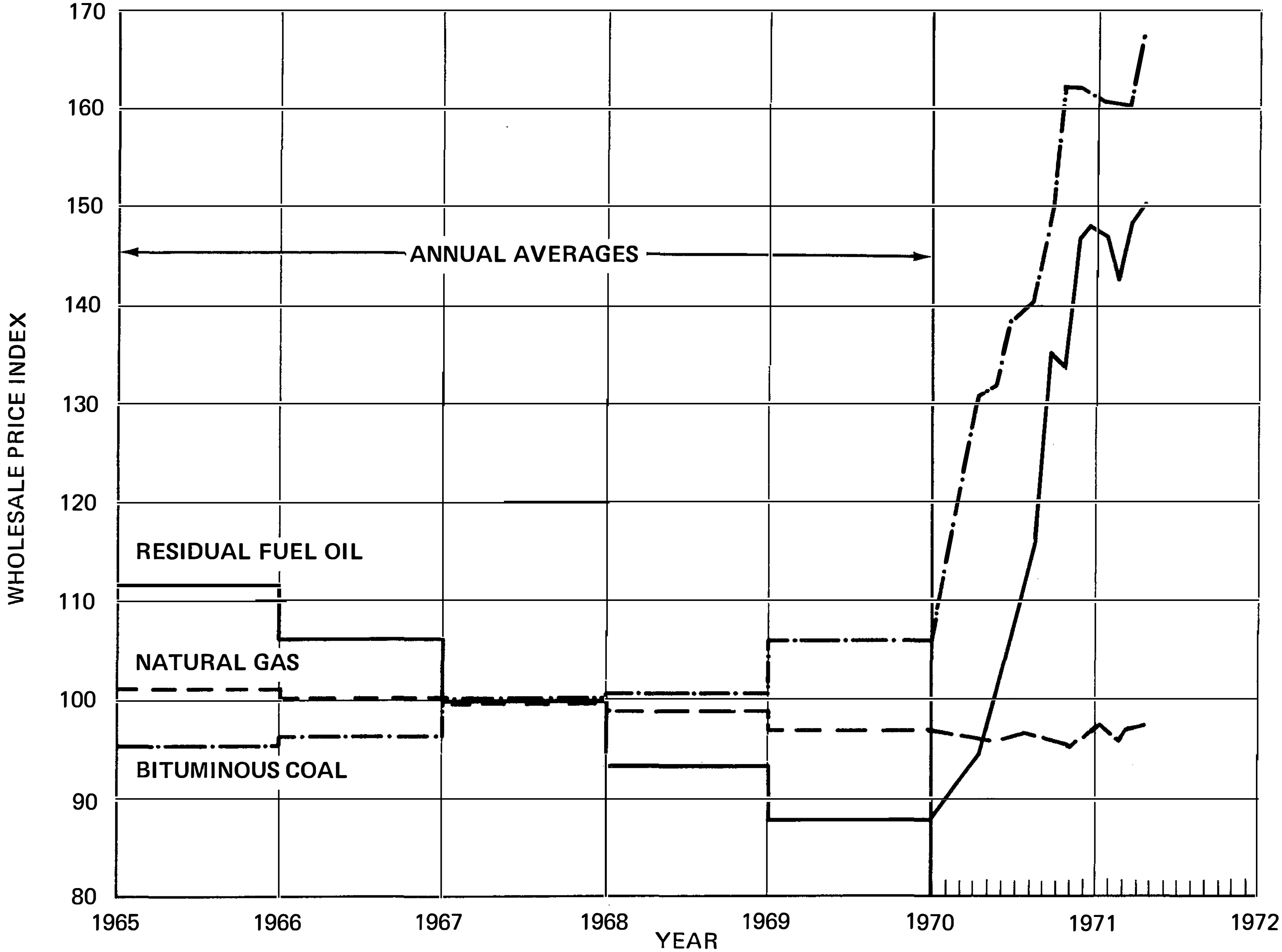


Figure 6. Relative Changes in the Wholesale Price Index of Fossil Fuels (Deflated by the Industrial Commodities Wholesale Price Index--Index 1967 = 100).

