**Energy Availabilities for State and Local
Development: A Methodological
and Data Overview**

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OAK RIDGE NATIONAL LABORATORY

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A METHODOLOGICAL AND DATA OVERVIEW

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Energy Division

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ABSTRACT

This report presents the methodology utilized by ORNL staff on a research project funded by the Economic Development Administration to determine energy resource extraction, energy production, and energy use for seven fuel types and four final consuming sectors for Bureau of Economic Analysis (BEA) areas and states for the years 1972, 1973, and 1974. The basic approach used to assess regional energy availability involved the collection and organization of data on a county or field basis, and the subsequent aggregation of this data to BEAs and states. For energy use data, the approach was to allocate state level data to county groups which could then be assembled into BEAs.

This report also describes the methodology used to forecast regional energy conditions in 1980 and 1985 consistent with the *1976 National Energy Outlook* of the Federal Energy Administration.¹ Energy use was projected using an allocation procedure based on projected levels of population and employment. Regional energy availability was projected based on historical energy supply patterns. In addition, the report discusses the format of the data volumes that will be subsequently released, as well as the proposed activities scheduled for completion during the third year of the EDA project.

I. INTRODUCTION

A. Purpose of Report

This report describes an ongoing research program sponsored by the Economic Development Administration at the Oak Ridge National Laboratory to construct regional statements of state and substate energy use and availability. The purpose of these statements is to create a nationally consistent medium for monitoring and projecting changes in energy delivery and consumption patterns that may affect regional economic development. Particular emphasis will be placed upon key energy forms whose shortage may inhibit economic activity or constrain new development.

This report also presents our progress thus far in the project. During the first year of the program, ending June 30, 1976, we concentrated on establishing the methodology required and collecting the necessary data for 1972. During this second year of the project we have collected data for 1973 and 1974 and focused on the development of regional energy statements and their incorporation into a projection methodology capable of assessing future energy uses and availabilities.

B. Background to Research Problem

Interest in substate energy use and availability has grown significantly in recent years. Barring a second international oil embargo, or similar exogenous event, the national economy can accommodate marginal changes in energy supplies and prices. The problem which arises is that minimal national changes are frequently distributed unequally among subnational areas. Marginal decreases in the production or availability of particular fuels often represent distinct shortages among some subnational regions. Solutions designed to remedy these energy shortfalls are also likely to be concentrated with regard to impacts. Thus, a regional evaluation of energy-related economic impacts appears appropriate and timely to assist the Economic Development Administration in developing its grant-in-aid investment strategy.

The analysis of regional economic development and its relationship to the availability of energy requires a substantial adaption of the economists' standard tools, largely due to the inadequacy of existing regional energy data bases. The state of the art in energy consumption data analysis remains at a relatively low level. For example, it is still difficult to trace energy supplies from point of extraction to final use due to the diversity of marketed energy forms, production intermediaries, and final users. Available information is frequently decentralized, incomplete, and even when gathered, inconsistent. Thus, to conduct meaningful regional analysis, a significant effort is necessary to construct an adequate regional energy-economic information base.

The lack of sound information sometimes leads to the development of well-defined methodological techniques that can be used to overcome data shortfalls. Although these tools are becoming operational at the national level, the "trickle down" process to link regional energy issues and regional economic activity with national trends has yet to be fully developed.² To construct a suitable regional analysis system we have focused on basic elements and on the particular way in which the composition is likely to affect energy usage at the regional level.

As a result, we have developed a consistent format for gathering and estimating national energy data on a regional grid. Moreover, we have developed a viable structure for making regional projections of energy use and availability. A primary objective has been to empirically link existing data structures with economic activity and to subsequently apply this system to identify possible structural energy shortages at a subnational level.

C. Organization of the Report

The remainder of the report is divided into four major chapters. Chapter II presents an overview of the methodological design developed to guide the research project. The section includes a statement of project goals, a summary of data items and spatial grid, and a brief examination of the manner in which energy uses and availabilities will be projected and analyzed. Chapter III discusses the data sources and conventions used in constructing the information sets for energy forms and fuel sources. Chapter IV discusses the energy use calculations. Because less data is available for energy use than for energy production at the substate level, we have set out the steps used to generate these statistics in some detail. Chapter V contains an evaluation of our work to date as well as anticipated progress during the third year of the program.

II. A METHODOLOGICAL OVERVIEW

A. Research Goal

The goal of this research is to develop a regional energy procedure to analyze historic and projected regional differences in the demand and availability of energy. This procedure is essential in order to make valid historic, current, or projected comparisons among regions.

To achieve the desired level of consistency of treatment of both historic and forecasted data would require considerable resources. Since such resources are not available in the current project, several simplifying assumptions were made to develop our methodological approach, as will be explained below.

B. Summary of Information Detail

The procedure developed is designed to report seven energy forms for four final consumption sectors across a regional grid, as shown in Table 1. This should provide sufficient detail for a comparison of regional energy patterns. In addition, five fuel sources are considered, though for coal and gas the fuel source and form are essentially identical. Energy forms are defined as products that serve energy end uses. Fuel sources are defined as inputs to energy forms. In addition, three transformation sectors are considered: (1) petroleum refineries, which transform crude oil into petroleum products; (2) natural gas processing plants, which transform natural gas and lease condensate into LPG, propane, and other products; (3) electric utilities, which transform coal, natural gas, uranium, hydro-power, and several petroleum-based energy forms into electricity.

The aggregation of consuming sectors chosen for this analysis generally corresponds to that used by the Bureau of Mines.³ Although other combinations were possible, we chose to combine residential and commercial users to be consistent with the Bureau of Mines. Combining sectors also facilitated the use of the aggregated forecasts of the Federal Energy Administration (FEA) as control totals. The transportation sector is treated separately because of its relative importance as an energy user. More detail by fuel and by sector than reported has been utilized in the empirical analysis. The level of detail retained is, however, constrained by the availability of historic data from the Bureau of Mines and the level of aggregation of forecasted data from the FEA scenarios. Because of the differences in the level of detail in each data set, the reporting units listed in Table 1 were selected as being most appropriate for reporting both the historic and forecasted data on a consistent basis.

The regional grid chosen for this analysis is Bureau of Economic Analysis (BEA) areas, developed by the Department of Commerce.⁴ Two considerations governed this choice: (1) it is a goal of the analysis to

Table 1. Summary of Information Detail

A. Classification of Fuel Sources and Energy Forms

5 Fuel Sources

Coal
Natural Gas
Crude Oil
Uranium
Hydropower

7 Energy Forms

Coal
Natural Gas
Distillate Oil
Residual Oil
Gasoline
Other Petroleum Products
Electricity

B. Classification of Transformation and Final Consuming Sectors

3 Transformation Sectors:

Petroleum Refineries
 Convert Crude Oil into
 Petroleum Products

Natural Gas Processing Plants
 Convert Natural Gas and
 Lease Condensate into
 Natural Gas Products

Electric Utilities
 Convert Uranium, Hydropower,
 Natural Gas, Coal, and Several
 Petroleum Products into
 Electricity

4 Final Consuming Sectors:

Residential, Commercial,
 and Agricultural

Manufacturing and Mining

Transportation

Miscellaneous Uses

project future levels of energy consumption using an ORNL employment-population projection system (MULTIREGION⁵) that operates on the BEA spatial grid; and (2) BEA areas conform closely to the concept of load centers commonly applied in electricity consumption analysis.

These 173 BEA areas (shown in Figure 1) can be easily disaggregated by county groups into 250 BEA portions, referred to as subregions, which are consistent with both BEAs and states. These areas are generally smaller than various types of homogeneous regions such as Petroleum Administration Districts, Coal Provinces, or heating degree day areas, familiar in other energy accounting systems. BEA areas conform purposefully to labor market boundaries and are thus well suited to an analysis of energy and economic development. Moreover, the selected grid is based on a system of functional economic regions for which reliable economic data is available.

C. Regional Energy Statements

Regional energy statements are an accounting of energy flows within a spatial unit during a period of time. Annual flows are used for the purpose of this study. Conceptually, such a statement might be prepared in a number of units—physical units, dollar values, thermal equivalent units, etc. We have chosen to gather the basic information in terms of physical units. This choice was dictated primarily by data availability, and we will convert these quantities to thermal equivalent units (BTUs) in the regional energy statements. Using this accounting format, we will analyze energy at the point of extraction, points of processing, and points of final consumption using both historic and forecasted values. Additional detail regarding the conventions adopted in preparing these statements is described below.⁶

D. Projecting Regional Energy Use and Availability

To project future regional energy consumption at the appropriate grid and analyze the manner in which these needs will be met, we will project regional energy use through a system which allocates national control totals of energy use to regions using socioeconomic activity measures. These measures, such as employment levels, are consistent with those used in generating the national energy control totals. With allocations of demands complete, we then analyze alternative ways of satisfying projected demands. This contrasts with the more traditional econometric method of estimating demand and supply relationships separately, and imposing equilibrium conditions through a price adjustment mechanism.

This ORNL approach has been adopted for several reasons, most of which center around the inherent difficulty of constructing a spatially distributed general equilibrium model: (1) sufficient information to conduct traditional econometric demand analysis is not available at a detailed regional grid level; and (2) it is difficult to construct a

Figure 1. BEA Areas in the United States.

spatial supply analysis which permits disequilibrium solutions. Thus, we intend to project energy use based upon the composition of socio-economic activities and then analyze the supply system as it is structured to respond to desired levels of energy use.

a. Projecting Energy Use

Four steps are involved in projecting regional energy use:

1. Choose a national economic scenario;
2. Choose a national energy use scenario;
3. Regionalize the economic scenario;
4. Regionalize the energy scenario based on regional economic and population levels.

