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REGIONAL REFERENCE ENERGY SYSTEMS: ELECTRIC UTILITY APPLICATIONS

ALAN HERMELEE

January 1979

TECHNOLOGY ASSESSMENT GROUP
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

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ABSTRACT

Reference Energy Systems have been developed for the region serviced by the Tennessee Valley Authority for the base year 1975 and projections developed for the years 1980, 1985, and 2000. This systems formulation has traditionally been applied to the assessment of energy technologies and policies on a national level. This paper presents a reformulation of the projection methodology in order to apply the Reference Energy Systems format to an electric utility region (e.g., the Tennessee Valley Authority). The Reference Energy System is a network representation of the technical activities required to supply various forms of energy to end-use activities. Technologies are defined for all operations involving specific fuels including resource extraction, refinement, conversion, transportation, distribution, and utilization. Each of these activities is represented by a link in the network for a given year with the levels of energy demand and supply specified.

A unique advantage of using the system presented here for utility planning is its integrative view of the entire energy system as opposed to an analysis limited exclusively to the electric sector. This systems approach, incorporating all resources, technologies and uses of energy, allows a utility to assess the impact of alternate technologies and policies across the entire energy system. Demand patterns for twenty-five end-use demand categories within the residential, commercial, industrial, and transportation sectors are developed for a base case scenario representing reasonable energy use patterns derived in a consistent manner by applying engineering techniques to the best available information. The impact of a new technology in terms of resource consumption may be evaluated by modifying the energy flow paths to incorporate the new technology. Alternate paths through the network reflect the substitutability of resources and technologies for one another.

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SUMMARY

Recent world events have led this nation to reexamine its energy priorities in terms of the production and demand for energy. Alternative conservation strategies, environmental policies and new supply technologies are several of the issues receiving increased attention as the United States attempts to develop a sound national energy policy. To assess the impact of alternative sources of energy, technologies and policies on the nation's energy system requires an analytical framework which incorporates the entire energy system. The systems formulation presented in this report is based on the Reference Energy Systems approach and incorporates all resources, technologies and uses of energy in a uniform manner. The Reference Energy System has traditionally been applied to the assessment of energy technologies and policies on a national level. This report presents a reformulation of the projection methodology developed on a national level and applies it to an electric utility region--The Tennessee Valley Authority. Reference Energy Systems have been developed for the region serviced by TVA for the base year 1975 and projections developed for the years 1980, 1985 and 2000.

Brookhaven National Laboratory and the Tennessee Valley Authority have entered into a cooperative agreement to model the energy system for the area serviced by TVA. This cooperative arrangement has proven mutually beneficial to both TVA and Brookhaven. TVA has agreed to supply the energy and economic data that are available to them for the region. Brookhaven has responsibility in the project for developing the energy model and deriving regional estimates of energy supply and demand not provided by TVA. A unique advantage of using the system presented here for utility planning is its overall view of the entire energy system as opposed to an analysis limited exclusively to the electric sector.

Final demands are disaggregated into twenty-five end-use demand categories within the residential, commercial, industrial and transportation sectors. Demand for energy in the residential sector is disaggregated into space heating, water heating, cooking, air conditioning, appliances and lighting. Space heating in the TVA region consumed 59% of the energy required by the residential sector in 1975. This figure is computed from the energy demand per household, 42×10^6 Btu's/household; the number of households, 2025×10^3 households; and the market penetration for space heating in the TVA

region, 100%. The basic energy demand for space heating, appearing in the Reference Energy System under the column heading DEMAND CATEGORY, is computed as the product of the delivered energy and the end-use device efficiency. The basic energy demand represents the net energy required to deliver a given level of service, for example, to maintain room temperature at 72°F. The proportion of households in the region using electricity to meet their space heating requirements is projected to increase from 43% in 1975 to 62% in 2000. The low cost of electricity and the relatively moderate climate in the region explain the continued reliance on electricity for space heating. Energy requirements for residential water heating, cooking, air conditioning, appliances and lighting are computed using a methodology analogous to that used for residential space heating.

The commercial sector incorporates a wide range of activities which can be disaggregated into two broad categories: 1) buildings and 2) agriculture and mining. A methodology analogous to the one followed in the residential sector is used to estimate the energy consumed in commercial buildings for space conditioning, water heating, cooking, lighting, refrigeration, computers and other electrical appliances. The commercial inventory in the TVA region was 680 million square feet in 1975 and is projected to 1980, 1985 and 2000 in proportion to output in the services sector for the U.S. from the Brookhaven National Laboratory input-output model, adjusted by regional earnings as follows:

$$\text{TVA COMMERCIAL INVENTORY}_t = \frac{(\text{OUTPUT})_t}{(\text{OUTPUT})_{1975}} \times [\text{EARNINGS RATIO}]_t \times [\text{TVA COMMERCIAL INVENTORY}]_{1975}$$

where, OUTPUT = Dollars of output in the services sector from the I/O model for the U.S.

t = Projection year -- 1980, 1985, 2000.

The regional adjustment or "Earnings Ratio" is computed as the ratio of projected regional earnings in the commercial sector to projected U.S. earnings in the commercial sector, normalized to 1970 as follows:

$$[\text{EARNINGS RATIO}]_t = \left[\frac{\left(\frac{E_{\text{TVA}}}{E_{\text{U.S.}}} \right)_t}{\left(\frac{E_{\text{TVA}}}{E_{\text{U.S.}}} \right)_{1970}} \right]$$

where, E = Earnings in the commercial sector
t = Projection year -- 1980, 1985, 2000.

earnings in the TVA region are derived from earnings in each of the states assuming earnings are proportional to population.

Agricultural uses of energy associated with on-the-farm operations to grow crops and raise livestock are currently estimated to be 2014 trillion Btu's in the U.S. This includes such indirect uses of energy as the production of fertilizers and pesticides. Energy associated with agricultural production is regionalized from national totals for 1975 by assuming energy demand in the TVA area is proportional to farm acreage. Mineral industries in the TVA region are primarily engaged in the mining of bituminous coal and lignite, the nonferrous metal ores bauxite and zinc, and the mining and quarrying of the nonmetallic minerals stone, clay and phosphate rock. Consumption of energy in the TVA region is derived from value added for these mineral industries. The basic energy demand derived for both agriculture and mining is escalated to 1980, 1985 and 2000 in proportion to projected output in the agricultural and mining sectors, respectively, of the BNL input-output model for the U.S. adjusted by regional earnings.

The industrial sector has been disaggregated into several major energy-intensive industries including aluminum, steel, petrochemicals and uranium enrichment; remaining industrial energy requirements (excluding petroleum refining) are included in the demand categories industrial process heat and industrial electric drive. Energy requirements for industrial process heat are initially estimated by determining overall industrial energy requirements. Industrial process heat then represents the balance of unaccounted fuels in the industrial sector after all other end uses are accounted for. It is assumed that overall energy requirements in the industrial sector in 1975 are proportional to regional value added in manufacturing. Regional value added is estimated in proportion to population. Energy requirements for industrial process heat, escalated at an annual growth rate of 3.6% from 1975 to 2000, are derived from the historical ratio of U.S. energy consumption in the industrial sector to gross national product (GNP) adjusted by regional earnings. The ratio of industrial energy consumption to GNP has been declining over time at the rate of 241 Btu per dollar of GNP per year. If it is assumed that this energy/GNP ratio continues to decline as it has since 1960, and that GNP increases at an annual rate of 3.2% between 1975 and 2000, then the demand for energy by industry in the U. S. will increase at an annual rate of 2.6% over the reference years compared to 3.6% in the TVA region. This regional variation in the demand for energy reflects the increasing proportion of earnings projected to originate in the region over the next 25 years.

In 1975 the automobile consumed 52% of the energy in the transportation sector compared to 31% projected for 2000, reflecting improved automobile fuel economy and

market saturation. Automobile gasoline consumption is computed as a function of the number of registered vehicles, miles traveled per vehicle (10,800), and the fleet average fuel economy. The number of registered vehicles, expected to be an increasing proportion of the driving age population, is projected to increase from .61 vehicles per driving age population in 1975 to .85 vehicles per driving age population in 2000. The fleet average fuel economy is computed as a function of the mix of model years on the road, the distribution of vehicle-miles with the age of the vehicle, and the fuel efficiency per model year. The fuel efficiency per model year is assumed to be 10% lower than specified in the Energy Policy and Conservation Act because of nonoptimum engine performance in older model vehicles. The fleet average fuel economy projected for 1980, 1985 and 2000 is 18.9 mpg, 19.3 mpg and 25 mpg, respectively.