adequate supplies of gas available. Indeed, it might be expected that all of the coal and oil burning electric generating plants would convert as quickly as possible to utility gas if supplies could be purchased. If that were the case, there would soon be a demand for an additiona 10 trillion cubic feet (TCF) of gas annually, for that is the approximate gas equivalent of oil and coal presently consumed for electric generation. Obviously, all of this demand could not be met even if enough gas was available because of limitations on transmission facilities and the inability of many power plants to convert to gas immediately. Furthermore, low-sulfur strip mine coal, which is available in the western states at low cost, will be more attractive than either oil or gas for power plant fuel in and near those states where it is available. Thus, this increased demand due to the increased prices reported by the Bureau of Labor Statistics will generally be limited to those regions east of the Mississippi River where high-sulfur coal and oil are more commonly used. There is no way of estimating the portion of this potential demand that might be served if adequate supplies of gas were available. It is an academic question in any case.

It may be more significant to note that, if the price of natural gas were increased by the same amount that the prices of low-sulfur residual oil and low-sulfur coal have increased, then the relative price of natural gas would be restored to the position it held before air pollution controls created a premium value for these clean fuels. The demand for natural gas in the electric generation market would then be represented by the base case projection which assumed no change in relative prices.

If the price of gas is increased sufficiently to clear the market and bring demand and supply into balance, it will be necessary to raise the price of gas by more than the increases that are occurring in oil and coal prices. Only in this way can the relative price of gas be increased and the demand for it be reduced to the levels of available supplies.

## INDUSTRIAL USES

The effect of environmental factors upon the demand for natural gas in the industrial market is more complex than in the electric generation market. Although the same shifts in fuel prices are present, certain industrial fuel applications are relatively insensitive to price, while others such as large industrial boilers are more comparable to the electric generation fuel market. In addition, there are new demands for gas for such uses as fume incineration and liquid and solid waste disposal. In the glass and non-ferrous metals industry, many gas-fired melting furnaces are being replaced by electric melting to eliminate the product fumes and dust that are discharged with exhaust gases from the furnace.

Small industrial boilers have much less flexibility in fuel selection than large boilers and can afford to pay higher premiums for gas fuel. They cannot afford the high capital costs of fume control equipment, and, since fuel costs are a relatively smaller cost, they can better afford to pay for higher priced gas than to install precipitators, filters or sulfur removal equipment in order to burn coal or oil. Thus, the small and medium industrial boiler operator will continue to demand gas, and in some areas he may have no suitable alternative.

A similar situation exists in many industrial processes that have been designed around the use of a particular fuel and cannot readily be changed. A conveyorized production drying oven, for example, may incorporate banks of infrared gas burners. Such burners cannot be switched to other fuels. Even electric infrared burners would usually require complete redesign of the production line. The use of gas for annealing in the metals industry is another rigid gas application because of the atmosphere control required to maintain product quality.

In the area of waste incineration, gas is one of the more expensive methods of eliminating pollution and has not been used wherever cheaper methods can produce acceptable results. As requirements for environmental control become more stringent, increased demands for gas are anticipated to dispose of various types of industrial waste materials.

As pollution controls are enforced, gas acquires an additional value. It can be used without the addition of mechanical equipment to control emissions of sulfur and particulate matter. Industrial plants that must shut down due to failures of this mechanical equipment incur additional costs which are reflected in the relative value of gas to other fuels. Also, delays in the startup of new equipment and plants because they lack approval of pollution controls can create an additional cost burden. This tends to shift the breakeven price of fuel in favor of gas.

A detailed examination of the net effect of all of these various influences is beyond the scope of this study. No comprehensive study of the problem as it pertains to the demand for pipeline gas has yet been made. Historical data on industrial gas usage cannot be relied upon because the impact of pollution control is too recent to be accurately reflected in reported statistics.

Although environmental considerations may tend to reduce gas demand in some applications, the expected overall effect is to increase the demand significantly. Some of this potential demand may not materialize because of supply limitations. Some of it is already included in the base case projection. While a quantitative estimate of this demand in relation to the base case cannot be made, it is believed to be a firm demand that will resist erosion due to relative price increases.

# Chapter Five

## EFFECTS OF FUEL PRICES

A survey of the literature indicates that most if not all forecasters see the future trend of fuel and energy prices moving upward. Such forecasters are projecting increases in prices of all forms of energy.