Although these steps are conceptually separate, they combine the results from several economic models and must be carried out consistently. It is particularly critical that the economic and energy scenarios be consistent. We have chosen to use the base case forecasts of energy consumption published by the FEA as energy control totals. We will adopt a set of national economic scenarios consistent with those driving the FEA model and based on the "Control Long 5/75" forecast of DRI.⁷ For the base case, we will choose an INFORUM forecast that is consistent with the energy control totals.⁸ The INFORUM forecast of national economic activity is then regionalized by MULTIREGION, a regional economic-demographic projection-simulation model under development at ORNL. At present, however, we have not completed work permitting aggregation of MULTIREGION forecasts to the state level. Thus, the regional and economic-demographic projections from OBERS have been substituted in the regionalization scheme as an interim approach.

b. Projecting Energy Availability

In contrast with the energy use analysis, which is designed to develop regional forecasts of national energy demands, our supply analysis is designed to answer the question of whether projected regional energy availabilities are adequate to meet projected regional levels of energy use. Ultimately we will determine which regions will have shortfalls in energy supply and the magnitude of these shortfalls. We will then rank the availability of specific fuels in specific regions relative to each region's projected level of energy use. This analysis involves five steps:

1. Determine the present location of fuel sources;
2. Determine the present location of energy forms;
3. Determine the region specific role of imported energy;
4. Examine the capacity of regional transport systems;
5. Reconcile projected energy uses and availabilities.

The first two steps of this process are straightforward and will be accomplished through the preparation of the historical energy statements. This information will provide the level of activity in fuel source extraction and energy production, as well as provide a brief time trend of these levels. If continued over future years, these statements should provide a valuable means of tracing energy supplies and their implications for regional economic development. The third step, examining imports, is more difficult, given the lack of appropriate data at the subnational level. We have, however, gathered information as to the ownership, location, and diameter of crude oil, petroleum product, LPG, and natural gas pipelines on a county basis which will soon be available in a machine-readable data base.

In conducting our research, we intend to place special emphasis on those energy forms where immediate scarcity is at issue, notably natural gas. An attempt will be made, nonetheless, to provide a balanced treatment of the supply side, with the overall aim of identifying whether the availability of specific energy forms will likely influence future patterns of regional economic development.

III. FUEL SOURCES AND ENERGY FORMS

A. Introduction

A major portion of our activity has been devoted to preparing a regional data base containing energy use and production information. This chapter discusses the data gathered for fuel sources and energy forms, while the following chapter discusses energy use data. The data discussed in these chapters have now been collected for 1972 and will be reported as a separate volume. The 1973 and 1974 supply data have also been collected, and these volumes will be forthcoming when the energy use data at the state level is available.

B. Coal Production

For the purposes of this study, coal is defined as an aggregate commodity including bituminous, lignite, and anthracite coal. In 1974 there were 28 states with coal reserves, but only 24 states engaged in coal production. Montana, Illinois, and Wyoming led the nation with approximately 52% of the remaining coal reserves, though these three states were not the leading coal producers. Indeed, the bulk of production (54%) emanated from Kentucky, West Virginia, and Pennsylvania. If no new reserves were to be found, and production were to remain constant, the nation currently has several hundred years of coal production remaining.

Complete information on all mines producing 1000 tons per year or more in 1972 and 1973 is given in the *Minerals Yearbook* and various Bureau of Mines information circulars at the county level.⁹ The 1974 county level detail was taken from the *1976 Keystone Coal Industry Manual*.¹⁰ All quantities represent net tons of marketable coal and exclude washery and other refuse. Statistics are based on the annual reports of production and mine operation furnished by individual coal producers to the Bureau of Mines.

Coal production in 1980 and 1985 was determined based on the detailed coal supply model of FEA (\$13-oil base case scenario) and historical production patterns. Twelve regional control totals were allocated to counties based on remaining reserves in each state and historical production in each county in 1973 and 1974. The county data were then aggregated to BEAs and states.

C. Crude Oil Production

There were 31 states engaged in the production of crude oil and lease condensate in 1974. The number of oil wells drilled has been declining since 1956, but has recently begun to increase in response to the two-tier price system enacted by the FEA in May 1973. Oil production has been declining since 1970, at least partially due to producers'

inability to discover any major new fields coupled with the abandonment and depletion of older fields. Texas and Louisiana lead the oil-producing industry with 62% of total domestic crude production. The balance of domestic demand must be met by foreign imports, however, and these imports amounted to 40% of domestic production in 1974. The reserve-production ratio, declining since 1949, was 11:1 in 1974, implying that if oil production continues at the same annual rate and no new discoveries are made, we will deplete domestic oil resources by 1986.

State estimates of 1972 oil production by county or field were obtained from Arkansas, Kansas, Louisiana, Oklahoma, and Texas.¹¹ When these state totals were inconsistent with those reported by the Bureau of Mines, the individual state reports were assumed to be the correct estimates and superseded Bureau of Mines estimates. County-level production was given in the *Minerals Yearbook* for Alabama, California, Colorado, Illinois, Kentucky, Michigan, Nebraska, New Mexico, North Dakota, Utah, and Wyoming and field-production for Alaska, Indiana, Mississippi, and Nevada. Oil fields were identified and located within counties to provide BEA production estimates. Since oil fields are not constrained to county, BEA, or even state boundaries, the dominant BEA was credited with total field production. In most cases this geographic area was sufficiently large to encompass the field in question.

Specific data were available for determining 98% of 1972 oil production. The remaining 2% was allocated to Tennessee, West Virginia, New York, Arizona, Missouri, South Dakota, Florida, Montana, Ohio, and Pennsylvania based on statistics provided by the Bureau of Mines and the *Oil and Gas Journal*, which publishes information on the production of large oil fields.¹² This data base was supplemented by examining the location of oil and gas fields in these states to restrict allocation to those counties known to have hydrocarbon deposits.¹³

Various state agencies were polled to obtain estimates of production in 1973 and 1974. Virginia, West Virginia, and New York were the only states which failed to provide either field or county level information. Specific information was available, therefore, for 99.9% of production during these two years. The cooperating state agencies who responded to our survey are enumerated in the data appendix. It is noted that the estimates of Mississippi were at such variance with those of the Bureau of Mines that they were used to construct weights to allocate the state production estimate of the Bureau. This decision was made to capitalize on the county-specific information being provided while retaining the consistency of the energy statistics in the *Minerals Yearbook*.

D. Natural Gas Production

Natural gas was produced from both oil (associated) and gas (nonassociated) wells in 30 states in 1974.¹⁴ Both the number of gas wells drilled and the amount of gas production have been declining since 1970. The production of natural gas, 75% of which comes from Texas and Louisiana, has exceeded new discoveries during six of the

previous seven years. Natural gas reserves declined 19% over that period. Indeed, if annual production were to remain at the 1974 rate and no new discoveries of natural gas were made, the reserve base would be depleted by 1986. Approximately 4% of domestic demand for natural gas was satisfied by foreign imports shipped by pipeline from Canada.

Efforts to supplement natural gas supplies through the gasification of liquid fuel continue. In 1974, there were 11 such operational synthetic gas plants and an additional 3 plants being planned.¹⁵ There were 5 pilot projects for the development and testing of processes for the production of high BTU gas from coal at yearend 1974. Gas usage has been declining, especially for electricity production, but it is primarily a consequence of the increase in curtailments of firm deliveries by pipelines rather than a surge in conservation efforts.

State publications of 1972 gas production by county or field were available for Arkansas, Kansas, Louisiana, Oklahoma, and Texas. The estimates of Louisiana, Mississippi, and Texas were used as weights in allocating the Bureau of Mines state control totals. Some of this discrepancy is attributed to the fact that Louisiana did not include offshore production and all three states distinguished casinghead gas, net production of natural gas, and condensate. The *Minerals Yearbook* provided county or field information for California, New Mexico, Colorado, and Wyoming. Some 96% of total gas production was known with certainty, such that only a small percentage of the total was based on *ad hoc* allocation procedures. In Arizona, for example, only one county (Apache) has producing oil and gas wells. In Tennessee, production occurs in only three counties, and in Missouri the bulk of production is in St. Louis County. Information on Virginia, West Virginia, Maryland, and New York was gained from examination of oil and gas fields in these states and careful scrutiny of the description of minerals production by the Bureau of Mines.

Production in Alabama, Florida, Illinois, Indiana, Kentucky, Michigan, Mississippi, Montana, Nebraska, North Dakota, Ohio, Pennsylvania, and Utah was determined on the basis of the characteristics of drilling activity in each. Data on each of the producing states as to total footage drilled, the number of exploratory and proven oil and gas wells, the percentage of oil produced from associated versus nonassociated wells, and the success ratio associated with each type of drilling activity were available. This information was utilized in a regression analysis to determine the relative importance of each variable in determining actual production in the state. The coefficients obtained were applied to these drilling statistics which were available on a county basis for the aforementioned states in the *Minerals Yearbook*. The allocation scheme calculated a weight for each county based upon the nature of the drilling activity and the importance of each characteristic to actual production. It was felt that all relevant information was taken into account and that the substate estimates thus derived are credible.

Most of the 1973 and 1974 data were obtained from the producing states who contributed estimates of oil production. Natural gas production in Indiana, Kentucky, New York, North Dakota, Pennsylvania, Virginia, and West Virginia was allocated to counties based upon the 1972 level of production in each. These states collected extensive oil production data (with the exception of Virginia and West Virginia), but did not estimate gas production at the same level of detail. As with the estimates of oil production, when discrepancies occurred between state estimates and Bureau of Mines estimates, the state estimates were assumed to be correct.

Oil and gas projections for 1980 and 1985 were determined using econometric analysis and national control totals from the detailed oil and gas supply models of FEA (\$13-oil base case scenario). Historical state production patterns were assumed to be explained by cumulative production, proved reserves, indicated and inferred reserves, and/or the ratio of cumulative production to ultimately recoverable reserves. An examination of partial correlation coefficients indicated that 95% of the variation in 1974 oil production and 98% of the variation in 1974 gas production was explained by the estimated ultimate recovery of the reserves of each. Individual BEA projections were determined based on average historical production patterns exhibited during 1972, 1973, and 1974. The regional projections thus embody the significance of finding rates, drilling costs, the domestic price of crude, the declining reserve base, as well as historical production patterns.