The truck and bus demand category includes all gasoline and diesel fuel not consumed by automobiles, excluding marine and aviation uses of motor fuels. Trucking activity is subdivided into two classes: 1) freight trucking (measured in terms of ton-miles) includes all trucks over 10,000 lbs GVW and 2) nonfreight trucking (measured in terms of truck-miles) includes all trucks under 10,000 lbs GVW. Historically, freight trucking activity in the U.S. has increased in proportion to GNP, and this trend is projected to continue through the year 2000. Regional freight trucking activity is derived from U.S. projections based on regional earnings and is projected to increase from 16 billion ton-miles in 1975 to 45 billion ton-miles in 2000 at an annual rate of 4.2%. The consumption of jet fuel by commercial air carriers, diesel fuel by railroads, and fuel oil by commercial shipping is projected in proportion to the modal transportation projections shown in Tables S-1 and S-2.

Coal production in the TVA region was approximately 27 million tons in 1975 and was estimated from data for individual counties within the region. Coal production is projected to increase at the same rate as forecast for the Interior Appalachia region from the "Recent Trends" scenario in the National Coal Assessment. This results in growth rates of 3.5% from 1975 to 1985 and 1.8% thereafter.

The Tennessee Valley Authority has traditionally depended upon hydroelectric power and coal to meet its power requirements. Electricity generated from nuclear plants is playing an increasing role in meeting the system's demand for base load electric power with gas turbines and pumped storage being used to meet the system's demand for peak power. Electricity generated from coal steam-plants met 72% of the demand for electric power in 1975, hydroelectric power satisfied 20% of demand, and

electricity generated from nuclear plants and gas turbine peaking units accounted for the remainder of the load in 1975. Electricity sales totaled 381 trillion Btu's or 112 billion kilowatt-hours in 1975, remaining approximately constant since 1973. Recent electric utility forecasts of future energy requirements have been reduced from what they were in the 1972 to 1973 time period. Higher energy prices, depressed economic conditions, and the "conservation ethic" have all been contributing factors to the low energy growth recently experienced. These factors have all added a considerable degree of uncertainty to future projections. Traditionally, utilities have depended upon historical trends in forecasting future loads, but this method is rapidly being replaced by more sophisticated techniques using econometrics and detailed engineering analyses of demands. A systems approach using the latter technique is being applied in this study to project requirements for fuel and electric power.

The mix of capacity additions projected for the Tennessee Valley Authority in 2000 results in a generation mix of 35% coal-steam and 57% nuclear steam with the remainder of the load being met by hydro, pumped storage and gas turbine peaking units. No capacity additions to hydropower are planned after 1980 and the electricity generated from hydro is projected to decrease from 22950 million kilowatt-hours in 1975 to 18276 million in 1980 and then remain constant at that level through the year 2000. Pumped storage is projected to play an increasing role in meeting the system's demand for peak power with four units totaling 1530Mw expected to be operational within the year and 5430Mw projected to be on line by the year 2000. No additional gas turbine peaking units are planned after 1980. Coal continues to be an important fuel in meeting TVA's energy requirements, although nuclear power dominates the schedule of planned additions over the next twenty-five years.

The overall demand for primary energy in the TVA region is projected to increase at an annual rate of 3.5% between 1975 and 2000 compared to a national growth rate of approximately 2.5% (see Figure S-1). This regional variation in the demand for energy reflects the increasing proportion of earnings projected to originate in the region by the year 2000. Total earnings is projected to increase at an annual rate of 3.7% in the U.S. compared to 4.1% in the TVA region. The demand for delivered energy in the TVA region is projected to increase at an annual rate of about 2.5% for gas and oil and 4.9% for coal as shown in Figure S-2. The relatively high growth in coal consumption is due to the increased use of coal by industry. The demand for electricity in the TVA region is projected to increase at an annual rate of 4.1% between 1975 and 2000 compared to a 4.6% growth rate in the preceding decade.

Table S-1
TVA MODAL TRANSPORTATION PROJECTIONS
(Billions)

	1975	1980	1985	2000
Passenger-Miles				
Air	2.2	3.4	4.7	10.7
Local & Intercity Bus	1.4	1.9	2.2	3.9
School Bus	1.2	1.3	1.3	1.4
Ton-Miles				
Air	-	-	-	-
Truck (GVW over 10,000 lbs.)	16	20	25	45
Ship	75	74	73	47
Rail	26	30	34	48
Truck-Miles				
Non-freight Trucking	9	12	16	31

Table S-2
ENERGY INTENSIVENESS BY TRANSPORT MODE

	1975	1980	1985	2000
Btu/Passenger-Mile				
Air	8698	7918	7431	7431
Local & Intercity Bus	1490	1490	1490	1490
School Bus	1704	1704	1704	1704
Btu/Ton-Mile				
Air	-	-	-	-
Truck (GVW over 10,000 lbs.)	4678	4444	4210	3509
Ship	567	567	567	567
Rail	709	709	709	709
Btu/Truck-Mile				
Non-freight Trucking (mpg)	12061 (10.4)	11458 (10.9)	10855 (11.5)	9046 (13.8)

Figure S-1. Primary energy - TVA region.

Figure S-2. Delivered energy to the TVA region.

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I. INTRODUCTION

The United States has traditionally been an energy independent country relying upon its own plentiful supply of resources to meet its energy needs. Over the past decade this situation has reversed itself as the nation has increasingly relied on imported oil. In 1970 the U.S. imported 3.4 million barrels of oil per day to meet about 25% of its demand for petroleum products. Since 1970 oil imports have more than doubled reaching 8.7 million barrels of oil per day in 1977 to meet nearly 50% of the nation's demand for petroleum. This rising level of imported energy coupled with the dramatic price increases following the Arab oil embargo of 1973 have led to a reexamination of the nation's energy priorities in terms of the production and demand for energy. Alternative energy sources such as coal synthetics, solar, and nuclear power have been receiving increased attention. Conservation strategies such as improvements in end-use device efficiency and in building construction practices, as well as specific lifestyle changes, are being pursued as a result of both government regulation and price inducement. To assess the impact of these alternative sources of energy, technologies, and policies on the nation's energy system requires an analytical framework which incorporates the entire energy system. The systems formulation presented in this report is based on the Reference Energy System approach and incorporates all resources, technologies and uses of energy in a uniform manner.

The Reference Energy System is a network representation of the technical activities required to supply various forms of energy to end-use activities and has wide application in the assessment of energy technologies and policies. Technologies are defined for all operations involving specific fuels including resource extraction, refinement, conversion, transportation, distribution, and utilization. Each of these activities is represented by a link in the network for which an efficiency is specified. The network is quantified for a given year with the level of energy demands and the energy flows through the supply activities that are required to serve these demands.

The Reference Energy System has traditionally been applied to the assessment of energy technologies and policies on a national level. The diversity of energy consumption across the United States is such that regional analysis of energy resources and consumption is essential for any meaningful analysis of policy issues. Both energy resources and end uses have such widely varying characteristics on a national level that analyses of such issues as conservation strategy, utility load forecasting, new technology implementation, and environmental policy require an in-depth knowledge of energy requirements on a regional level.

This report presents a reformulation of the projection methodology developed on a national level and applies it to an electric utility region--the Tennessee Valley Authority. Reference Energy Systems have been developed for the region serviced by TVA for the base year 1975 and projections were developed for the years 1980, 1985 and 2000. Brookhaven and the Tennessee Valley Authority have entered into a cooperative agreement to model the energy system for the area serviced by TVA. This region, typical of the area serviced by many utilities, cuts across both state and county political boundaries. Thus energy supply and demand data available for political entities from published government statistics can not be utilized directly in this study. The Tennessee Valley Authority has agreed to supply Brookhaven with the necessary energy and economic data available to them for the region. Brookhaven has responsibility in the project for developing the energy model and deriving regional estimates of energy supply and demand not provided by TVA. This cooperative arrangement has proven mutually beneficial to both TVA and Brookhaven. As a result of this study the Tennessee Valley Authority currently has access to energy consumption data for all fuels consumed in the region. These data were not available previously. In addition, TVA is planning to run the Brookhaven Energy System Optimization Model using the Reference Energy Systems developed in this study as input. Brookhaven has had an opportunity to successfully demonstrate the applicability of its modeling capabilities to a utility region. The general methodology demonstrated in this study is also directly transferrable to other utility regions. The methodology employed in deriving regional energy demands in the residential, commercial, industrial and transportation sectors is described in Section II. The methodology employed in developing the energy supplies for the region including the electric utility sector is discussed in Section III.