Although price estimates generally include consideration of current inflationary pressures, they also reflect additional real costs that are due to one or more of four general causes:

- The additional costs associated with finding and producing new fuel supplies from greater depths and in more remote or difficult terrain
- The additional costs of bringing new fuel supplies to market from more remote locations
- The costs of additional refinement and modification of raw fuels to meet more demanding market conditions
- The increasing costs of capital and labor.

It would be difficult enough to quantify the impact that these future fuel prices will have on gas demand if they could be precisely estimated. The broad ranges that must be given at the present time preclude any attempt to estimate the price differentials that might exist during the projected period. Therefore, it is necessary to confine this discussion to the pricing trends that are evident, noting those relationships that are likely to prevail during the foreseeable future.

It has already been noted that coal and oil prices have increased relative to gas prices where sulfur content is a factor in fuel selection. Thus, the relative price of gas is lower than it was compared to these other fuels, and potential demand is higher even where it cannot be supplied. As time goes on, the price of gas must increase as wellhead prices are increased and as more expensive alternate gas supplies are added to the mix of gas that is distributed. However, other fuel prices will be increasing also.

While fuel prices cannot be predicted very far into the future, it is apparent that residential fuel prices will gradually escalate during the projected period, primarily because of the increasing costs of labor, capital and capital equipment. Since all of the energy industries are capital-intensive, it is expected that the price of the different forms of energy will all tend to rise together. The expenses of transporting and distributing the fuel to the customer account for about 75 to 80 percent of the price paid by the residential user for fuel. These costs will increase as capital and labor costs increase. Production of the fuel in the field accounts for only 20 to 25 percent of the price. Thus, because fuel production costs represent only a minor part of the retail market price, residential fuel prices will not increase proportionately as supply costs increase.

Among existing users, the premium has a higher value to gas users because of the cost which would be incurred if these users would have to convert to other fuels. The premium has a lower value to other fuel users because of the cost of converting to gas. This creates a stabilizing effect in that existing users would maintain their present fuel form unless there is a sufficient change in price to offset the conversion costs. To discourage existing industrial gas uses by increasing price, it is necessary to increase the price of gas by more than the increases occurring in competitive fuels plus the premium value, including the cost of conversion as well. If this is done, the demand would be reduced and, in time, the market would be cleared.

The amount of this premium may vary considerably in different applications due to local conditions and the values placed upon various factors by the user. It is not possible in this report to give detailed consideration to specific situations that exist. No comprehensive study has yet been made that would provide an estimate of the overall effects of these changing values. In general, the premium has a positive value--the market price of gas is higher at the breakeven value to the user. Moreover, it is increased by the enforcement of air pollution controls as discussed in the preceding chapter.

In the industrial market, it is generally believed that gas can compete with other fossil fuels at a price premium. This premium is created by the additional costs associated with burning other fuels, costs which are not incurred when burning gas. These additional costs result from heating of oil lines to improve atomization and flow characteristics, stack cleanup and fuel handling facilities for coal, fuel storage and inventory costs for both coal and oil, and maintenance. It is necessary to consider these additional expenses incurred in the use of each fuel in determining the relative costs to the user on an as burned fuel cost basis. When this is done, the market price of gas may be higher at the breakeven point than the market price of other fuels.

It does not appear that the regulated price of natural gas will be allowed to rise to the levels required to clear the market very soon. It is only through the addition of other higher cost sources of gas that the average price of gas can escalate to values that will begin to reduce the demand. Since these sources are developing slowly and there is reluctance to increase the wellhead price of gas by large amounts, it is not anticipated that gas prices will rise sufficiently above other fuel prices to bring demand and supply into balance before the end of the projection period.

## Chapter Six

## TECHNOLOGICAL ADVANCES AND IMPROVED UTILIZATION EFFICIENCY

The growing energy crisis has already caused a major redirection of the trend of energy technology. Research laboratories are finding that projects seeking to increase fuel supplies or to improve the efficiency of the utilization of energy are more readily sponsored than those seeking to obtain a larger share of the market for a particular fuel. The emphasis is now placed almost entirely on fuel economy and energy conservation. At least one large research project studying the increased use of natural gas in blast furnace operations of the steel industry has been shelved because of the growing gas shortage. The curtailment of industrial gas consumption has encouraged industrial users to review their energy applications more critically with a view toward economizing and, in some cases, eliminating unnecessary fuel consumption. As the trend of increasing costs for all forms of energy continues, it can be expected that much more attention will be paid to the conservation of energy.