E. Petroleum Refining

The nation's 259 operating refineries processed 4.4 billion barrels of oil in 1974, 29% of which was obtained from foreign sources. In addition, 272 million barrels of natural gas liquids from natural gas processing plants were processed by petroleum refiners. Texas, Louisiana, and California led the nation with 39% of the refineries and 51% of the crude distillation capacity. In addition to 15 mmbbl/day throughput capacity, most refiners have catalytic, thermal, coking, and hydro-cracking capacities for refining crude oil.

The primary output from the refining process is gasoline, which accounts for approximately 46% of the yield from a barrel of crude input. Only 3% of the domestic demand for gasoline is met by foreign imports. Gasoline production by state is published annually by the Bureau of Mines, and this was the basic data source for all refining outputs. In some instances, the Bureau aggregates production from several states for reporting purposes. In such cases, the amount of crude runs to stills, available by state, was used to disaggregate the lump sum totals. Refining capacity, available by plant, was relied upon to disaggregate any lump sum figures reported for crude runs to stills, a measure of the crude throughput of the refiner.¹⁶ Production of gasoline by county was determined by constructing a weight based on both plant capacity and state-level crude throughput, and then applying this weight to the multi-state total.

Distillate oil accounts for 22% of the yield of a barrel of crude, with 10% of its domestic demand being met by foreign imports. The other major products are residual oil (9% of the yield) and jet fuel (7% of the yield). Approximately 59% of the domestic demand for residual oil is met by foreign imports, and 16% of the domestic demand for jet fuel is met by imports.

The output of these and other petroleum products are reported by refining district (there are 11 districts) rather than by state. These districts not only lump states together, but occasionally divide states as well. The county production of distillates, residual oil, and jet fuel was determined by using the county production of gasoline as a weight to allocate shares of the district totals. This weight incorporates information as to individual plant capacity, state crude throughput, and actual gasoline output. Some refineries, of course, produce only asphalt or coke, and in these cases this procedure was not applied.

The significance of incorporating both capacity and throughput into the determination of petroleum product output levels is based on the technical relationship which exists between crude oil input and refined petroleum output. Yields seldom vary over 6% to 7% and generally vary only in response to seasonal changes in product demands (i.e., there is a greater demand for distillate heating oil in the winter), rather than different producing characteristics of refiners. The actual throughput of crude oil is important since few refiners are capable of operating at full capacity.

Projections of processed oil and NGL and petroleum product production in 1980 and 1985 were based on projected refinery capacity and the refinery linear-programming model employed by FEA (\$13-oil base case scenario), which provides control totals for seven refining regions. Announced planned expansions and additions to capacity supplemented information on refining capacity by plant in January 1977. These projected capacity estimates were used as weights to allocate the refining district projections of FEA. The county projections were then aggregated to BEAs and states.

F. Natural Gas Processing

There were 768 natural gas processing plants in operation in 1974 according to the *Oil and Gas Journal*, and these plants received approximately 90% of the natural gas marketed for sale. The long-term trend of annual increases in processing capacity came to a halt in 1971 and has been declining ever since. The center of the industry is located in Texas and Louisiana, which have 63% of the plants and 61% of the total capacity in the United States. Approximately 47% of the natural gas liquids produced by processing plants are used by refiners as input into the production of gasoline, distillates, residual oil, etc. Of the residue gas, 79% was shipped to pipeline transmission companies, and 11% was shipped directly to consumers.

Annual reports containing information as to the number of plants, their capacity, throughput, and production are submitted to the *Oil and Gas Journal* when capacity exceeds 75 mmcf daily.¹⁷ These served as primary data sources for determining processing activity and supplied specific information in 1972 and 1973 on 76% of the total gas throughput. A complete survey of all plants was conducted in 1974 and published in the 1975 *International Petroleum Encyclopedia*.¹⁸ The data are given alphabetically by plant and were aggregated by counties to serve as the basis for allocating the capacity of the smaller plants (less than 75 mmcf daily) in 1972 and 1973.¹⁹

Since a complete survey was not available for 1972, some simplifying assumptions were made to determine county-level throughput and production. If the number of operating plants was unchanged between 1972 and 1974, the assumption was made that these were the same plants. It was then assumed that the county had the same share of the state's capacity in 1972 as in 1974. This share was then applied to the unallocated portion of the 1972 capacity for the state. The output of processing plants is sent to refineries for use as feedstock and to ultimate consumers. The estimated share of capacity was used for the allocation of the output of the smaller plants, which was then adjusted by the proportion of output going directly to consumers. Throughput, defined to include extraction loss, gas used at the plants, returned to formations, or vented and flared, was similarly adjusted by the proportion of output going directly to consumers and allocated to smaller plants based on their capacity.

When the number of plants in operation in 1974 in a given state or county was greater than in 1972, these plants were simply subtracted from the 1974 total before the weights were constructed. Generally, however, the number of plants in 1974 was less than the number in 1972, and when the throughput of the plant was less than 75 mmcf daily, there was no way to determine with certainty which plant had ceased operation during the two-year period. Since the number of plants and total capacity represented in these cases was relatively small, it was felt that the potential error generated by the *ad hoc* procedures employed was minimal. It is stressed that in all cases the state control totals served to constrain the arbitrary allocations to plants or counties.

G. Electricity Generation

In 1974 there were 36 nuclear plants, 1,156 hydro plants, and 2,443 fossil fuel plants in operation in the United States generating approximately 6%, 16%, and 78%, respectively, of the total electricity generated in the nation. Illinois currently has the largest share of nuclear capacity, followed by South Carolina, New York, Connecticut, Wisconsin, and Florida. Together these states accounted for 65% of all nuclear-generated electricity in 1974. The majority of the hydro capacity is located on the Pacific coast, particularly in the state of Washington. The South generated only 7% of its electricity with hydro-power in 1974. Fossil fuel plants are more randomly distributed throughout the nation.

In 1974, coal was used for 57% of steam generation, natural gas for 22%, and petroleum products for 21%. The current trend appears to be toward coal and nuclear, and away from petroleum and gas.

The spatial location of electricity generation can be obtained by aggregation of plant level data. With the acquisition of an historic generation (and fuel use) data series for each utility plant, provided by the FPC from their "Form 4" series, the BEA regional totals can be obtained by accumulating the generation of each nuclear, hydro, and fossil fuel plant located within a BEA.²⁰

ORNL has updated another data set obtained from the FPC (*Generating Unit Reference File*) such that all plants are located by state, BEA, and county.²¹ This data series also includes planned capacity expansions (new plants) and retirements, as well as existing capacity. Given the assumed heat rates and load factors used by FEA in their forecasts, the amount of electricity generation and fuel consumption of each plant that is expected to be on line in 1980 and 1985 will be estimated. Estimated generation at the plant level will then be adjusted to be consistent with FEA forecasts at the census level. The "adjusted" plant data will be aggregated then to the BEA level to provide projected spatial patterns of generation and fuel use.

IV. ENERGY USE: DATA SOURCES AND ALLOCATION PROCEDURES

A. Introduction

This chapter describes the procedures developed to regionalize historic and forecasted energy consumption data to a BEA grid. The energy production data was obtained from gathering and reorganizing very detailed regional information such as that from oil and gas fields. Information on energy use, however, is not available below the state level. Thus, a procedure to allocate state level information to a substate grid, based on a series of energy sensitive weights, was developed to generate the historic energy consumption data series.

This procedure lends itself to regional allocation of national scenarios of energy use, providing a simple, consistent method for forecasting BEA energy consumption estimates based on the national FEA energy scenarios. The baseline historical data for 1972 has been completed, and the results will be reported as a series of regional energy statements. It is anticipated that this data series will be extended as the basic data become available. Such statements for the forecast years 1980 and 1985 will also be published in forthcoming volumes.

The goal of the energy consumption analysis is to identify patterns of energy consumption at the BEA level according to the use and fuel categories previously shown in Table 1. The categories shown in Table 2 will be used in the regional energy statements. (This table is explained in detail in Appendix B). The data presented in this table represent 1972 national totals and are characteristic of the data available at the BEA level. In addition, Tables 3 and 4 present U.S. totals for 1980 and 1985, respectively, based on the FEA reference scenario. The BTU conversion factors are given in Appendix C.

The basic allocation procedure attempts to make use of the best available data when deriving the overall energy consumption estimates. It was desired that the procedure developed satisfy the following criteria:

1. That readily available data sources be utilized to allow for easy replication on a continuing annual basis;
2. That the methodology for preparing the energy statements be consistent with that used in preparing the regional projections;
3. That the initial structure be developed to utilize as much region specific information as possible, given the available time and resources;

Table 2. Regional Energy Balance Table by Sector and Fuel, 1972

Sector	Distillate Oil	Residual Oil	Gasoline	Other Hydro- Carbons (Trillions of BTUs)	Crude Oil	Natural Gas	Coal	Electricity	Total Fuel Consumed
Final Demand Sectors									
Residential, Comm.	3191	1176	0	1164 ¹	0	7642	387	2878	16438
Industrial	722	1198	0	1237	0	10591	4267	2493	20508
Transportation	1887	652	12821	1522	0	790	4	17	17693
Miscellaneous	64	56	0	30	0	0	0	0	150
Total Final Demand Sectors	5864	3082	12821	3953	0	19023	4658	5388	54789
Transformation									
Electricity Gen.	398	2737	0	0	0	4102	7836	-4848	10225
Petroleum Products	-5606	-1839	-12153	-2206	24829	1220	0	0	4245
Natural Gas	0	0	0	-1518	0	1674	0	0	156
Syn-Gas	0	0	0	0	0	0	0	0	0
Net Fuel Used in Transformation	-5208	898	-12153	-3724	24829	6996	7836	-4848	14626
Total Net Usage	656	3980	668	229	24829	26019	12494	540	69415
Supply of Energy									
Fossil Fuel	0	0	0	0	19977	24224	14999	0	59200
Hydroelectric	0	0	0	0	0	0	0	931	931
Nuclear	0	0	0	0	0	0	0	184	184
Geo. & Solar	0	0	0	0	0	0	0	0	0
Total Supply	0	0	0	0	19977	24224	14999	1115	60315
Loss, Errors and Omissions²	-276(4%)	-48(1%)	-542(4%)	256(6%)	-147(1%)	-773(3%)	1160(9%)	600(11%)	230
Total Net Supply	276	48	542	-256	20124	24997	13839	515	60085
Net Imports of Region	380	3932	126	485	4705	1022	-1345	25	9330

¹Excludes asphalt.²Percentage of loss, error or omissions based on gross usage.