The Tennessee Valley Authority is a wholly owned corporate agency of the United States government established by Act of Congress in 1933 to develop the Tennessee River System and to assist in the development of other resources in the Tennessee Valley. The production and sale of electric power are part of TVA's resources

program. TVA supplies power at wholesale to 160 municipal and cooperative distributors which in turn distribute power to about 2.5 million residential, commercial and industrial customers. These customers are located in seven states including the entire state of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina and Virginia as shown on the map of the TVA Power System (Figure I-1). TVA also serves directly 49 industrial customers with large or unusual power requirements and several federal installations including uranium enrichment plants located at Oak Ridge, Tennessee and Paducah, Kentucky.

The Tennessee Valley Authority has traditionally depended upon hydroelectric power and coal to meet its power requirements. Electricity generated from nuclear plants is playing an increasing role in meeting the system's demand for base load electric power with gas turbines and pumped storage being used to meet the system's demand for peak power. Electricity generated from coal-steam plants met 72% of the demand for electric power in 1975. This is projected to decrease to 35% by 2000 as the nuclear plants presently under construction become operational. By the year 2000 nuclear generating capacity is projected to reach approximately 30,000Mw, meeting over 50% of the systems demand for electricity. No substantial additions to hydroelectric generating capacity are planned over the next twenty-five years.

A unique advantage of using the system presented here for utility planning is its overall view of the entire energy system as opposed to an analysis limited exclusively to the electric sector. This systems approach allows a utility to assess the impact of alternative technologies and policies across the entire energy system. Recent electric utility forecasts of future energy requirements have been reduced from those made in the 1972 to 1973 time period. Higher energy prices, depressed economic conditions and conservation have all been contributing factors to the low energy growth recently experienced. These factors have added a considerable degree of uncertainty to future projections. Traditionally, utilities have depended upon historical trends in forecasting future loads, but this method is rapidly being replaced by more sophisticated techniques using econometrics and detailed engineering analyses of demands. A systems approach using the latter technique is being applied in this study to project requirements for fuel and electric power. Demand patterns for twenty-five end-use demand categories within the residential, commercial, industrial and transportation sectors are developed for a base case scenario representing reasonable energy use patterns derived in a consistent manner by applying engineering techniques to the best available information. Demand for electric power is then obtained from the summation of electric demands over all other demand categories.

Figure I-1. TVA power syotem - map.

The Reference Energy Systems presented here were formulated with minimal introduction of new technologies, and projections were derived from data available in the various sectors. Allowances for moderate conservation were incorporated into the energy systems in appropriate demand categories where the technology currently exists. These reductions in energy demand brought about by government regulation or price-induced cutbacks in consumption include a 15% efficiency improvement for air transportation, a 25% efficiency improvement for trucks, and a fleet average fuel economy of 25 miles per gallon for automobiles by the year 2000. In the residential sector new construction practices and retrofitting in older homes over the next twenty-five years are assumed to reduce the heat loss of a typical household by 10%. Reductions in industrial energy requirements per dollar of GNP observed since 1960 are assumed to continue, reducing the growth rate of energy consumed by industry in the TVA region from 4.2% to 3.6% over the reference years. Detailed assumptions regarding those conservation measures explicitly included in the projections are noted in the Fuel Mix Tables in Appendix B.

Fundamental to the proper use of information contained in this report is recognition that data presented here are base line projections and must not be construed as predictions of the future. These projections are not forecasts of what "will be", but are intended to be used for technology assessments (see Section IV). They are reference projections in the sense that new technologies are not included in the projections. This does not imply that new technologies such as the electric car will not be prevalent by the year 2000, but it allows these new technologies to enter the system in some predetermined fashion. The impact of a new technology in terms of resource consumption may be evaluated by modifying the energy flow paths to incorporate the new technology. Alternate paths through the network reflect the substitutability of resources and technologies for one another.

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II. ENERGY DEMAND IN THE TVA REGION-METHODOLOGY

The methodology for developing final energy demands and the fuel mix in each demand sector is discussed in this section. Final demands are disaggregated into the following end-use categories:

RESIDENTIAL

- Space Heating
- Water Heating
- Air Conditioning
- Cooking
- Appliance and Lighting

COMMERCIAL

- Space Heating
- Water Heating
- Air Conditioning
- Cooking
- Appliance and Lighting
- Outdoor Lighting

INDUSTRIAL

- Aluminum
- Steel
- Petrochemicals
- Process Heat
- Electric Drive
- Uranium Enrichment

TRANSPORTATION

- Automobiles
- Truck and Bus
- Railroads
- Air
- Ship
- Pipelines

AGRICULTURE

MINING

ELECTRIC UTILITIES

These final demands drive the Reference Energy System, that is, the "intermediate energy form" appearing in the RES between the column headings DECENTRALIZED CONVERSION and UTILIZING DEVICE is initially computed for each of the above end-use categories. Intermediate energy forms include transmitted and distributed electricity, for example, gasoline in an automobile, or oil in a home oil tank. Intermediate energy or delivered energy is generally computed as a function of demand per unit (i.e., per household or per ton of steel), basis for energy requirements (i.e., number of households or tons of steel), and the level of market penetration. In the case of residential space heating:

$$\begin{aligned} \text{SPACE HEATING DEMAND} &= \text{UNIT DEMAND} \times \text{BASIS} \times \text{SATURATION} \\ [\text{Btu's}] &= \left[\frac{\text{Btu's}}{\text{Household}} \right] \times \left[\begin{array}{c} \# \text{ of House-} \\ \text{holds} \end{array} \right] \times [1.00] \end{aligned} \quad (\text{II-1})$$

The values on the right hand side of the RES under the heading DEMAND CATEGORY represent the basic energy demand for the above set of end-use categories. These basic energy demands should be distinguished from the more commonly used fuel demands (intermediate energy forms) indicated above. Basic energy demand represents the net energy required to provide a given level of service, e.g., to maintain room temperature at 72°F. It is derived from the various fuel requirements and the fuel efficiencies of utilizing devices. This is useful both conceptually, since it more closely represents the level of service rendered by energy use, and for projection purposes since it is directly related to underlying causative factors, e.g., number of households, vehicle-miles, etc.

"Fuel Mix Tables" are included in Appendix B for each end-use category containing a detailed description of 1) reference technologies utilized, 2) derivation of fuel demands and efficiencies for the year 1975 and 3) the basis of energy projections. Data sources referenced in deriving the base case and projected energy demands are noted in the Fuel Mix Tables. Values for fuel fraction (f_i), fuel demand (D_i), relative effectiveness (e_i), saturation (S), and basis of projection (B) for each demand category are included in the Fuel Mix Tables with definitions of the above terminology preceding the tables. The Basic Energy Demand (E) is computed in the Fuel Mix Tables as the intermediate energy form (as listed in Tables A-1 through A-4 of Appendix A) times the relative efficiency (e_i) summed over all fuels:

$$E = \sum_i D_i \times e_i \quad (\text{II-2})$$

This is a measure of the energy requirement and is independent of the fuel or energy form employed. The Unit Basic Energy Demand (E_u) is the Basic Energy Demand per unit (e.g., per household).

The projected Basic Energy Demand as defined above accounts for 1) any saturation effects that may be present (i.e., 100% of the households are air conditioned by 2000), 2) the effect of overall growth in households, vehicle-miles, tons of steel, etc., and 3) changes in the Unit Basic Energy Demand due to technological or conservation efforts. The fuel mix is then specified in terms of fuel fraction

(f_i) for each reference year allowing for switches to alternative fuels. For example, a shift from natural gas to electricity in residential cooking is forecast.

The relative efficiencies (e_i) of the various fuels that satisfy the projected basic energy demands are specified in the Fuel Mix Tables. It is more accurate to consider these efficiencies in terms of relative effectiveness since this both reflects the technical efficiency of an end-use device, and takes differences in utilization practices between fuels into account. Thus, the "efficiency" that is derived from 1975 data for commercial space heating supplied by electric resistance heat¹ has a value of 1.00 compared with 0.4 for gas; this reflects the improved insulation that is generally used with electric heat as well as the higher technical efficiency. The relative effectiveness is also employed to reflect differences between reference years. Existing construction practices are gradually improving the insulation levels of the overall fossil-heated housing stock; this is taken into account by increasing the efficiency factor, e_i .

The remainder of this section describes the underlying methodology in the development of each demand sector in the base case and projected RES's.