As a result of these developments, the future impact of current technology will tend to reduce the consumption of gas, particularly in the residential/commercial and industrial market segments. However, the resulting effects upon future gas demand will be slow in developing for two reasons. First, this redirection of effort is of recent origin, and the projects going forward are in their early stages. It will be several years before the results of this redirected technology appear in commercial products. Second, in addition to the time required for the development of new equipment, more time must be allowed for these new devices to be produced in sufficient numbers to influence the total demand for gas.

Time is required to build up a gas load from a new appliance or gas consuming device. Assume--for example--that a new product, one which is 20 percent more efficient, is placed on the market and that the sales of this appliance increase to a maximum in 5 years declining at a 10-percent per year rate thereafter. In this case, a certain level of annual appliance sales would be achieved. If the appliance uses only 80 percent of the fuel required by a previous model, a corresponding reduction in gas consumption of the total number of these new appliances would occur. It can thus be anticipated that 10 to 15 years would be required after a new gas consuming device is placed on the market before the full effect of its gas consumption characteristics can be felt. Thus, the full effects of the technology now being developed may not be felt before 1980 or even later.

### RESIDENTIAL MARKET

During the next decade or two, the most significant changes in energy use may stem from the development of residential dwellings as an overall system. The technology of home heating and cooling equipment in gas appliances has been well developed over the years, and it appears that only minor refinements and adaptations are likely to be developed in the individual appliances themselves. However, the changing technology in home construction, particularly in the areas of modular houses and mobile homes, may have a significant impact upon the future gas demand.

As increasing attention is given to the conservation of fuel during the next 20 years, more attention will be paid by the builder to the details of house construction that contribute to more economical use of heating energy. We can expect to see more tightly sealed houses and more heavily insulated walls in order to reduce heating loads. The increasing numbers of modular homes and mobile homes, where more engineering effort can be applied to the details of house construction, will accelerate this trend. There is a growing trend toward exterior installation of heating and cooling equipment to increase available living space. Under these circumstances, it is relatively easy to keep the combustion air circuit outside of the living space, transferring only the heat to the interior. This eliminates the venting of heated air through the combustion system during the off cycle of furnace operation. Such equipment has already been developed and applied in the commercial market and is now being produced for the residential builder as well. As the cost of heating fuel increases, we can anticipate that heavier and more effective insulation will be used in walls, floors and ceilings. The increasing use of air conditioning encourages such insulation because the higher insulation costs can be offset by savings in cooling load as well as heating load. More general use of double glazing can be anticipated in order to reduce condensation on window panes during extremely cold weather where central humidifiers are used.

## INDUSTRIAL GAS USES

The growing shortage of clean fuels and the projected increases in fuel costs will provide additional incentives for industrial plant engineering staffs to examine and improve the energy utilization practices within their plants. Some of the steps that they may take are as follows:

- Install additional control equipment to maintain closer control of combustion processes.
- Install heat recovery devices on combustion equipment to use exhaust heat for water heating or steam generation.
- Install heat exchangers to transfer heat in waste water streams to incoming city water that must be heated for processing.
- Add automatic controls to turn furnaces on and off as required. Workers will often leaving heating equipment running when not needed to avoid relighting.

- Perform maintenance work to replace deteriorated insulation and close air and heat leaks in furnaces and ovens.

- Replace window glass, tighten building structures and add insulation to reduce space heating loads.

- Install more efficient heating devices such as infrared burners in place of convection heaters to improve heating efficiency.

- Modify production procedures to minimize reheating of work.

- Rebuild furnaces for better adaptation to production processes.