Table 3. Regional Energy Balance Table by Sector and Fuel, 1980

Sector	Distillate Oil	Residual Oil	Gasoline	Other Hydro- Carbons (Trillions of BTUs)	Crude Oil	Natural Gas	Coal	Electricity	Total Sector
Final Demand Sectors									
Residential, Comm.	3111	1209	0	2083	0	6137	156	4662	17358
Industrial	973	1465	0	4241	0	12315	4044	3133	26171
Transportation	2506	639	12753	3516	0	681	3	15	26113
Miscellaneous	50	20	0	20	0	0	0	0	90
Total Final Demand Sectors	6640	3333	12753	9860	0	19133	4203	7810	61732
Transformation									
Electricity Gen.	745	2272	0	0	0	3614	11486	-6095	15022
Petroleum Products	-6887	-2229	-12556	-9565	27332	2822	0	0	-663
Natural Gas	0	0	0	0	0	0	0	0	0
Syn-Gas	0	0	0	0	0	0	0	0	0
Net Fuel Used in Transformation	-6122	-43	-12556	-9565	27332	6436	11486	-6095	+10959
Total Net Usage	+ 518	-3376	+ 197	+ 295	+27332	+25569	15689	+1715	74691
Supply of Energy for									
Fossil Fuel	0	0	0	0	22996	24111	17975	0	65082
Hydroelectric	0	0	0	0	0	0	0	1160	1160
Nuclear	0	0	0	0	0	0	0	1323	1323
Geo. & Solar	0	0	0	0	0	0	0	22	22
Total Supply	0	0	0	0	22996	24111	17975	2505	67587
Loss, Errors and Omissions	0	- 15(.3%)	- 10(.1%)	+ 557(6%)	0	0	+ 486(.3%)	+ 790(10%)	1838
Total Net Supply	0	- 15	+ 10	- 557	22996	24111	17489	1715	65749
Net Imports of Region	+ 518	3391	187	+ 852	+ 4336	1458	-1800	0	8942

Table 4. Regional Energy Balance Table by Sector and Fuel, 1985

Sector	Distillate Oil	Residual Oil	Gasoline	Other Hydro- Carbons (Trillions of BTUs)	Crude Oil	Natural Gas	Coal	Electricity	Total Fuel Consumed
Final Demand Sectors									
Residential, Comm.	4266	1461	0	2505	0	6440	114	6432	21218
Industrial	1298	1785	0	5083	0	13000	4817	3864	29847
Transportation	2875	635	14440	4417	0	811	2	14	23194
Miscellaneous Uses	50	20	0	0	0	1022	0	0	1092
Total Final Demand Sectors	8489	3901	14440	12005	0	21273	4933	10310	75351
Transformation									
Electricity	401	2295	0	0	0	3219	15381	-7064	14232
Petroleum Products	-8625	-4418	-14343	-11524	35880	2768	0	0	- 260
Natural Gas	0	0	0	0	0	0	0	0	0
Syn-Gas	0	0	0	0	0	- 169	261	0	92
Net Fuel Used in Transformation	-8222	2123	-14343	-11524	35880	5818	15642	-7064	14064
Total Net Usage	267	1778	97	481	35880	27091	20575	3246	89415
Supply of Energy									
Fossil Fuel	0	0	0	0	26000	25748	22236	0	73984
Hydroelectric	0	0	0	0	0	0	0	1284	1284
Nuclear	0	0	0	0	0	0	0	2957	2957
Geo. & Solar	0	0	0	0	0	0	0	52	52
Total Supply	0	0	0	0	26000	25748	22236	4293	78277
Loss, Errors and Omissions	0	0	- 4(1%)	- 13(.1%)	0	- 25(.1%)	- 139(.7%)	1047(10%)	866
Total Net Supply	0	0	4	13	26000	25773	22375	3246	77411
Net Imports of Region	267	1778	93	468	9880	1318	-1800	0	12004

4. That the format be flexible to permit ease of revision and update;
5. That the procedure be sufficiently general to address a variety of questions as to the regional impacts of alternative energy policies and problems, conservation efforts, changing fuel mix patterns, specific fuel shortages, etc.;
6. That the estimates of regional energy deficiencies and/or surpluses provide a meaningful characterization of potential problems encountered in a region under alternative energy futures;
7. That the system operate with efficiency to facilitate prompt analysis of alternative scenarios.

The complicated dimensions of the energy system and lack of consistent data sets make satisfaction of each of the above criteria difficult. However, the present structure provides a strong base which can be systematically improved as better data sets become available. In its present form, the ORNL procedure can provide estimates which are sufficiently detailed to address energy-related issues at the level of fuel aggregation reported in Table 2.

To regionalize state energy data, several inconsistencies in the data must be resolved. Few of the state-level sources of energy data maintain a single consistent framework for defining the dimensions of energy consumption. Therefore, to remap aggregate energy data to sub-aggregates adequately, at least four dimensions of the energy use system should be considered:

1. The regional reporting grid of collected data;
2. The consumption sector defined for reporting the data;
3. The fuel classification defined in the data;
4. The particular fuel use as reported in the data.

Because regional patterns may differ significantly in any subaggregate of each dimension, the inconsistencies in the published historical data must be resolved. In several instances, conflicts between these sources were readily evident, even after accounting for differences in definitions and coverage.

To minimize problems associated with inconsistent data sources, the approach used here has been to use a well-defined set of state-level aggregates (from the Bureau of Mines) as control totals which constrain the level of individual disaggregate components, and use other sources (e.g., Edison Electric and the Department of Transportation) to help establish the relative distribution of the aggregates to the disaggregated

components. A similar procedure is followed in using the forecasted data based on the FEA scenarios. We have reformulated the detailed data reported in the *National Energy Outlook* to be consistent with the reporting scheme followed by the Bureau of Mines unless otherwise noted.

The definitions established for the purposes of this project are shown in Tables 5 and 6. Each table represents the potential disaggregation for each of the four dimensions. While not all data have been retained at the lowest possible level of detail, it was determined that the entire scheme should be shown.

The basic procedure followed in the regional disaggregation analysis is to estimate the fuel consumption of each of the defined consuming sectors listed in Table 7 for each of the subregions. The details on fuels considered and the uses detailed are determined for each sector based on applicability (whether the fuel is used by the sector) and availability of data. Consequently, not all fuels and uses are considered, nor is the lowest level of detail outlined in the tables always utilized. The specific data considered is detailed as part of the documentation of the generated series.

B. Regionalization of Energy Consumption

Regional demand for energy is determined primarily by the level of activity occurring in each sector in the region. Regional variation in the basic demand levels and fuel mix are determined by such factors as regional differences in delivered fuel costs, heating and cooling degree days, income, and many institutional factors.

Traditional energy demand analysis and projection procedures estimate functional relationships between demand (i.e., consumption) and a set of regional variables that are postulated to determine regional demand. One can then forecast a time-series of future energy demand based on a projected series of the chosen causal variables.

Two practical considerations limit the usefulness of this traditional approach for the purposes of this project. First, sufficiently consistent data are unavailable at the desired level of regional and fuel use detail. One of the purposes of the project is to estimate such a data series. Secondly, although we could estimate formal relationships at the state level and subsequently modify them to fit substate areas, this approach would require more time and resources than available to handle the detailed sectoral and fuel use definitions necessary for adequate spatial analysis.

A simpler approach that embodies two simplifying assumptions has been adopted in the present research. The first assumption is that for each consuming sector considered (Table 7), the primary determinant of a subregion's share of the state's energy consumption is its relative share of the overall state level of activity in the sector. Additional variables are assumed either uniform across the state (e.g., heating

Table 5. Definitions of Fuel Use Categories

ALL USES^{*}

A. Heat and Power^{*}

1. Heat

- a. Space heating
- b. Process heat

- 1. Cooking
- 2. Water heating
- 3. Drying
- 4. Manufacturing process heat

2. Power^{*}

- a. Lighting
- b. Mechanical drive

E. Non-energy Demand^{*}

1. Feedstock

2. Direct consumption^{*} (e.g. lubes and waxes in transportation and asphalt in the residential and commercial sector)

^{*}Definitions include categories used in current analysis.

Table 6. Fuel Classification

Fuel	Reporting Aggregate
Coal	Coal
Anthracite	
Bituminous and lignite	
Metallurgical coal*	
Electricity	Electricity
Natural Gas	Natural Gas
Petroleum Products	
Distillate fuel oil	Distillate fuel oil
Residual fuel oil	Residual fuel oil
Gasoline	Gasoline
Other hydrocarbon products	
Jet fuel	Other hydrocarbons
Kerosene	Other hydrocarbons
Liquid petroleum gas	Other hydrocarbons
Asphalt and road oil*	Other hydrocarbons
Liquified refinery gases	Other hydrocarbons
Still gas*	Other hydrocarbons
Naptha*	Other hydrocarbons
Special naptha*	Other hydrocarbons
Lubricants and waxes*	Other hydrocarbons

*Currently these fuels are included only in forecast data based on FEA scenarios. Thus, comparison directly between historic and forecasted data in other hydrocarbons may be misleading.