RESIDENTIAL SECTOR

Demand for energy in the residential sector is computed as follows:

$$(\text{Fuel Demand})_i = \sum_j (D_{ij} \times B_j) \times S_i \quad (\text{II-3})$$

where D_{ij} = Annual fuel demand for end use i and housing type j .
 B_j = Number of households per housing type j .
 S_i = Market penetration of end-use i .
 i = End-use 1,..., end-use i , end-use $i + 1$,...
 j = Housing type 1,..., housing type 5 (for space heating)
 j = 1 (for other end-uses).

The housing stock is divided into five distinct housing types according to the Census of Housing:

- Mobile Homes
- Single-family Detached
- Single-family Attached
- Multi-family Low Rise
- Multi-family High Rise

¹The value appearing in the commercial space heating Fuel Mix Table has a value of 1.018 because it is weighted by the C.O.P. for heat pumps.

Residential building types for 1975 were estimated using 1970 Census of Housing⁽²⁾ data and data provided by TVA for 1975. Projected changes in the housing mix are assumed to follow those forecast for the East South Central Census Region.⁽³⁰⁾ The greatest change occurs in the number of mobile homes,

Table II-1
RESIDENTIAL BUILDING TYPES IN THE TVA REGION
(Thousands)

Building Type	1975	1980	1985	2000
Mobile Homes	87	171	207	263
Single-Family Detached	1632	1735	1921	2361
Single-Family Attached	184	219	254	331
Multi-Family Low Rise	83	89	107	138
Multi-Family High Rise	39	47	57	75

projected to increase by a factor of three over the next twenty-five years. Also, the percentage of single-family detached households in the region decreases from 81% to 75% as the number of multi-family housing units increase. This can be attributed to a combination of factors including a predicted decrease in the ratio of persons per household and the escalating cost of owning your own home.

The population in the TVA service area in 1975, 1980, 1985 and 2000 is derived from population estimates reported by TVA for the years 1972 through 1990. The population is projected to increase between 1990 and 2000 at the same rate as it did from 1985 to 1990 (see Table II-2). The number of households in the TVA service area in 1975, 1980, 1985 and 2000 is derived from household estimates reported by TVA for the years 1972 through 1990. The number of households is projected to increase between 1990 and 2000 such that the population per household ratio decreases at a decreasing rate, leveling off at 2.50 in 2000.

Table II-2
TVA POPULATION AND HOUSEHOLDS, 1975 - 2000
(Thousands)

	1975	1980	1985	2000
Population	6290	6630	6940	7919
Number of Households	2025	2261	2546	3168
Population/Household	3.11	2.93	2.73	2.50

In addition to projecting total population in the TVA service region, it was also necessary to estimate regional population at a state and county level for the year 1975. State and county population data are used in deriving energy consumption in the commercial, industrial and transportation sectors as will be described in this section. The population in each state that is serviced by TVA is equal to the sum of the individual county populations within that state serviced by TVA.

$$POP_{STATE_j}^{TVA} = \sum_i^{COUNTY} \left(POP_{county_i, state_j}^{TVA} \right) \quad (II-4)$$

Here, i = counties in the TVA service area, j = states in the TVA service area,

$POP_{STATE_j}^{TVA}$ refers to the population in state j serviced by TVA, and similarly,

$POP_{county_i, state_j}^{TVA}$ refers to the population in county i and state j which is serviced by TVA. County population is equal to the total county population as reported by the Bureau of the Census for 1975 if the entire county is within the TVA service territory. If the entire county is not within the TVA service territory then the population serviced by TVA in the county is assumed proportional to that fraction of land area in the county that is within the TVA service territory. Land area was approximated from a map of the region showing county borders. A weighting factor is applied to land area which is dependent upon the demography of the county. If population centers in a border county are equally distributed throughout the county the weighting factor equals 1.0. If population centers in a border county tend to be located within the TVA service territory, the weighting factor is greater than 1.0. Conversely if if population centers tend to be located outside the borders of the TVA service territory, the weighting factor is less than 1.0. Comparing the total population in the TVA region as reported by TVA to that estimated by summing individual county populations using the above procedure reveals only a 1% difference in the total 1975 TVA population.

Space Heating

The primary end-use demand in the residential sector is space heating, consuming almost 60% of the energy used in that sector during 1975. The total number of households in 1975 using natural gas, fuel oil, coal, wood, LPG, electric resistance heat and electric heat pumps for space heating is based on data provided by TVA. There is no data currently available which specifies space heating fuel by region and building type, although the Bureau of the Census does publish data at a national

level.(16) Therefore it was necessary to map the number of households by fuel type, which forms the (7 x 1) vector

Gas
Oil
Coal
Wood
LPG
Electric
Heat Pump

by fuel type and building type

	Mobile	SFD	SFA	MFLR	MFHR
Gas	.	.		.	.
Oil	.				.
Coal					
Wood					
LPG					
Electric	.				.
Heat Pump	.	.		.	.

In mapping the (7x1) vector of households by fuel type into the (7x5) matrix of households by fuel and building types it was assumed that all wood is burned in single-family detached units and that no coal is burned in mobile homes.

The energy requirement for space heating is proportional to population weighted= average annual heating degree days in the region. Heating degree days in the state of Tennessee are assumed to approximate heating degree days in the TVA region. Energy demand for space heating in residential buildings in terms of basic energy demand (delivered energy x efficiency) is shown in Table II-3.

Table II-3
RESIDENTIAL SPACE HEATING

Building Type	Energy Req't/Household (10 ⁶ Btu)
Mobile Home	30.5
Single-Family Detached	45.8
Single-Family Attached	29.1
Multi-Family Low Rise	15.8
Multi-Family High Rise	9.9
Average	41.7

The burner efficiency and the relative shell effectiveness for the various fuels that satisfy the basic energy demands specified in the residential space heating fuel mix table are given in Appendix B. In computing the basic energy demand, $E = D_i \times e_i$, the relative efficiency, e_i , is simply the product of the burner efficiency and the relative shell effectiveness. The burner efficiencies for natural gas, fuel oil, coal and electric resistance heat are .75, .63, .70 and 1.00, respectively. No burner loss is assumed for electric resistance heat.

The Seasonal Performance Factor (SPF) for the electric heat pump, 1.60 in the TVA region, is a measure of the of operational efficiency for a specific heat pump system in a given house, under normal climate conditions. This measures all energy input to the system including backup system inputs (e.g., electric resistance heat) relative to the amount of heat actually required for the house. The Coefficient of Performance (COP) is a measure of the efficiency of operation for a heat pump based on laboratory tests and is generally greater than the SPF. The terms Coefficient of Performance and Seasonal Performance Factor are used interchangeably in reference to heat pumps throughout this report, although the SPF measurement of efficiency is implied. The burner efficiency for electricity to residential space heating shown in the Fuel Mix Table in Appendix B (1.027 for 1975) is the product of the burner efficiency for electric resistance heat, 1.00, and the COP for heat pumps, 1.60, weighted by the respective inventories.

The apparent relative shell effectiveness reflects construction practices typical of the 1975 inventory and construction practices projected over the reference years. The relative shell effectiveness of an electrically heated home is set at 1.00 in 1975. The shell effectiveness of other buildings reflects reduced insulation and other building practices typical of conventional housing units. Housing units constructed after 1985 are assumed to meet ASHRAE 90 - 75 standards. Retrofitting in one-half of all residential buildings constructed prior to 1975 is projected such that they meet the ASHRAE 90 - 75 standards by the year 2000.

The basic energy demands derived for 1975 are escalated in proportion to the projected number of households and the housing mix. The projected fuel mix which satisfies the demand for space heating in 1980, 1985 and 2000 is derived from the forecast of electric space heating customers provided by TVA and an extrapolation of recent (1970-1975) changes in the fuel mix. The only energy source projected to increase its market penetration in residential space heating is electricity, where the percentage of households using electricity is projected to increase from 43% in 1975 to 62% in the year 2000. This includes 435,000 households projected to have

electric heat pumps in 2000 compared to 60,000 in 1975. It is assumed that 15,000 new heat pump installations in the residential sector will occur annually over the next twenty-five years. This is equal to the number of new installations that occurred in 1976. The number of households using coal to meet their space heating requirements is expected to approach zero by the year 2000. The percentage of households using oil, wood and LPG to satisfy their heating load is projected to decrease from 18% in 1975 to 13% in 2000, although the absolute number of households will increase from 364,000 to 412,000 households. Natural gas is projected to satisfy the remainder of the residential space heating load, decreasing from 32% in 1975 to 25% in 2000.