The extent to which these and other practices may be employed will depend on the amount of price increases and the degree of curtailment imposed on industrial fuel users. Experienced industrial gas sales engineers have stated that at least a 10-percent reduction in gas consumption should be attainable in an average industrial plant. The industrial use of gas per customer has grown at an average annual rate of about 2.3 percent during the past 10 years, increasing by 26 percent during the decade. Assuming that a 10-percent reduction could be achieved during the next decade, this growth rate would be decreased to 16 percent if no new industrial customers were added. If it is assumed that new customers are added at more efficient utilization rates, this 10-percent reduction would be achieved at a later date for the entire industrial market, including new customers. If it is assumed that a 10-percent reduction could be achieved for the entire market by 1985, industrial gas requirements would be reduced by approximately 1,780 trillion BTU's. This would reduce the total gas requirement by approximately 4.3 percent.

This reduction in gas consumption is based on an overall view of the general practices that can be employed. In some of the more energy-intensive industries such as the steel industry, there are opportunities to reduce the consumption of gas by significant amounts through changes in process technology. While each individual industry cannot be examined in detail, the steel industry can be discussed as an example of the potential developments in these energy-intensive industries.

In 1970, the steel industry consumed 594 trillion BTU's of natural gas, amounting to about 18 percent of the total consumption of energy by the steel industry and almost 7 percent of the industrial gas load in the entire country. The use of natural gas has been growing at an average annual growth rate of over 5 percent during the past decade, while the production of steel has increased at an average rate of only 2.8 percent per year. However, the use of fuels for many applications in the steel industry is quite flexible, and the growing concern for future gas supplies is already guiding technology in directions that will conserve the use of natural gas.

The most energy-intensive process in the steel industry is the operation of blast furnaces for the production of iron. This process consumes approximately 18 million BTU's of energy per ton of iron produced. At the present time, natural gas provides only about 0.5 million BTU's of that total, and coke provides almost 16 million BTU's. Metallurgical grade coke presently costs approximately $35 per ton or more. There has been active interest in reducing the coke rate in a blast furnace by injecting other fuels such as natural gas, fuel oil and coke oven gas in order to reduce the quantity of coke required and to improve the productivity of the blast furnace process.

At present, natural gas supplies about 60 percent of the fuel injected for this purpose, or about 50 billion cubic feet annually. This amount can be expected to increase in future years to 100 billion CF or more in the absence of any restrictions on the use of natural gas. However, at least one research and development project aimed at increasing the use of natural gas in blast furnaces has been shelved because of the future outlook on gas supply. It is now believed that this level of consumption may remain fairly static or may even decline if steel mills consider other uses for natural gas within the mill to have higher priority over gas use in blast furnaces.

Of the three principal methods of melting steel, the open hearth furnace makes the most extensive use of gas. The basic oxygen and the electric arc furnace use less amounts, mostly for auxiliary services. Open hearth furnaces, because of their relatively low productivity and high capital investment, are gradually being replaced by basic oxygen and electric furnaces. As these furnaces are phased out, the use of natural gas for steel melting will gradually decline (see Table 9).

**TABLE 9**

**EFFECTS OF TECHNOLOGY ON GAS DEMAND IN THE STEEL INDUSTRY**
**(Trillion BTU's)**

| | Change in Annual Consumption Due to Technological Changes | | |
|---|---|---|---|
| | 1975 | 1980 | 1985 |
| Scrap Preheating | + 0.2 | + 1.0 | + 2.5 |
| Continuous Casting | - 10 | - 7 | - 6 |
| Steel Melting | - 16 | - 23 | - 8 |
| Steel Reheating | - 5 | - 24 | - 58 |
| Elec. Induct. Heat | - 2 | - 6 | - 11 |
| **Total Reduction in Steel Making** | **- 29.2** | **- 41** | **- 25.5** |

The growing use of continuous casting will also tend to reduce the requirements for natural gas in the steel industry. At the present time, about 12 percent of the steel production capacity is based on continuous casting methods, and this is expected to grow to about 20 percent of capacity by about 1980. Continuous casting is limited to less critical quality steel because of the inability to control quality as closely as in conventional batch production. Since this process eliminates the need for soaking pits, and to some extent the need for reheating large billets and slabs, it permits a net reduction in fuel consumption of about 1.5 million BTU's per ton of steel. The resulting reduction in gas use from this development is presented in Table 9, based on the assumption that 40 percent of the fuel used is natural gas.