Table 7. Detailed Consuming Sectors Considered

Sector	Activity Variable
RESIDENTIAL	Population
COMMERCIAL AND GOVERNMENT	
Wholesale and Retail Trade	Employment in Sector
Finance, Insurance and Real Estate	Employment in Sector
Services	Employment in Sector
Federal Government	Employment in Sector
State and Local Government	Employment in Sector
Armed Forces	Employment in Sector
RESOURCE ORIENTED INDUSTRIAL ACTIVITY	
Agriculture	Employment in Sector
Forestry and Fishery	Employment in Sector
Metal Mining	Employment in Sector
Coal Mining	Employment in Sector
Crude Oil and Gas	Employment in Sector
Non-Metallic Mining	Employment in Sector
CONSTRUCTION	Employment in Sector
MANUFACTURING ACTIVITIES	
Food and Kindred Products	Employment in Sector
Textiles	Employment in Sector
Apparel	Employment in Sector
Lumber and Furniture	Employment in Sector
Paper Products	Employment in Sector
Printing and Publishing	Employment in Sector
Chemicals	Employment in Sector
Petroleum Refining	Employment in Sector
Fabricated Metals	Employment in Sector
Primary Metals	Employment in Sector
Machinery (non-electrical)	Employment in Sector
Electrical Machinery	Employment in Sector
Motor Vehicles	Employment in Sector
Transportation Equipment	Employment in Sector
Other Manufacturing	Employment in Sector
TRANSPORTATION	
Automobiles	Population
Truck and Bus	Employment in Transportation
Rail and Transit	Employment in Transportation
Air	Employment in Transportation
Water	Employment in Transportation
Pipelines	Employment in Crude Oil and Gas
MISCELLANEOUS	Population

degree days) or unimportant relative to differences in the level of activity (e.g., per capita income or regional price differences). This is a reasonable first approximation within states, but is clearly less appropriate between states.

The second assumption is that the effects of spatial differences in energy consumption between states can be measured in a simple aggregate comparison of state to state differences in energy use per unit of activity exhibited in historical data. Furthermore, we assume each state's relative position will remain constant during the period of forecast, unless specifically modified by scenario assumptions.

Under these assumptions the estimation of BEA consumption patterns can be performed in three steps. Initial energy demands in the first stage are estimated for each subregion using the historic patterns of energy use per unit of activity and the forecasted level of regional activity in each sector.²² Next, these subregion estimates of demand are adjusted to be consistent with the aggregate consumption totals provided by either the historic or forecasted data set. Adjusted demands are then interpreted as estimated consumption forecasts which are consistent with the aggregated energy consumption patterns. Finally, the consumption forecasts at the subregion level are aggregated to the desired level of spatial and sectoral detail. These three steps are discussed in detail below.

STEP 1: ESTIMATION OF SUBREGIONAL DEMANDS

The basic procedure is to estimate the demand for each fuel, sector, and use at as detailed a level as possible. This "demand" estimate represents each subregion's potential demand for a particular fuel in a given use in the sector of interest under the use patterns exhibited in the base year (1972) and the regional level of activity for the sector in the year of interest. Simply, we can say that this figure represents the demand for a sector's use of a particular fuel if it behaved as it did in the base year, but had the level of activity in the year under consideration.

For each subregion we specify a detailed set of relationships for each combination of fuel, sector, and use:

$$\text{Demand (S,F,U)} = \text{Level (S,F,U)} \times \text{Relative (S,F,U)} \times \text{Special (S,F,U)} \\ \times \text{Activity (S)}$$

Where S = sector (Table 8)
 R = state to which subregion belongs
 F = fuel (Table 7)
 U = fuel use (Table 6)

and Level (S,F,U) = the average level of fuel F used per unit of activity in sector S for use U as determined by the national average in the base year

Relative (S,F,U) = the relative use per unit of activity of the state R compared to the national average, for the use U of fuel F in sector S

Special (S,F,U) = a special variable applicable to a specific subregion for sector S, fuel F, and use U—if Special is set to zero, then the fuel is unavailable for use

Activity (S) = the level of activity in sector S (Table 8).

An intuitive explanation of this equation is that each demand represents the national average demand for energy given the level of activity in a region, with the average value modified according to state or substate deviations. Tables 8, 9, and 10 illustrate the use of the equation. Table 8 shows the amount of electricity used per unit of activity by each sector in the United States.²³ Table 9 indicates the amount of electricity used per unit of activity by each state (for three aggregated sectors). Table 10 shows the amount of electricity used per unit of activity by each state for detailed manufacturing sectors. As of yet we have not defined further distinguishing regional characteristics, although special consideration should be given to the increased use of electricity associated with uranium processing plants and intraurban transit modes.

A variety of data sources were used to compute the level, relative, and special variables for defined sectors, fuels, and uses. This permitted the use of more specific regional detail, but increased the difficulty of maintaining comparable data definitions. Since the demands are controlled by Bureau of Mines state totals, however, the indices can be used to disaggregate the data set by sector, region, and fuel use, while maintaining consistency.

Documentation of the values for each of the defined indices and data sources will be presented as part of the individual data volumes for each historical and forecast year. In this report only the control data set will be discussed in detail.

STEP 2: ESTIMATION OF CONSUMPTION

The estimates of the energy demands by detailed sector and fuel for the year of interest are accumulated to aggregate sector, fuel, and regional totals consistent with the control data set definitions (either the historic or forecasted series). The relative differences between the sum of aggregate demand estimates are adjusted proportionally. These adjusted demands are referred to as estimates of consumption and may be

Table 8. Electricity Used per Unit of Activity by Sector in 1972

Sector	Electricity Use Billions of BTU per Unit of Activity
RESIDENTIAL	0.0084
COMMERCIAL AND GOVERNMENT	
Wholesale and retail trade	0.0387 ¹
Finance, insurance and real estate	0.0387 ¹
Services	0.0387 ¹
Federal government	0.0107 ²
State and local government	0.0107 ²
Armed forces	0.0107 ²
RESOURCE ORIENTED INDUSTRIAL ACTIVITY	
Agriculture	0.2695
Forestry and fishery	0.0000
Metal mining	0.4003
Coal mining	0.1328
Crude oil and gas	0.1804
Non-metallic mining	0.2200
CONSTRUCTION	0.0058
MANUFACTURING ACTIVITIES	
Food and kindred products	0.0768
Textiles	0.0941
Apparel	0.0142
Lumber and furniture	0.0467
Paper products	0.3914
Printing and publishing	0.0312
Chemicals	0.4004
Petroleum refining	0.5725
Fabricated metals	0.0537
Primary metals	0.3573
Machinery (non-electrical)	0.0437
Electrical machinery	0.0486
Motor vehicles	1.0575 ³
Transportation equipment	0.0575 ³
Other manufacturing	0.0766
TRANSPORTATION	
Automobiles	1.0000 ⁴
Truck and bus	.0000
Rail and transit	1.0000 ⁴
Air	.0000
Water	.0000
Pipelines	.0000
MISCELLANEOUS	.0003

Table 8 (continued)

Notes:

1. Aggregate index for all commercial activities used for each sub-sector.
2. Due to data limitations, aggregate index for public authority use applied to all government sub-sectors.
3. Index for aggregate transportation equipment sectors (SIC 37) used for both sub-sectors.
4. For automotive and rail and transit, dummy indices have been used. The effect of these is to allocate total use of electricity by population and employment in transportation.
5. Miscellaneous category for electricity includes electricity used for street and highway lighting as well as interdepartmental use.

Table 9. State Relative Use of Electricity
per Unit of Activity by Sector in 1972

State	Residential	Commercial	All Manufacturing
Alabama	1.40	1.17	1.65
Alaska	.89	1.22	1.00
Arizona	1.16	1.52	.77
Arkansas	1.05	1.26	1.14
California	.77	1.21	.75
Colorado	.71	1.15	.60
Connecticut	.92	.90	.45
Delaware	.95	.96	2.61
District of Columbia	.82	.93	.30
Florida	1.65	1.06	.75
Georgia	1.23	1.27	.80
Hawaii	.71	.46	.27
Idaho	1.55	2.27	4.15
Illinois	.81	.92	.70
Indiana	1.03	.91	.98
Iowa	.97	.78	.82
Kansas	.97	1.39	1.06
Kentucky	1.06	1.04	2.71
Louisiana	1.18	1.16	2.61
Maine	.83	.81	.81
Maryland	.82	.93	.89
Massachusetts	.72	.69	.43
Michigan	.84	.90	.81
Minnesota	.09	.52	.61
Mississippi	1.23	1.45	3.10
Missouri	.94	.79	.57
Montana	.97	1.19	8.11
Nebraska	1.02	1.15	.79
Nevada	1.87	1.44	4.03
New Hampshire	.98	.57	.65
New Jersey	.76	.94	.63
New Mexico	.58	1.38	.59
New York	.60	.70	.59
North Carolina	1.29	1.31	.81
North Dakota	.95	.93	.66
Ohio	.91	.91	1.09
Oklahoma	1.08	1.31	.78
Oregon	1.93	1.63	2.14
Pennsylvania	.84	.76	.78
Rhode Island	.65	.79	.45
South Carolina	1.24	1.39	1.28
South Dakota	1.00	.83	.41
Tennessee	2.01	.55	1.85
Texas	1.19	1.34	1.70
Utah	.72	.90	.88
Vermont	1.21	.75	.54
Virginia	1.13	1.16	.69
Washington	2.07	1.55	2.72
West Virginia	.90	1.13	2.78
Wisconsin	.92	.75	.65
Wyoming	.82	2.22	1.57

Table 10. State Relative Use of Electricity per Unit of Activity Compared to the National Average