A sharp difference is noted when the percentage of households in the TVA region currently using coal (7%), wood (5%) and LPG (8%) relative to that using fuel oil (5%) is compared with other regions of the U.S. In New England, for example, less than 1% of the households use coal and wood to meet their space heating demand, while 85% of the households use fuel oil. Forty-three percent of the housing units have electric space heating in the TVA region compared to about 4% in New England. This is primarily due to the lower price of electricity in the TVA region, (\$.025/ kWh¹) compared to the price in New England (\$.044/kWh).

Air Conditioning

Energy requirements for air conditioning vary regionally with temperature, humidity and cloud cover. Equivalent full load operating hours is a measure of air conditioning energy requirements that more accurately reflects these meteorological variables than cooling degree days which considers only temperature. The annual hours of compressor operation for a properly sized air conditioner are given in Figures II-1 and II-2 for any U.S. location.⁽⁴¹⁾ Taking a point slightly south of the geographical centroid of Tennessee as the approximate population center in the region gives an estimate of equivalent full load operating hours for air conditioners in the region of 1200 hours. A 78°F inside temperature is assumed, with one-half of the air conditioners used in conjunction with natural ventilation and one-half the air conditioners operating with no ventilation allowed. Average annual unit energy requirements for air conditioners in the U.S., operating at 1000 hours, is 1390 kWh for room units and 3560 kWh for central units.⁽³⁾ Increasing these unit energy demands by the ratio of operating hours in the region to operating hours in the U.S. results in an annual electric demand in the TVA region of 1668 kWh/unit for room air conditioners and 4272 kWh/unit for central air-conditioners. The unit basic energy demand shown in the Fuel Mix Table in Appendix B assumes there are 1.47 room air conditioners per household.

¹As of January 1, 1975 based on average monthly consumption of 500kWh.⁽⁴⁶⁾

Source: D. A. Pilati⁽⁴¹⁾

Figure II-1. Annual air-conditioner compressor-operating hours for homes that are also naturally ventilated.

Figure II-2. Annual air-conditioner compressor-operating hours for homes that are not naturally ventilated.

The coefficient of performance (COP) for currently installed room air conditioners of typical capacity is 1.75.⁽⁴¹⁾ The COP for currently installed central air conditioners of typical capacity is 2.00.⁽⁴⁷⁾ The coefficient of performance of all air conditioners is increased to 3.00 by the year 2000 to reflect the use of the more efficient devices that are on the market today.

The current market penetration of air conditioners in the TVA region is derived from 1970 Census of Housing data⁽²⁾ updated to 1975 using the Annual Housing Survey.⁽⁴²⁾ The number of air conditioners in the TVA region is computed from state census data weighted by the population serviced by TVA in each state as follows:

$$\text{Market Penetration of A/C in the TVA Region} = \frac{(\#HH^{A/C})_{TVA}}{(\#HH)_{TVA}} = \frac{\left\{ \sum_j^{STATES} (\#HH^{A/C})_j \times \left(\frac{P_j^{TVA}}{P_j} \right) \right\} / (\#HH)_{TVA} + (\#HH^{A/C})_{TENN} / (\#HH)_{TENN}}{2} \quad (II-5)$$

where, $(\#HH^{A/C})_{region}$ = Total number of A/C households in region.

P_j = Total population in state j

P_j^{TVA} = Population in state j that is serviced by TVA

j = States in TVA service area

The fraction of households having air conditioners in the state of Tennessee (the second term in the above expression) is more typical of the TVA region than that fraction computed from individual state data (the first term in the expression) because of the common price of electricity in the TVA region. Therefore, market penetration in Tennessee is more heavily weighted by inclusion of the second term in equation II-5.

The basic energy demands derived for 1975 are escalated in proportion to market penetration and the number of households projected in the reference years. Virtually all homes are projected to have air conditioners by the year 2000, with central air conditioning dominating the market.

Water Heating, Cooking, Appliances and Lighting

Energy requirements for domestic hot water heating in 1975 are computed from the unit basic energy demand (19.2×10^6 Btu/household)⁽¹⁾, the market penetration of water heaters (90%), and the number of households in the region (2,025,000 households). The mix of fuels satisfying the demand for water heating in 1975 are derived from 1970 Census of Housing data updated to 1975 using the Annual Housing Survey. The mix of fuels is estimated from census data for each state weighted

Table II-4
RESIDENTIAL APPLIANCES --
ENERGY USE AND REGIONAL
MARKET PENETRATION

	Million Btu Per Household ⁽¹⁾	Market Penetration (Percent)			
		1975	1980	1985	2000
Refrigerators, Lighting, & Small Appliances	7.9	100	104	106	113
Dishwasher	1.2	29	43	56	100
Electric Dryer	3.2	41	49	56	79
Gas Dryer	8.8	12	11	10	7
Television	1.5	143	151	160	186
Food Freezer	4.6	42	47	51	65
Clothes Washer	0.3	75	77	79	86
New Uses	1.6	0	29	46	100
TOTAL	29.1	-	-	-	-
AVERAGE	-	51	56	60	72

(1) Source: Reference 1.

by population using a methodology analogous to the one used to compute the market penetration of air conditioners in the region [see Eq. (II-5)]. The basic energy demand derived for 1975 is escalated in proportion to the number of households and market penetration projected in the reference years. Electric hot water heating is projected to continue dominating the market such that over three quarters of the households use electricity to meet their domestic hot water energy requirements by 2000. This implies that all additions to the housing inventory using electricity to meet their space heating requirements also use electricity for water heating. Moreover, approximately 60,000 new additions to the housing inventory using natural gas to meet their space heating requirements will use electricity for domestic hot water heating.

Energy requirements for cooking in the residential sector are computed from the unit basic energy demand (3.9×10^6 Btu/household) and the number of households in the region. The mix of fuels satisfying the demand for cooking in the residential sector in 1975 are derived from 1970 Census of Housing data updated to 1975 using the Annual Housing Survey. The mix of fuels is estimated from census data for each state in the region weighted by population using a methodology analogous to the one used to compute the market penetration of air conditioners in the region [see Eq. (II-5)]. The basic energy demand derived for 1975 is escalated in proportion to the number of households projected in the reference years. The fuel fraction, f_i , is projected in proportion to the increasing market penetration of electric ranges and the decreasing use of natural gas, LPG, coal and wood for cooking. The shift toward electric ranges which occurred from 1970 to 1975 is assumed to continue such that by the year 2000 electric ranges have completely saturated the market.

The residential lighting and appliance category accounts for energy consumed by refrigerators, dishwashers, electric dryers, gas dryers, televisions, food freezers, clothes washers, lighting, and miscellaneous small appliances. Energy requirements in this demand category are computed from the unit basic energy demand for each appliance shown in Table II-4, the market penetration of each appliance, and the number of households in the region. The current market penetration of the various appliances in the TVA region is derived from fuels and appliance data for each state from the 1970 Census of Housing⁽²⁾ updated to 1975⁽⁴²⁾ as follows:

Market Penetration of Appliance "k" in the TVA Region =

$$(\#HH^{APLk})_{TVA} / (\#HH)_{TVA} = \left[\sum_j^{STATES} (\#HH^{APLk})_j \times (P_j^{TVA} / P_j) \right] / (\#HH)_{TVA} \quad (II-6)$$

where, $(\#HH)_{TVA}$ = Total number of households in the TVA region.

$(\#HH^{APLk})_{region}$ = Number of households with appliance k
in the region.

P_j^{TVA} = Population in state j that is serviced by TVA.

j = States in TVA service area.

The basic energy demand derived for 1975 is escalated in proportion to the number of households and the market penetration projected in the reference years. To allow for the introduction of new electrical devices not yet in use, it is assumed that these devices will consume as much energy in 2000 as small appliances per household did in 1970, 1.6×10^6 Btu/household.

COMMERCIAL SECTOR

The commercial sector incorporates a wide range of activities which for the purposes of this study are disaggregated into two broad categories: 1) buildings, and 2) agriculture and mining. A methodology similar to the one followed in the residential sector is used to compute energy consumption in commercial buildings. Energy is consumed in commercial buildings for space conditioning, water heating, cooking, lighting, refrigeration, computers and other electrical appliances. Outdoor lighting is also included in this sector. Following the section of this report on commercial buildings, energy consumption in agriculture and mining is discussed.