One of the major applications for natural gas in the steel industry is for the reheating of steel for rolling and forming. While other fuels can be used, natural gas is presently used for about 60 percent of the reheating required for billets and slabs and about 40 percent of the fuels used in soaking pits. Some significant reductions in the consumption of natural gas for this purpose is foreseen due to improvements in the efficiency of the utilization of gaseous fuels in reheating furnaces. The present trend is toward increased sophistication in the control and programing of reheating furnaces and toward increased use and improved design of recuperators for conserving and utilizing the exhaust heat from these furnaces. The anticipated reductions in gas use for this purpose are also presented in Table 9.

Some additional reductions in demand for natural gas may be brought about through the increased use of electrical induction heating in certain special applications of steel working. It is expected that induction heating will reduce gas consumption for slab and billet heating by about 5 percent by 1985. The high capital cost of electric generation equipment and the demand for electric generating capacity will serve to restrict deeper penetrations of induction heating into this market.

In contrast to these reductions in demand for natural gas, the increased use of basic oxygen furnaces and electric arc furnaces requires a greater amount of preheating of steel scrap in order to improve the productivity of these new furnaces. Natural gas is a very desirable fuel for this purpose since it minimizes the pollution by incinerating the fumes produced from heating dirty and oil covered scrap. By 1985, a total net savings of 255 trillion BTU's of gas is anticipated. It should be pointed out that this is not a net reduction in gas use, but only a reduction from the level that would otherwise exist. If the current rate of gas consumption in the steel industry remains constant, an additional 108 trillion BTU's will be required by 1975 to supply normal growth. This is considerably larger than the savings of 29.2 trillion BTU's projected by 1975. Even though the technological savings reach 25.5 trillion BTU's by 1985, it is still far below the increasing demands for natural gas in the steel industry.

## MOTOR FUEL USE

Some interest is being shown in the use of natural gas as a motor fuel for the purpose of reducing exhaust pollution. Potentially, this could increase the demand for natural gas in the transportation market.

The use of natural gas in place of gasoline reduces the exhaust emissions from an automobile to as little as 15 percent of the level produced with gasoline, the exact amount of reduction varying with the specific pollutant, as well as with the operating conditions and equipment installed. The ability of natural gas to reduce harmful exhaust emissions has been amply demonstrated by over 3,000 automotive vehicles that have been converted to natural gas use.

However, the Nation is committed to a program reducing emissions from gasoline-fueled cars to meet acceptable standards by 1976. While there is presently some question as to what emission levels can be achieved and what will be accepted in 1976, there seems little doubt that some acceptable agreement will be reached. Until then, there is little incentive for the vehicle owner to adopt some other device, such as gas fuel, except for economic reasons. At the present time, the economics are conducive to the use of gas fuel only in certain geographical regions where there is favorable tax treatment and where gas prices are relatively low. The cost of converting an existing vehicle may range from $300 to $1,000, depending upon the system selected and the modifications made to the vehicle.

In view of these costs and other deterrents, it is anticipated that there will be few large scale conversions of automotive vehicles to the use of natural gas even for commercial fleets in urban areas unless the automotive industry is unable to meet reasonable pollution standards for these areas.

## CONCLUSION

The effects of increased utilization efficiency and improved technology upon future gas demand will be minor in comparison to other influences, and the net effect will be to reduce the total gas requirements presented in the base case by about 5 percent. Greater decreases are projected for individual market segments, but these decreases become diluted when considering their effect upon total gas requirements.

## Chapter Seven

# DISTRIBUTION OF AVAILABLE GAS SUPPLIES

Thus far, the discussion of future gas demand recognizes that the present price picture may not be altered sufficiently or in time to restore a balance between supply and demand within the projection period. This leads to the question of how much of the demand can be supplied and how that supply should be distributed.

Those utilities that have been forced to curtail gas deliveries to customers have generally done so by interrupting large industrial customers for short periods of time. This has been done on an emergency basis when the utilities have experienced deliverability problems during periods of unexpected high demand. Utilities seek to avoid such interruptions by declining to attach new industrial customers and by limiting the supply of gas to existing customers whose demands may have increased. The nature and extent of these restrictions varies with the particular region involved and according to the degree of curtailment required.