Manufacturing Sectors

State	Food & Kindred	Textiles	Apparel	Lumber & Furniture	Paper	Printing	Chemicals	Petroleum	Fabricated Metals	Primary Metals	Machinery	Electrical Machinery	Transportation Equipment	Other Manufactures
Alabama	0.89	1.41	1.30	0.14	2.08	1.40	2.11	0.24	1.10	1.28	1.23	1.03	0.61	2.03
Alaska	*	*	*	0.32	*	5.47	*	*	*	*	*	*	*	*
Arizona	1.27	*	0.51	1.23	*	0.44	0.33	*	2.17	0.85	1.06	1.40	0.14	2.09
Arkansas	1.02	1.91	0.42	1.33	1.27	0.35	0.39	0.93	0.83	5.51	*	0.08	0.09	1.06
California	0.87	0.47	0.45	1.17	0.80	0.97	0.54	1.66	1.21	0.63	0.88	0.95	0.91	1.42
Colorado	1.16	*	1.29	*	0.38	0.84	0.65	1.06	1.43	0.56	1.17	0.93	0.67	1.80
Connecticut	0.76	0.56	0.41	0.30	0.12	1.06	0.29	0.09	0.83	0.45	1.03	0.71	0.75	1.63
Delaware	1.28	0.25	9.79	4.22	1.84	*	*	*	1.06	1.95	0.86	*	*	1.66
District of Columbia	*	*	*	*	*	1.36	*	*	*	*	*	*	*	1.00
Florida	1.18	*	0.78	0.91	0.59	0.72	1.09	0.73	1.14	0.92	0.08	0.17	0.12	1.55
Georgia	0.87	1.15	1.16	0.40	1.06	1.70	0.85	*	1.10	0.59	0.87	1.43	0.87	1.24
Hawaii	0.72	*	1.42	*	*	0.42	*	*	*	*	*	*	*	2.90
Idaho	1.49	*	*	1.79	*	4.03	5.85	*	0.92	*	0.53	*	*	8.03
Illinois	1.37	0.45	0.06	0.43	0.41	1.09	0.42	1.15	1.14	0.65	1.02	0.62	0.93	0.85
Indiana	1.17	*	1.13	0.47	0.53	1.17	0.50	0.31	1.17	0.86	1.01	1.13	1.15	0.87
Iowa	1.40	*	*	2.20	0.69	1.00	0.11	*	1.20	1.55	0.86	1.00	0.75	1.24
Kansas	1.52	*	1.10	1.80	0.33	*	1.18	0.90	1.19	*	2.54	*	0.91	3.29
Kentucky	0.36	1.69	1.09	0.26	1.29	1.50	8.65	*	1.62	1.74	1.29	1.72	1.30	1.85
Louisiana	0.67	*	0.31	2.52	1.37	0.17	2.71	1.52	0.91	0.09	*	1.74	0.54	1.57
Maine	0.33	0.53	0.92	0.51	1.58	0.95	0.29	*	*	0.55	0.83	*	0.74	0.44
Maryland	0.73	*	0.11	0.45	0.59	1.04	0.44	*	1.15	0.95	1.06	0.79	1.00	1.27
Massachusetts	1.29	0.57	0.94	0.51	0.44	0.88	0.29	*	0.87	0.24	0.79	0.88	0.78	0.54
Michigan	0.95	0.76	1.61	0.82	0.67	1.03	0.64	*	1.46	0.56	1.03	0.88	1.46	1.67
Minnesota	1.19	0.65	0.99	0.30	1.14	1.06	0.32	0.16	1.04	0.40	1.13	0.81	0.06	1.42
Mississippi	1.11	0.86	1.40	1.74	0.55	0.34	1.82	*	1.12	0.73	0.87	0.93	0.59	0.98
Missouri	1.13	1.09	1.31	0.53	0.03	0.22	0.29	0.31	1.19	0.87	0.83	0.84	0.81	1.34
Montana	1.86	*	*	13.61	*	7.49	0.11	7.21	1.85	*	*	*	*	9.24
Nebraska	1.32	*	1.69	1.90	*	1.15	0.11	*	1.01	0.55	0.08	0.95	0.65	1.24
Nevada	*	*	*	*	*	1.17	3.33	*	*	*	*	0.29	*	2.01
New Hampshire	1.48	0.73	*	0.10	2.18	0.78	0.26	*	0.54	0.17	1.00	0.73	*	0.46
New Jersey	1.01	0.65	1.07	0.44	0.65	1.17	0.36	0.77	1.25	0.49	0.97	0.84	1.05	0.64
New Mexico	*	*	*	*	*	*	*	*	*	*	*	*	*	*
New York	0.89	0.43	1.25	0.83	0.63	0.92	0.49	0.96	1.36	1.14	0.95	1.20	1.11	0.63
North Carolina	0.85	1.08	1.03	0.70	1.14	*	0.56	*	1.18	2.91	1.09	1.64	*	1.57
North Dakota	1.34	*	*	*	*	1.22	*	*	*	*	*	*	*	4.01
Ohio	0.88	0.55	0.11	0.62	0.56	1.33	1.50	1.30	1.31	0.92	1.05	1.00	1.23	1.03
Oklahoma	0.93	*	0.23	0.59	2.33	0.25	2.08	1.01	0.91	0.80	0.35	0.66	0.91	1.22
Oregon	0.98	0.83	7.53	2.05	7.01	4.40	3.33	1.43	0.62	8.93	1.96	2.82	1.59	3.73
Pennsylvania	0.79	0.57	0.81	0.44	0.75	1.35	0.40	0.67	1.24	0.61	1.02	1.17	0.79	1.13
Rhode Island	0.10	0.68	1.76	0.53	0.31	1.29	0.25	*	*	0.38	0.10	0.88	*	0.66
South Carolina	*	1.60	1.75	1.23	2.07	0.27	0.64	*	*	3.34	1.80	2.01	0.81	1.80
South Dakota	0.89	*	*	0.70	*	0.40	*	*	*	*	0.74	*	*	1.14
Tennessee	1.05	0.93	1.17	0.76	1.49	1.03	1.68	0.43	1.51	3.64	1.29	1.76	0.79	1.28
Texas	1.13	*	0.18	1.00	0.95	0.16	1.89	1.01	1.35	1.94	1.17	1.00	0.73	1.93
Utah	1.01	*	0.92	*	*	0.54	1.07	1.47	*	*	0.21	0.17	1.15	2.29
Vermont	0.28	*	2.45	1.82	*	1.48	0.63	*	*	0.69	1.34	*	*	1.67
Virginia	0.69	0.83	1.08	0.51	0.96	1.06	0.46	*	1.20	0.68	0.92	1.53	0.62	1.55
Washington	1.02	*	1.05	1.47	3.30	0.70	1.88	*	1.27	7.60	1.84	0.36	1.48	0.65
West Virginia	*	*	0.50	0.31	*	0.26	1.51	0.57	1.32	2.01	0.68	3.36	*	1.09
Wisconsin	0.99	0.33	0.89	0.32	1.21	1.07	0.38	*	1.19	0.34	1.05	0.93	0.86	0.67
Wyoming	0.81	*	*	*	*	*	*	1.28	*	*	*	*	*	1.14
Average	1.02	0.83	1.35	1.26	1.20	1.23	1.27	1.13	1.18	1.51	1.00	1.09	0.83	1.75

*Detailed state data was not available. Consequently, these values will be estimated by an indirect procedure.

viewed as representing estimated subregion consumption patterns which are consistent with the consumption control totals and the relative energy use patterns in the base year.

The controlling data set chosen for the historic data series is the state data provided in *Fuel and Energy Data: United States by States and Regions: 1972*.²⁴ Since these Bureau of Mines data are for state areas, the state relatives are not actually used in spatial disaggregation, but the effect of the relatives in this case is important in disaggregating fuel and sector totals within the state.

The available level of regional and fuel definitions for the historic data used is presented in Table 11. Also shown are the levels of energy use in the United States in 1972 as determined by the Bureau of Mines. The forecasted regional energy patterns are based on the FEA base case (\$13 per barrel for oil) forecasts for 1980 and 1985.²⁵ The finest regional detail used by FEA is the census region. The state relatives are, therefore, quite important in the regional disaggregation, as well as in the sector and fuel decompositions. Table 12 presents the fuel and sector definitions of FEA and the forecasted energy levels in 1985 for the nation as a whole.

STEP 3: ESTIMATES OF BEA ENERGY CONSUMPTION PATTERNS

The last stage of analysis is to aggregate subregional estimates to the national level, census regions, states, and BEAs bringing together the estimates of both consumption and supply to formulate the regional energy balance statements. We then compare the total demand for energy with the actual consumption. The difference between these values indicates how much change in established patterns of energy use must be undertaken through conservation or legislation. Alternatively, if we assume that energy use patterns will not change significantly, we can compute the number of workers likely to be affected by the anticipated shortage.

While it is true that some adjustment in base year energy use patterns will occur in the event of a shortage, these measures provide a simple way of denoting the range of extremes. The aggregation of activity loss, however, requires caution. Residential and industrial activity cannot be aggregated, nor can the loss in employment associated with a shortage of fuel for heat and power be added to the employment loss associated with a shortage of fuel used as feedstock.

An example of the methodology for measuring impacts at the regional level is provided by a comparison of state level forecasts derived from the census region scenarios for 1985. Estimated 1985 total demand (unconstrained) for natural gas in California based on the 1972 energy use patterns is 1.26 times that of the forecasted consumptions (constrained to the scenarios).

Table 11. Aggregate Fuel and Sectors Defined

Historic Data
United States Total Consumption
1972

(Trillions of BTUs)

Fuels	Residential & Commercial	Industrial	Transportation	Miscellaneous	Undistributed ¹
Anthracite	0	0	0	162.0	52.0
Bituminous	210.5	3863.6	0	0	9579.5
Electricity	3478.1	2492.7	16.9	0	.3
Natural gas	7613.1	10549.5	787.0	0	73.2
Petroleum products	6716.7	3157.0	16881.0	149.6	2927.6 ²
Distillate fuel oil	3191.0	722.1	1886.6	63.6	
Residual fuel oil	1176.4	1198.3	651.5	55.7	
Gasoline	0	0	12821.1	0	
Jet fuel	0	0	1380.6	0	
Kerosene	375.3	111.4	0	0	
Liquid petroleum gas	788.2	1125.2	141.2	30.3	
Asphalt	1185.8	0	0	0	
TOTAL	24735.1	23219.8	34565.9	461.2	12632.6

¹Undistributed refers to the amount of fuel used in the United States which is not distributed to individual states by the Bureau of Mines.

²Undistributed amount show for all petroleum products, amount for individual products not available.