Commercial Buildings

Commercial buildings serve a broad range of functions which include:

- Retail Stores
- Warehouses
- Offices and Banks
- Service Stations
- Libraries and Museums
- Educational Buildings
- Hospitals
- Government Buildings
- Churches
- Passenger and Freight Terminals
- Other Miscellaneous Nonresidential Buildings
- Dormitories, Motels, and Hotels

These buildings have widely varying energy requirements, but in order to develop unit energy requirements for the commercial inventory in a consistent fashion the following building definitions were established:

- Office buildings - include offices, banks and public buildings (15% of commercial inventory).
- Retail Buildings - include stores, other mercantile buildings, garages and service stations (18% of commercial inventory).
- Schools - (26% of commercial inventory).
- Hospitals - (7% of commercial inventory)
- Other - includes warehouses (22% of commercial inventory), churches, amusement and recreational buildings, transportation terminals, and other miscellaneous nonresidential buildings (12% of commercial inventory).

The commercial inventory in the region, 680 million square feet or 108 square feet per capita, is from data provided by TVA for 1975 and appears to be consistent with commercial floor space per capita estimates for the East South Central census region.⁽³⁰⁾ The commercial inventory is classified by building type as shown in Table II-5, according to key economic variables, in proportion to the commercial inventory in the South.⁽¹⁾

Table II-5
COMMERCIAL INVENTORY IN THE TVA REGION - 1975
(Millions square feet)

Offices	102
Retail	123
Schools	174
Hospitals	47
Other	234
Total	680

The total commercial inventory in the TVA region is projected to 1980, 1985 and 2000 in proportion to output in the services sector from the Brookhaven National Laboratory input-output model, adjusted by regional earnings. The following methodology is used to project the commercial inventory in the region. First, exogenously specified primary energy prices and quantities are input into the Data Resources Incorporated (DRI) 10 sector general equilibrium macroeconomic model. Then using aggregate economic and

energy estimates from the DRI model, the BNL input-output model solves for energy service levels and output in each of the 110 sectors.⁽⁴⁰⁾ The commercial inventory in the TVA region is then calculated from U.S. output in the services sector from the I/O model, adjusted by regional earnings as follows:

$$[TVA \text{ COMMERCIAL INVENTORY}]_t = \frac{(OUTPUT)_t}{(OUTPUT)_{1975}} \times [EARNINGS \text{ RATIO}]_t \times [TVA \text{ COMMERCIAL INVENTORY}]_{1975} \quad (II-7)$$

where, OUTPUT = Dollars of output in the services sector from the I/O model for the U.S.

t = Projection year -- 1980, 1985, 2000

The regional adjustment or "Earnings Ratio" is computed as the ratio of projected regional earnings in the commercial sector to projected U.S. earnings in the commercial sector, normalized to 1970.

$$[EARNINGS \text{ RATIO}]_t = \left(\frac{E_{TVA}}{E_{U.S.}} \right)_t \bigg/ \left(\frac{E_{TVA}}{E_{U.S.}} \right)_{1970} \quad (II-8)$$

where E = Earnings in the commercial sector which includes a) wholesale and retail trade, b) finance, insurance and real estate, c) services, and d) federal, state and local government.

t = Projection year -- 1980, 1985, 2000.

Earnings projections for the U.S. and by state are from the 1972 OBERS Projections of Regional Economic Activity in the U.S.⁽¹⁷⁾ developed by the Bureau of Economic Analysis for the Water Resources Council. These projections are based on the 1972 Series E population projections from the Bureau of the Census. Earnings in the TVA region are derived from earnings in each of the states by assuming earnings is proportional to that fraction of the population which is serviced by TVA in each of the states:

$$[EARNINGS]_{TVA} = \sum_j^{STATE} \left[(EARNINGS)_j \times \frac{POP_{STATEj}^{TVA}}{POP_{STATEj}} \right] \quad (II-9)$$

where j equals the states in the TVA service area. POP_{STATEj} refers to the total population in state j. POP_{STATEj}^{TVA} refers to the population in state j serviced by TVA and is derived from the sum of the individual county populations that are serviced by TVA, as previously defined in Eq. (II-4).

Energy requirements for space heating in commercial buildings is proportional to population weighted heating degree days in the region and is derived from unit energy demands for five building categories--offices, retail, schools, hospitals and other as shown in Table II-6. The average energy requirement per square foot is 23,000 Btu/sq ft as shown in the Fuel Mix Table for commercial space heating. The mix of fuels satisfying this demand was estimated relative to the mix of fuels in residential space heating. Over one-half of the energy requirements for space heating in commercial buildings are projected to be met by electricity by 2000 compared to an estimated 25% in 1975. Electric heat pumps are projected to meet the demand for space conditioning in an estimated 200 million square feet of commercial buildings by the year 2000, reducing the demand for electricity in those buildings by a factor of over one-third relative to conventional electric heat. The fraction of the commercial inventory heated by natural gas, fuel oil, LPG, coal and wood is projected to decrease over the reference years.

The energy requirement for air conditioning in commercial buildings is proportional to equivalent full load operating hours in the TVA region (1200 hours) and is computed from the unit energy demand for commercial air conditioning by building type shown in Table II-6. The unit energy demand for commercial air conditioning in the region is a function of the unit demand in the South⁽¹⁾ and the ratio of operating hours in the TVA region to operating hours in the South. The average energy requirements per square foot of commercial floor space in the region is 53,500 Btu/sq ft as shown in the fuel mix table for commercial air conditioning. This unit demand is in terms of basic energy demand and must be divided by the COP to obtain delivered electricity. The market penetration for air conditioning is projected to reach 100% by the year 2000.

The energy requirement for water heating in commercial buildings is a function of the unit energy demand for water heating as shown in Table II-6 and the commercial inventory. The mix of fuels satisfying this demand is estimated relative to residential water heating, with electricity projected to dominate the market over the reference years.

Energy demands for commercial cooking are a function of the number of meals served and the energy required to cook a meal. The energy required to cook a meal is assumed to be 75% of the energy demand in the residential sector. The number of meals served is proportional to the population and the fraction of all meals eaten in commercial establishments. In 1975 an estimated 20% of all meals were eaten in commercial establishments and this is projected to increase to 25% by the year 2000.

Table II-6

UNIT ENERGY DEMAND IN COMMERCIAL BUILDINGS
THE TENNESSEE VALLEY AUTHORITY - 1975

Building Type	Delivered Energy (10^3 Btu/Sq. Ft./Year)						
	Space Heating	Air Conditioning	Water Heating	Lighting	Refrigeration	Appliances	HVA/C Auxiliary Equipment
Office Buildings	32.0	20.4	3.4	25.5	-	6.1	7.5
Retail Establishments	19.0	23.4	1.7	27.2	30.4	6.8	12.2
Schools	24.0	16.3	3.4	22.1	-	5.1	11.2
Hospitals	25.0	27.2	17.0	51.0	-	20.3	59.6

The energy demand in commercial buildings for lighting, refrigeration, HVA/C auxiliary equipment, and miscellaneous electrical appliances including computers is a function of the unit energy demand in each of these categories as shown in Table II-6 and the commercial inventory. The energy requirement for refrigeration that relates to food and beverage distribution is estimated to be 37.5 billion kilowatt hours in the U.S.⁽¹⁾ This results in an energy demand for refrigeration of 30,400 Btu per square foot in the retail inventory. This is projected to increase by a factor of two by the year 2000. The minor energy requirements for refrigeration in offices, schools, and hospitals are included with miscellaneous electrical appliances. The consumption of electricity by miscellaneous electrical appliances including computers is projected to increase by a factor of two from 7,200 Btu/sq ft in 1975 to 14,400 Btu/sq ft in 2000.

Consumption of electricity for outdoor lighting in the TVA region was 867 million kilowatt-hours in 1975⁽²³⁾ and this is projected to increase by more than a factor of three to 2784 million kilowatt-hours by 2000.