A statistical description of how this problem is being treated by the utility industry can be obtained from an examination of the operational estimate presented in the 1971 FRC report.* This estimate was prepared from questionnaires circulated to gas companies throughout the country. The initial effort made for the FPC included 38 standard metropolitan statistical areas, and that data base was expanded by FRC in preparing its 5-year operational estimate.†

Respondents were asked to forecast their gas requirements, recognizing the current and near-term gas supply situation, for each market segment during the 5-year period 1971-1975. A summary of the data obtained is presented in the 1971 FRC report and is reproduced in Table 10.

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* FRC, *Future Natural Gas Requirements of the United States*, Vol. No. 4 (October 1971).

† FPC, Bureau of Natural Gas, *Summary and Analysis of the Future Requirements Committee Special Survey of Gas Requirements in 38 of the Largest Standard Metropolitan areas and Alternate Fuels Required to Alleviate Gas Deficiencies* (February 1971).

## TABLE 10

### NATIONAL REQUIREMENTS VERSUS OPERATIONAL ESTIMATE (TCF)

| Class | 1970 Actual | 1975 Requirements | 1975 Operational Estimate | 1975 Difference TCF | 1975 Difference Percent |
|---|---|---|---|---|---|
| Residential | 4.94 | 5.87 | 5.75 | 0.12 | 97.9 |
| Commercial | 1.96 | 2.57 | 2.42 | 0.15 | 94.1 |
| Industrial | 5.94 | 8.25 | 7.04 | 1.21 | 85.4 |
| Electric Utilities for Power Generation | | | | | |
| Firm | 1.92 | 2.67 | 2.36 | 0.31 | 88.4 |
| Interruptible | 2.00 | 2.79 | 1.66 | 1.13 | 59.6 |
| Interruptible | 3.09 | 4.39 | 3.60 | 0.79 | 82.0 |
| Other | 1.58 | 1.94 | 1.77 | 0.17 | 91.5 |
| **Total** | **21.43** | **28.48** | **24.60** | **3.88** | **86.4** |

It can be seen that the gas industry expects to serve 98 percent of the residential load requirements and to curtail the interruptible electric generation load most severely by reducing it to 60 percent of the original requirement. Overall, the industry expects to supply about 86 percent of the total base case requirements (excluding field use) in 1975.

This estimate is made only to the year 1975, and the uncertainties of supply, energy policy, regulatory matters, etc., suggest that it should not be extrapolated very far beyond 1975. No regional breakdown of this estimate is provided for the various market segments, although totals are given by FRC regions. However, the initial study done for the Federal Power Commission does provide a regional breakdown by market segment. The data presented in both reports are used to provide a basis for estimating the anticipated distribution by PAD district and market segments defined in this study (see Table 11). The percentages presented in Table 11 are slightly different from those given in Table 10 because the data have been regrouped to conform to the NPC categories, and only the residential/commercial, industrial and electric utility market segments are totaled. No data are available to estimate the transportation and raw materials and other categories.

It should be recognized that these percentages are based upon data of variable quality and detail. The operational estimate is a first attempt by the FRC to measure the impact of the present and near-future gas supply situation on the ability of the gas industry to meet gas requirements for the next 5 years.

TABLE 11

PROJECTED AVAILABILITY OF GAS AS A PERCENTAGE OF BASE CASE REQUIREMENT IN 1975

| | Residential/ Commercial | Industrial | Electric Utilities | Total |
|---|---|---|---|---|
| PAD District I | 97.8 | 84.7 | 85.9 | 90.9 |
| New England | 97.0 | 92.2 | 100.0 | 96.0 |
| Middle Atlantic | 97.5 | 80.1 | 64.2 | 88.4 |
| South Atlantic | 98.7 | 87.7 | 98.7 | 92.9 |
| PAD District II | 95.0 | 81.4 | 34.1 | 79.7 |
| East North Central | 93.4 | 78.6 | 24.3 | 80.0 |
| All Others | 98.6 | 86.4 | 40.7 | 79.2 |
| PAD District III | 100.0 | 99.3 | 98.8 | 99.2 |
| PAD District IV | 100.0 | 100.0 | 31.4 | 91.9 |
| PAD District V | 100.0 | 75.0 | 47.1 | 74.6 |
| **Total** | **96.8** | **83.2** | **76.5** | **85.7** |

As additional data are developed and more details become available, it can be expected that the percentages may change. In addition, changes in the basis for distributing the available supplies may require revision of these estimates.