Table 12. FEA 1985 Scenario

(Trillions of BTUs)

Fuel	Residential & Commercial	Industrial Heat & Power	Industrial Non-Energy	Transportation	Miscellaneous
Anthracite	46.52	4.94	--	--	--
Bituminous	67.60	3,229.97	--	2.42	--
Metallurgical	--	--	1,582.01	--	--
Electricity	6,432.38	3,863.86	--	14.42	--
Natural gas	6,440.32	12,984.87	15.01	811.14	1,021.99
Distillate fuel	4,266.39	1,297.89	--	2,875.37	50.01
Residual fuel	1,460.94	1,785.43	--	634.68	20.00
Gasoline	--	--	--	14,440.24	--
Jet fuel	--	--	--	4,037.06	--
Kerosene	214.76	100.16	--	--	--
Liquid gas	1,048.71	390.39	--	209.97	19.99
Liquid refinery gas	--	--	196.25	--	--
Liquid petroleum gas	--	1,030.31	--	--	--
Asphalt & road oil	1,241.66	--	--	--	--
Still gas	--	1,334.06	88.60	--	--
Naphthas	--	--	397.68	--	--
Special naphthas	--	--	211.84	--	--
Lubes and waxes	--	--	276.87	169.68	--
Petroleum coke	--	397.30	241.33	--	--
Raw material	--	--	--	--	398.28
TOTAL	21,219.28	26,419.18	3,009.59	23,194.98	1,510.27

This means that to realize the activity levels currently projected, a more than 20% savings in natural gas use must be achieved through increases in energy efficiency.

In terms of sector differences the largest efficiency gains must be realized in the residential and commercial sectors. To be consistent with the FEA scenario a 46% savings in natural gas usage relative to 1972 patterns must occur in the residential and commercial sectors. In contrast, a slight increase of about 2% is implied for the industrial sector.

In essence, these efficiency changes suggest the need for extensive conservation efforts. Such efforts will differ among individual subregions of each state, depending on mixes of regional activity and historic dependence on particular energy forms.

Given the structure of the analysis, further implications as to the regional consequences of national energy scenarios are possible. The ORLN procedure can provide a convenient methodology for addressing these impacts upon regional conservation efforts and employment activity and subsequent development.²⁶

V. SUMMARY AND CONCLUSIONS

The research discussed in this volume was sponsored by the Economic Development Administration to develop information and analyses on the availability of basic and converted energy resources and to determine the relationship between these resources and regional economic development. A major goal has been to analyze the degree to which energy availability may hamper the implementation of economic development plans. This program has been designed to develop information that will assist EDA in determining suitable target areas for future infrastructure development investment.

A. Summary of Progress

The statements of regional energy use and availability developed in this study represent the first attempt at constructing a national and regional accounting system for functional economic areas. Our past research has led to: (1) the construction of an historical energy data base appropriate to addressing development issues; (2) a basic methodology for formulating regional energy statements; and (3) acceptable procedures for examining regional availability and projecting regional energy use. We have now assembled sufficient information and developed the requisite expertise to conduct analyses of regional energy production, transformation and consumption.

During the first twelve months of the project, ORNL compiled regional energy statements for census regions, states, and BEAs for 1972 and developed a methodology for projecting regional energy use and availability. In addition, we examined the uses of energy forms in somewhat more detail than requested in our original agreement with EDA. In order to provide consistent regional energy statements for each historical year, it was necessary to recalculate the energy use statistics. The ability to better analyze the changes occurring in energy use across regions and across time was felt to be of sufficient import to justify a delay in publishing our 1972 data. However, we expect to publish the 1972 volume in the near future.

Our agreement for the second twelve months of the project involves extending our data set to 1973 and 1974, and projecting regional energy use and availability to 1980 and 1985 based upon the methodology developed during the first year of the project. In addition, a preliminary analysis of natural gas availability in the past and future is scheduled to determine which regions will experience the most critical shortages of natural gas and the potential options for dealing with projected curtailments.

A detailed work plan of our second year of activity is shown in Table 13. We anticipate that by July 1, 1977, we will have completed four data volumes to accompany this methodological and data overview, as well as a volume containing an analysis of natural gas availability based

Table 13. Scheduling of Activities¹

Output	1972 Volume	1973 Volume	1974 Volume	1980-1985 Volume
Energy Supply Data	Ready	Ready	Ready	Ready
Energy Demand Data	May 1	June 1	June 1	May 15
Computer Program to Output Statistics Reconciling Supply and Demand	May 7	June 7	June 7	May 22
Manuscript Accompanying Volumes	May 1	June 1	June 1	May 30
Ready for Printing	May 7	June 7	June 7	May 22
Allow 6 Weeks for Printing				
Distribution of Data	June 21	July 21	July 21	July 7

¹Work proposed for the first and second years of the project will extend 27 months rather than 24 months to adjust the fiscal year for EDA with the October to September fiscal year used by most ORNL projects. This has been agreed to in principle by EDA staff.

on the historical data and our regional projections. The next step is to conduct similar research into the distribution of energy to better determine regional energy availability.

B. Proposed Future Activities

The term "energy availability" has been used somewhat ambiguously throughout the agreements funding this research. We are aware that "availability" means more than the point of energy production or transformation. We believe that future research must focus on the transportation of final energy forms to points of final use, as well as the trade-offs in energy forms required by inadequate energy supplies or by conservation measures. We are planning to actively investigate the transportation issue to fully explore the concept of availability and associated constraints on regional economic development.

We plan to approach the availability issue in a manner similar to that used in analyzing regional energy production and consumption. We will first construct a data base of the historical energy transportation flows, and then proceed to a projection mode in which assumptions can be modified. We believe this approach superior to optimizing the network flow since optimization approaches reduce the importance of historical patterns.

A simple example may illustrate the inherent difficulties. If distance is in itself a significant aspect of energy cost and a determinant of final energy usage, one would expect utilities located near coal mines to use coal extensively. Nonetheless, the Tennessee Valley Authority is located in close proximity to eastern coal producing areas, but employs nuclear fuel rather than coal in most planned plant expansions.²⁷ Considerable uncertainty characterizes the projections of energy forms available and those actually used in any given region, despite proximity.

Our detailed proposal, which is contained under separate cover, proposes to extensively analyze the energy distribution network and determine future transportation flows of energy. By synthesizing network distribution models for each energy form with the regional energy statements we have already developed, we will be able to analyze the impact upon regional economic development of: (1) changes in the input of distribution networks, (2) changes in the pattern of energy distribution which result from administrative action, and (3) changes in energy consumption patterns which result from energy shortages.

Focusing first on natural gas, we will examine the natural gas pipeline network—its capacity, accessibility, and throughput. We will also analyze the proposed curtailments of natural gas and the number and location of electric utilities which will be ordered to convert to other fuel forms, as well as the available fuel alternatives of regions affected by changes in natural gas production and distribution. We will then conduct similar analyses of the distribution network of coal and petroleum products to permit a complete evaluation of energy availability.

In addition to our analysis of availability, we will update our data set to 1975 and adjust our 1980 and 1985 projections of regional energy use and availability when FEA makes available its most recent projections of energy supply and demand. We will use MULTIREGION projections of population and employment, rather than OBERS projections, to disaggregate these national supply and demand factors. Finally, discussions between EDA and ORNL have led to mutual interest in exploring water as a constraining influence both to energy development and subsequent economic development. During the third year of the project we will prepare a brief discussion paper outlining a parallel effort to examine the effects of water availability on economic development.

FOOTNOTES

¹Federal Energy Administration, *1976 National Energy Outlook*, FEA-N-75-713, Washington, D.C., February, 1976.

²A broad range of national energy-related models have been constructed over the past few years, most notably, the Reference Energy System of Brookhaven National Laboratory and the Project Independent Evaluation System of FEA.

³The Bureau of Mines publishes a number of statistical series regarding energy production and use such as *Fuel and Energy Data: U.S. By States and Regions: 1972*, IC-8647, 1974.

⁴A description of BEA areas, their origin and characteristics, and a rationale for their use is presented in R. J. Olsen, *et al.*, *MULTIREGION: A Simulation Forecasting Model of Regional Population and Employment*, ORNL-RUS-25, Oak Ridge National Laboratory: Oak Ridge, Tennessee, 1975.

⁵*Ibid.*

⁶The data gathered in preparing these regional energy statements will be contained in forthcoming ORNL data volumes.

⁷Federal Energy Administration, *op. cit.*

⁸MULTIREGION regionalizes national economic and demographic control totals. The national economic forecasts are drawn from the INFORUM model (see Clopper Almon, *et al.*, *1985 Interindustry Forecasts of the American Economy*, Lexington-Heath Publishing Company: Boston, Massachusetts, 1974).

⁹U.S. Bureau of Mines, *Minerals Yearbook: Area Reports—Domestic*, 1972 and 1973 editions, U.S. Government Printing Office: Washington, D.C., 1974.

¹⁰*1976 Keystone Coal Industry Manual*, McGraw-Hill Publishing Company: New York, New York, 1976. This manual is published annually.

¹¹Arkansas Oil and Gas Commission, *Annual Oil and Gas Report*; Kansas Geological Survey, *1972 Oil and Gas Production in Kansas*, University of Kansas; Louisiana Department of Conservation, "Crude, Condensate, Calculated Theoretical Condensate, Casinghead Gas, and Natural Gas Production by Parishes," 1972, 1973, and 1974; Oklahoma Corporation Commission, *Quarterly Summary of Liquids and Gas Runs by Counties: 1972, 1973, and 1974*; Texas Railroad Commission, *Annual Report of the Oil and Gas Division*.

¹²*Oil and Gas Journal*, selected issues, The Petroleum Publishing Company: Tulsa, Oklahoma, weekly.

¹³Kenneth K. Landes, *Petroleum Geology of the United States*, Wiley Publishing Company: New York, New York, 1970; E. N. Tiratsoo, *Oilfields of the World*, Scientific Press, Ltd: Beaconsfield, England, 1970.

¹⁴Natural gas is produced in Maryland and Virginia where no crude oil is produced. Crude oil is produced in Nevada and South Dakota, where no natural gas is produced. The other 28 states referred to produce both crude oil and natural gas.

¹⁵U.S. Bureau of Mines, "Natural Gas," preprint from the 1974 *Minerals Yearbook*.

¹⁶The Bureau of Mines reports one figure for Florida, Georgia, and Virginia, one for Kentucky and Tennessee, one for Missouri and Nebraska, one for Minnesota and Wisconsin, one for Alaska, Washington, Oregon, Arizona, and Hawaii, and one for Delaware and Maryland.