Agriculture and Mining

Agricultural uses of energy associated with growing crops and raising livestock are currently estimated to be 2014 trillion Btu's in the U.S.⁽¹³⁾ Energy consumption associated with the marketing, distribution and processing of foods as well as energy consumed by farmers for residential uses are not accounted for in this estimate. Included in this estimate are the contributions to energy consumption by such activities as plowing, planting, irrigation, harvesting, crop drying, livestock handling, feed handling and space conditioning, in addition to such indirect energy uses as fertilizer and pesticide production. Petrochemicals used to manufacture fertilizers and pesticides account for 716 trillion Btu's or 36% of the 2014 trillion Btu's of energy used in agricultural production as shown in Table II-7. In the analytic framework of the Reference Energy System, feedstocks used as raw material input in the manufacture of fertilizers and pesticides are included in the industrial sector of the RES. Gasoline and diesel fuel consumed for business purposes by automobiles, trucks and other farm machinery account for an additional 708 trillion Btu's or 35% of the 2014 trillion Btu's used in agricultural production. These motor fuels as well as those used for non-business purposes by farmers are accounted for in the transportation sector of the Reference Energy System. The remaining 590 trillion Btu's of energy associated with agricultural production is disaggregated by fuel type, as shown in the Agriculture Fuel Mix Table in Appendix B,

Table II-7
FUNCTIONAL USE OF ENERGY IN THE U.S.
FOR AGRICULTURAL PRODUCTION, 1974*

	Trillions, Btu
FIELD MACHINERY	391
tillage, plant, cultivate, applications, harvest	
TRANSPORTATION	317
pickups, trucks, on farm hauling, business auto trips	
IRRIGATION	261
LIVESTOCK, DAIRY, POULTRY	161
CROP DRYING	107
MISCELLANEOUS	61
TOTAL FUELS AND ELECTRICITY	1,298
INDIRECT ENERGY: petrochemicals used to manufacture fertilizers and pesticides	716
TOTAL	2,014

*Source: U.S. Department of Agriculture, Energy and U.S.
Agriculture: 1974 Data Base (13)

Table II-8
FUELS AND ELECTRICITY USED IN AGRICULTURAL
PRODUCTION, 1974*

Gasoline	3.7 billion gal.
Diesel Fuel	2.6 billion gal.
Natural Gas	164 billion cu. ft.
LP Gas	1.5 billion gal.
Electricity	32 billion kwh
Fuel Oil	304 million gal.
Coal	33,000 tons

*Source: U.S. Department of Agriculture, Energy and U.S.
Agriculture: 1974 Data Base (13)

and regionalized from national totals by assuming energy demand in the TVA region is proportional to farm acreage. The energy flows shown in this demand category are those associated with on-the-farm operations excluding transportation and fertilizer production, as previously noted.

The basic energy demand derived for agriculture is escalated in proportion to projected output in the agriculture sector of the BNL input-output model for the U.S., adjusted by regional earnings. This methodology is analogous to the one followed in the commercial sector, with commercial sector output replaced by agricultural sector output as follows:

$$\text{TVA [AGRICULTURAL OUTPUT]}_t = \frac{(\text{OUTPUT})_t}{(\text{OUTPUT})_{1975}} \times [\text{EARNINGS RATIO}]_t \times [\text{TVA AGRICULTURAL OUTPUT}]_{1975} \quad (\text{II } 10)$$

where, output = dollars of output in the agriculture sector from the I/O model for the U.S.

t = Projection year--1980, 1985, 2000.

The Earnings Ratio is given in Eqs. (II-8) and (II-9) for the commercial sector where earnings in this sector is redefined to be earnings in agriculture, forestries and fisheries from OBER'S Projections of Regional Economic Activity.⁽¹⁷⁾ Output in the agriculture sector from the BNL input-output model for the U.S. increases at an annual rate of 3.5% between 1985 and 2000 compared to 2.8% in the TVA region. This regional variation in agricultural output reflects the decreasing proportion of earnings projected to originate in the region by the year 2000. Earnings in agriculture is projected to increase at an annual rate of 0.9% in the U.S. compared to 0.7% in the TVA region.

Mineral industries in the TVA region are primarily engaged in the mining of bituminous coal and lignite, the nonferrous metal ores bauxite and zinc, and the mining and quarrying of the nonmetallic minerals stone, clay and phosphate rock. Consumption of energy in the TVA region is derived from value added for these mineral industries. Value added is estimated for the minerals mined in the region using the Census of Mineral Industries.⁽³⁸⁾ Assuming that energy demand per dollar of value added is regionally independent, consumption of energy in the TVA region is estimated as a function of value added and energy consumption in the U.S. for each of the mineral industries noted above.

Consumption of energy for mining is escalated in proportion to projected output in the mining sector of the BNL input-output model for the U.S., adjusted by regional earnings. This methodology is analogous to that followed in the commercial and agricultural sectors.

[TVA MINING OUTPUT]_t =

$$\frac{(\text{OUTPUT})_t}{(\text{OUTPUT})_{1975}} \times [\text{EARNINGS RATIO}]_t \times [\text{TVA MINING OUTPUT}]_{1975} \quad (\text{II-11})$$

where, OUTPUT = Dollars of output in the mining sector from the I/O model for the U. S.

t = Projection year--1980, 1985, 2000.

The Earnings Ratio is given in Eqs. (II-8) and (II-9) for the commercial sector where earnings in this sector is redefined to be earnings in mining from OBERS Projections of Regional Economic Activity. Output in the mining sector of the BNL input-output model for the U.S. increases at 3.2% between 1985 and 2000 compared to 4.5% in the TVA region. This difference appears reasonable in view of the dominant role coal mining plays in the region and its projected growth relative to other mining in the nation.

INDUSTRIAL SECTOR

The industrial sector has been disaggregated into several major energy intensive industries, including aluminium, steel, petrochemicals and uranium enrichment; remaining industrial energy requirements (excluding petroleum refining) are included in the demand categories industrial process heat and industrial electric drive. Consumption of fuels in these demand categories is initially projected in proportion to industrial activity in the United States, and then regionalized based upon earnings in manufacturing as follows:

$$[\text{TVA INDUSTRIAL ACTIVITY}]_{i,t} =$$

$$\frac{\left(\frac{\text{U.S. INDUSTRIAL ACTIVITY}}{\text{U.S. INDUSTRIAL ACTIVITY}} \right)_{i,t}}{\left(\frac{\text{U.S. INDUSTRIAL ACTIVITY}}{\text{U.S. INDUSTRIAL ACTIVITY}} \right)_{i,1975}} \times [\text{EARNINGS RATIO}]_{i,t} \times [\text{TVA INDUSTRIAL ACTIVITY}]_{i,1975} \quad (\text{II-12})$$

where,

(INDUSTRIAL ACTIVITY)_{i,t} = Activity in manufacturing industry i in year t.

i = Manufacturing industries 1,...,n.

t = Projection years--1980, 1985, 2000.

and

$$[\text{EARNINGS RATIO}]_{i,t} = \left(\frac{E_{\text{TVA}}}{E_{\text{U.S.}}} \right)_{i,t} \bigg/ \left(\frac{E_{\text{TVA}}}{E_{\text{U.S.}}} \right)_{i,1975} \quad (\text{II-13})$$

where, (E)_{i,t} = Earnings in industry i in period t.

i = Manufacturing industries 1,...,n.

t = Projection year--1980, 1985, 2000.

Earnings projections for the U.S. and by state are from the 1972 OBERS Projections of Regional Economic Activity in the U.S.⁽¹⁷⁾ Earnings in the TVA region, E_{TVA} , are derived from earnings in each state serviced by TVA by assuming earnings is proportional to population as given in Eq. (II-9).

Aluminum

Electric power is the major form of energy used to produce primary aluminum and is required in the electrolysis of alumina. The electrolytic efficiency of this process is based on a minimum theoretical requirement of 27.3 million Btu per ton. Oxidation of carbon at the anode is accounted for in the losses to coal. Secondary recovery from scrap is less energy intensive than primary production and is projected to represent a growing share of the market. This is expected to increase from 20% of total production in 1975 to 33% by the year 2000, thus decreasing energy consumption per pound of aluminum produced. It is estimated that 1144 million pounds of primary aluminum was produced in 1975 at the four major plants located in the region. This estimate was derived from plant capacity data by assuming that the average capacity factor for plants in the region is equal to the average capacity factor in the United States (79%).⁽⁸⁾ In addition to primary production, 289 million pounds of aluminum was produced from scrap. This estimate assumes that the fraction of aluminum produced from scrap in the region is equal to the fraction of aluminum produced from scrap in the U.S. Total domestic production of aluminum is projected to increase at 5.6% per year to 1985 and 4.9% per year thereafter.^(18,19) Production in the TVA region is projected in proportion to domestic production, adjusted by regional earnings in total manufacturing [see Eqs. (II-12) and (II-13)]. Aluminum production over the fifteen year period from 1985 to 2000 is projected to grow at an average annual rate of 5.5% in the TVA region versus 4.9% in the U.S. This difference is consistent with the higher growth in manufacturing earnings projected for the region, 3.5%, compared to 2.9% in the U.S.