# Appendices

APPENDIX A

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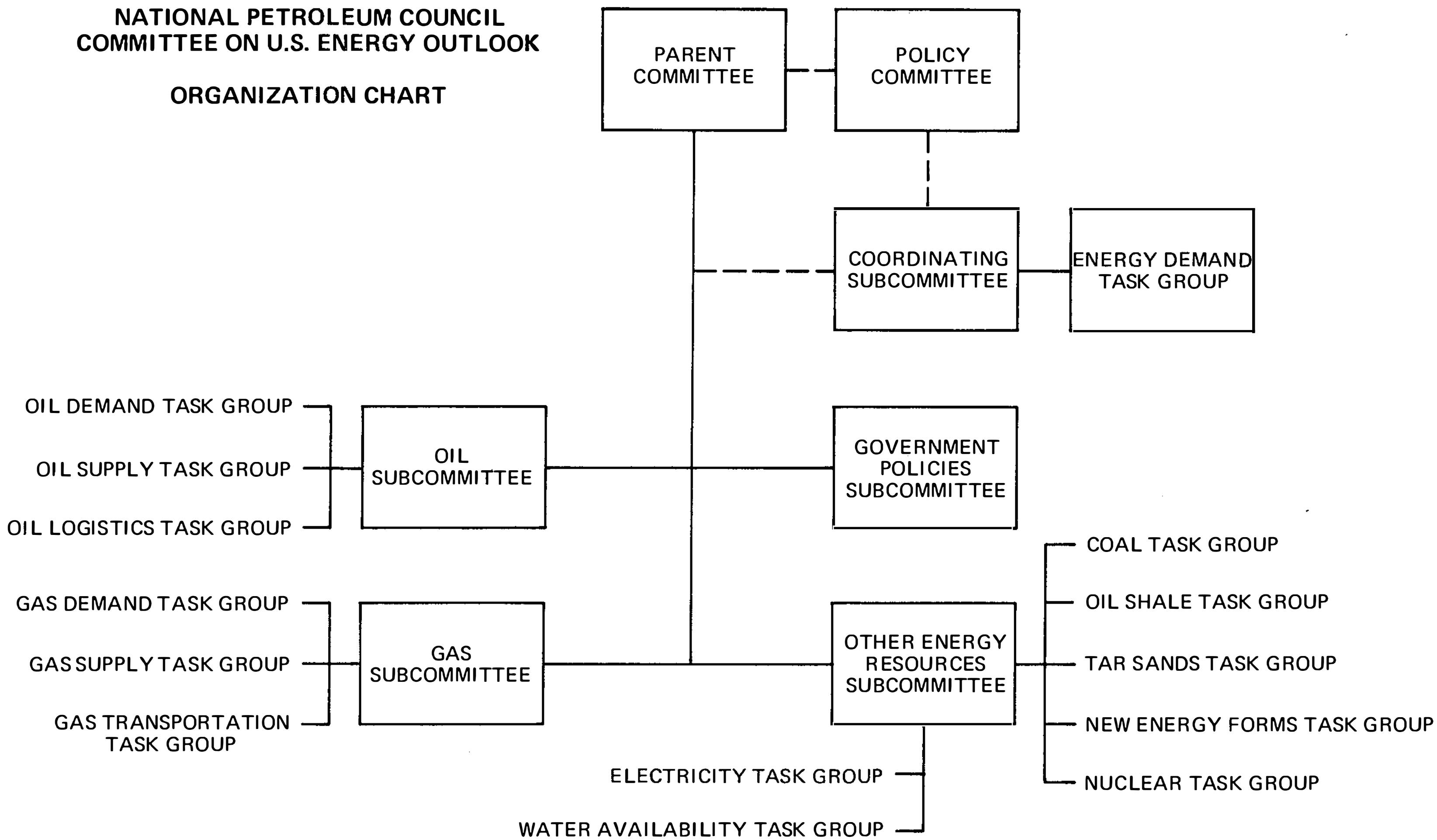

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* Served until December 15, 1972; replaced by Duke R. Ligon.

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