¹⁷*Oil and Gas Journal*, *op. cit.*

¹⁸*International Petroleum Encyclopedia*, The Petroleum Publishing Company: Tulsa, Oklahoma, 1975.

¹⁹The number, location, ownership, and crude distillation capacity of individual refining plants is published annually by both the Bureau of Mines and the *Oil and Gas Journal*. There are minor discrepancies between capacity estimates of these two sources, given that the Bureau of Mines focuses on capacity per calendar day, while the *Oil and Gas Journal* focuses on capacity per stream day.

²⁰"Form 4" is a computer tape file available from the Federal Power Commission containing information on electric utilities by plant.

²¹*Generating Unit Reference File* is a computer tape available from the Federal Power Commission containing information on electric utilities.

²²Given the data availability, the indices were constructed using information from several different years. The residential and commercial data presented in Table 2 is based on 1972 data from Edison Electric Institute, while the manufacturing data is available only for 1971 from *State Projections of Industrial Fuel Needs*, Federal Power Commission. It is assumed that any year to year variation is relatively small and that 1971 is a good proxy for 1972.

²³The level of economic activity is either population or employment. In the case of the historic data, we aggregate the *County Business Patterns* employment to the desired level of detail. For the forecast years 1980 and 1985, we have estimated sub-region population and employment by detailed sector, based on the OBERS regional population and earnings forecasts at the state and BEA level.

²⁴The basic data on petroleum in fuel and energy data has been supplemented by a more detailed breakdown provided on computer tapes from the Bureau of Mines.

²⁵The 1980 estimates are not presented in the 1976 *National Energy Outlook*, but may be obtained directly from FEA.

²⁶The forecasted regional employment currently used in the analysis is based on the OBERS forecasts. We intend to eventually utilize the ORNL-MULTIREGION model to increase the predictive power of our model.

²⁷TVA also seems to have made a commitment to use low sulfur coal in existing coal-fired stations rather than rely extensively on pollution control technology, even though the bulk of low sulfur coal is located in the west.

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APPENDIX A

DATA SOURCES FOR OIL AND GAS SUPPLY

1973 and 1974

Alabama State Oil and Gas Board
Alaska Department of Natural Resources
Arizona Oil and Gas Conservation Commission
Arkansas Oil and Gas Commission
California Resources Agency, Division of Oil and Gas
Colorado Oil and Gas Conservation Commission
Florida Department of Natural Resources
Illinois State Geological Survey
Indiana Department of Natural Resources
Kansas Geological Survey
Kentucky Department of Mines and Minerals
Louisiana Department of Conservation
Michigan Department of Natural Resources
Mississippi State Oil and Gas Board
Missouri State Oil and Gas Council
Montana Oil and Gas Conservation Division
Nebraska Oil and Gas Conservation Commission
Nevada Department of Conservation and Natural Resources
New Mexico Oil Conservation Commission
North Dakota Geological Survey
Ohio Department of Natural Resources
Oklahoma Corporation Commission—Oil and Gas Conservation Division
Pennsylvania Department of Environmental Resources
South Dakota Geological Survey
Tennessee Department of Conservation—Division of Geology
Texas Railroad Commission
Utah Division of Oil and Gas Conservation
West Virginia Geological and Economic Survey
Wyoming Oil and Gas Conservation Division

29 of the 30 oil producing states accounting for 99.9% of oil production.

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APPENDIX B

THE STRUCTURE OF THE REGIONAL ENERGY BALANCE STATEMENTS

The regional energy balance statements depicted in Tables 2, 3, and 4 were constructed to provide a simple, consistent methodology for examining and comparing regional energy patterns. For each region we will show where energy is used, in what fuel form it is used, and how it is provided to the region.

The underlying structure is somewhat unique to our representation and requires further elaboration. All energy data is internally processed in British Thermal Units (BTUs), and the regional energy tables will also be presented in BTUs. Average conversion measures are incorporated such that these tables may also be presented in the traditional units for each fuel.

The basic sectors: the final demand sector, the transformation sector, and the energy supply sector, correspond to the discussion in the text. Consumption in the final demand sectors is for final end use, but the transformation sectors use energy in one form, then supply it to the final demand sectors in another. Consequently, total energy usage in the transformation sector is defined as the conversion loss in the process and considered part of final regional demand. In the transformation sector, a positive number represents input to the conversion process and a negative number represents the output of the transformation process.

The energy supply sector consists of fossil fuel production and electricity generated by hydropower, nuclear energy, solar and geothermal sources. The electricity conversion rate is that of end use (3.412 BTU/kwh) rather than fossil fuel equivalents. It was not felt essential to our overall goal of portraying regional energy conditions to trace the flow of uranium from point of extraction to point of processing to point of end use, since most BEAs must import enriched uranium.

The tables indicate the total amount of fuel consumed in each sector as well as the consumptions of each specific fuel. For example, the residential sector consumed 16,438 trillion BTUs of total energy in 1972, primarily natural gas (7,642 trillion BTUs). None of the final demand sectors consume unprocessed crude oil. The total energy consumption of all sectors is presented in the row labeled "Total Final Demand" (54,789 trillion BTUs). Natural gas consumption (19,023 trillion BTUs) accounted for the greatest single share of the total in 1972.

The coefficient signs of the numbers in the transformation sector indicate whether the fuel is an input or an output of the transformation process. A positive number represents an input (i.e. demand) to the conversion process, while a negative number represents an output (i.e. supply or a negative demand) of the process. The sector total is the total output minus all inputs measured in BTUs. For example, in the

electricity sector the output is total generated electricity by fossil fuel plants in BTUs minus the BTU content of the fuels consumed. The output (demand) of electricity by fossil fuel plants in 1972 was 4,848 trillion BTUs, while inputs were 398 trillion BTUs of distillate oil, 2,737 trillion BTUs of residual oil, 4,102 trillion BTUs of natural gas and 7,836 trillion BTUs of coal. The total BTUs lost in the conversion operation, and treated as consumption by the sector was 10,225 trillion BTUs. This loss implies an efficiency in electricity transformation of fossil fuels of 47 percent.

The amount of BTUs lost in a conversion process may reflect either the actual conversion loss, as in the case of the electric generating plants, or may include unaccounted for outputs. In particular, for the case of petroleum products we have not included asphalt, although the crude oil input reflects this potential output. The consumption of asphalt is included as part of the total consumption of the petroleum transformation sector, rather than part of a final demand sector. The net consumption of fuel used in the oil transformation sectors is presented in the row labeled "Net Fuel Used." The total net regional demand for fuel minus the supply of fuels by the transformation process is presented in the row labeled "Total Net Usage" (69,583 trillion BTUs). This energy is the amount which came from primary sources or foreign imports.

SUPPLY AND IMPORTS

The total supply by all forms of primary energy is given in the row labeled "Total Supply." Distillate oil, residual oil, gasoline and other hydrocarbons are all zero, indicating that these products are not considered primary energy sources.

The tables were constructed to balance, i.e., the sum of row totals will equal the sum of column totals. Consequently, the last row represents the net regional imports by fuel (a negative number indicates exports). With the exception of the national tables, these values do not represent measured imports or exports, but are derived from the consumption and supply data. The number in the last row and last column gives a single measure of net energy imports of a region, characterizing the region as to its external reliance upon energy supplies. The U.S., a net importer of energy, acquired 9,330 trillion BTUs of energy products from foreign sources in 1972. To maintain consistency with measured imports at the national level, the tables are constructed such that the tables report estimated net imports equal to the actual data. Any initial differences between estimated and actual net imports are allocated based on each region's share of total gross usage of each fuel and reported in the row labeled "Loss, Errors, and Omissions." The transmission loss associated with electricity generation is based on the national average loss and imputed to the consuming region, and is also reported in the row labeled "Loss, Errors, and Omissions."

APPENDIX C

CONVERSION FACTORS

Crude oil	5,800,000 BTU per barrel
Natural Gas (consumption)	1,021,000 BTU per thousand cubic feet
Natural Gas (production)	1,093,000 BTU per thousand cubic feet
Electricity	3,412,000 BTU per thousand kilowatt hours
Distillate Oil	5,825,000 BTU per barrel
Residual Oil	6,287,000 BTU per barrel
Gasoline	5,248,000 BTU per barrel
LPG	4,011,000 BTU per barrel
Kerosene & Jet Fuel	5,670,000 BTU per barrel
Natural Gas Liquids	4,032,629 BTU per barrel
Coal (production)	
Alabama	25,740,000 BTU per short ton
Alaska	22,860,000 BTU per short ton
Arizona	21,840,000 BTU per short ton
Arkansas	28,760,000 BTU per short ton
Colorado	22,320,000 BTU per short ton
Illinois	22,780,000 BTU per short ton
Indiana	23,200,000 BTU per short ton
Iowa	19,420,000 BTU per short ton
Kansas	24,340,000 BTU per short ton
Kentucky	24,812,000 BTU per short ton
Maryland	25,440,000 BTU per short ton
Missouri	21,800,000 BTU per short ton
Montana	21,336,000 BTU per short ton
New Mexico	23,080,000 BTU per short ton
North Dakota	14,160,000 BTU per short ton
Ohio	24,600,000 BTU per short ton
Oklahoma	25,240,000 BTU per short ton
Pennsylvania	26,720,000 BTU per short ton
Tennessee	26,200,000 BTU per short ton
Texas	13,200,000 BTU per short ton
Utah	25,440,000 BTU per short ton
Virginia	26,360,000 BTU per short ton
Washington	19,340,000 BTU per short ton
West Virginia	26,800,000 BTU per short ton
Wyoming	20,620,000 BTU per short ton

The conversion factors for coal consumption are the same with the following exceptions: Massachusetts, Maine, New Hampshire, Rhode Island, Vermont, Delaware, District of Columbia and Maryland—26.8; Kentucky, South Carolina, Tennessee, Florida and Georgia—25.46; Idaho, Montana and Minnesota—20.58; Iowa, Missouri and Wisconsin—22.78; New Jersey and New York—26.72; Oregon and Washington—20.58; California—25.4; Connecticut—26.12; Michigan—24.6; North Carolina—24.34 million BTUs per ton.

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