Steel

The primary metals industry consumed the largest share of energy used in the U.S. industrial sector, with iron and steel accounting for most of this consumption. The principal uses of natural gas and fuel oil in the steel industry are in heating and annealing furnaces and in open hearth furnaces, which are declining in number. Electric power is used in the steel industry for driving mills, forges, process lines, and in the steelmaking process itself. The quantity of electric power required in the steelmaking process is highly dependent upon the type of furnace uti-

lized (open hearth, basic oxygen, or electric furnace). From an ad hoc survey of the major steel producers in the region and plant capacity data published by the American Iron and Steel Institute, it has been estimated that 383,400 tons of steel were produced in 1975 using the electric furnace. Considering the low cost of electricity, the lack of blast furnaces to produce pig iron and the minor role of the steel industry in the region, the electric furnace is projected to continue dominating the steelmaking process in the TVA area. Scrap metal is the primary raw material used in the electric furnace with essentially no pig iron required. Requirements for electric power in the electric furnace are 675 kilowatt-hours per ton of steel produced. Projections of steel production in the region are proportional to BNL estimates of steel production in the U.S.⁽²⁷⁾, adjusted by regional earnings in the primary metals industry [see Eqs. (II-12) and (II-13)].

Petrochemicals

Hydrocarbons derived from natural gas and crude oil, including natural gas itself, natural gas liquids, naphtha and refinery gas serve as the raw material basis for production of most organic chemicals. Coal and coal tar are still used as a raw material in the production of certain aromatic compounds. Historically, the mix of raw materials supplying the chemical industry has shifted from coal to oil and gas. This trend is not expected to continue as coal becomes more readily available relative to oil and gas. Regional demand for hydrocarbons as a petrochemical feedstock in 1975 is assumed to be proportional to value added in the chemicals and allied products industry (SIC-28). Value added in the TVA service area is estimated from 1972 Census of Manufacturing data.⁽⁹⁾ The mix of resources supplying the petrochemical industry is assumed to be proportional to the mix of resources in the East South Central Census region.⁽³⁰⁾ Demand for petrochemical feedstocks is escalated in proportion to projected output in the chemical and allied products sector of the BNL input-output model¹ for the U.S., adjusted by regional earnings in SIC-28. This projection methodology is analogous to that followed in the commercial sector [see Eqs. (II-7), (II-8), and (II-9)]. Output in the chemicals and allied products sector of the BNL input-output model for the U.S. increases at an annual rate of 4.0% between 1985 and 2000 compared to 4.1% in the TVA region. The slightly higher growth rate projected for the region reflects the higher earnings in the chemical industry that is projected for the area relative to the rest of the nation.

¹Chemicals and allied products include the following sectors from the BNL 110 sector I/O model: chemicals and selected chemical products; plastics and synthetic materials; drugs, cleaning and toilet preparations; and paints and allied products.

Uranium Enrichment

The Tennessee Valley Authority supplied almost 22 billion kilowatt-hours of electricity in 1975 to the two federally operated gaseous diffusion uranium enrichment plants located in Paducah, Kentucky and Oak Ridge, Tennessee. Sales to these federal agencies are projected to increase by almost a factor of two, to 40 billion kilowatt-hours by 1980, and then level off at that demand through the year 2000.(23)

Electric Drive

Electricity sales to industry by the Tennessee Valley Authority includes sales to municipalities and cooperatives, federal agencies, and sales directly served to industry. All electricity used in the industrial sector and not consumed in the aluminum, steel and uranium enrichment industries is accounted for in the category Miscellaneous Electric Drive as shown in the Fuel Mix Table in Appendix B for 1975. Directly served industry sales and sales to federal agencies are escalated to the year 2000 from data provided by the Tennessee Valley Authority. Electricity sales to industry through municipalities and cooperatives is projected by TVA through 1985 and estimated by BNL from 1985 to the year 2000.

Process Heat

All energy used for fuel in the industrial sector which is not consumed in the aluminum, steel, petrochemical, uranium enrichment or petroleum refining industries is accounted for in the category industrial process heat. To estimate demand for energy in this category overall energy requirements by industry are initially estimated. Industrial process heat then represents the balance of unaccounted fuels in the industrial sector after all other end uses are accounted for. Total energy requirements in the industrial sector are assumed to be proportional to regional value added in manufacturing. Thus,

$$(ENERGY)_{TVA} = \left(\frac{ENERGY}{VA} \right)_{ESC} \times (VA)_{TVA} \quad (II-14)$$

$$\text{and, } (VA)_{TVA} = \sum_i (VA_i \times POP_i^{TVA} / POP_i) \quad (II-15)$$

where, ENERGY = Industrial energy consumption

VA = Dollars of value added in manufacturing

POP_i = Population in county i

i = Counties in the TVA region.

POP_i^{TVA} equals the population in county i that is serviced by TVA and is estimated from Bureau of the Census data (for additional details on its derivation refer to the residential sector at the beginning of this section).

The ratio of industrial energy consumption per dollar of value added in manufacturing in the east south central census region, (ENERGY/VA)_{ESC}, is assumed to

approximate energy consumption per dollar of value added in the TVA region. The energy intensiveness of industries in the east south central census region more closely typifies those industries in the TVA region than does the overall mix of industries in the U.S. This can be attributed, in part, to the common price of electricity in the two regions relative to the U.S. as shown in Table II-9. The fact that energy-intensive industries, such as aluminum and uranium enrichment, are located in the region has traditionally been attributed to the low cost of electric power. The average price of electricity to large light and power customers during 1975 was 1.59 ¢/kWh in the east south central census region and 1.54 ¢/kWh in the state of Tennessee, 15% to 20% less than the average price of electricity to large light and power customers in the U.S., 1.92 ¢/kWh. The energy intensiveness of industry in the east south central census region (as measured in terms of industrial energy consumption per dollar of value added in manufacturing) was 46.9×10^3 Btu/\$ in 1975 compared to 39.8×10^3 Btu/\$ in the nation reflecting the differential in the price of electricity between the two regions. The mix of fuels in the TVA region is assumed to be the same as the mix of fuels in Tennessee. 263 trillion Btu's of energy was consumed in the industrial process heat category in 1975, in addition to the fuels and electric energy consumed by industry in those categories previously noted. The fuel fraction, f_i , shown in the Fuel Mix Table for industrial process heat indicates that 68% of the energy consumed in this category was in the form of natural gas.

Energy consumed in the industrial process heat category is escalated at an annual growth rate of 4.8% from 1975 to 1980, 3.4% from 1980 to 1985 and 3.2% thereafter. This growth rate is derived from (1) the historical ratio of U.S. energy consumption in the industrial sector to gross national product (GNP), and (2) the ratio of TVA to U.S. earnings in manufacturing in the projected year divided by the ratio of TVA to U.S. earnings in 1970 [see Eqs. (II-12) and (II-13)]. Energy consumed in the industrial sector in the U.S. between 1960 and 1972 grew at 2.0% per year, whereas GNP grew at 3.4% per year over the same period (see Figure II-3). The ratio of industrial energy consumption to GNP (in constant dollars) has been declining over time and is projected to continue to decline through 2000. A least squares fit to Energy-GNP data over the period 1960-1972 results in the following equation:

$$(\text{ENERGY}/\text{GNP})_t = (\text{ENERGY}/\text{GNP})_{1960} + M (t-1960) \quad (\text{II-16})$$

where, $\text{ENERGY}/\text{GNP}_{1960} = 32,453 \text{ Btu}/\$ \text{GNP}$

$M = -241 \text{ Btu}/\$ \text{GNP per year}$

$t = 1960, \dots, 1972$

Table II-9
REGIONAL VARIATIONS IN ENERGY PER VALUE ADDED
AND THE PRICE OF ELECTRICITY

Region	Industrial Energy Consumption Per Dollar of Value Added in Manufacturing (10^3 Btu/\$)	Price of Electricity to Large Light & Power (¢/kWh)
East South Central Census Region	46.9	1.59
Tennessee	-	1.54
United States	39.8	1.92

Table II-10
INDUSTRIAL ENERGY CONSUMPTION VS. GNP IN
THE UNITED STATES

Year	Industrial Use of Energy (10^{15} Btu)	GNP (Billions of 1958 \$)	Energy/GNP (10^3 Btu/\$)
1975	21.5	816	26.3
1980	26.4	955	27.6
1985	29.5	1118	26.4
2000	40.9	1793	22.8
Rate of Change Per Year	2.6%	3.2%	-241.0

Figure II-3. Industrial energy consumption relative to GNP, 1951-2000.

Thus, if it is assumed that the ratio of industrial energy consumption to GNP continues to decline as it has since 1960, at the rate of 241 Btu per dollar of GNP per year, then the following equation can be used to project the ENERGY/GNP ratio in 1980, 1985 and 2000:

$$(ENERGY/GNP)_t = 32,453 \text{ Btu}/\$GNP - 241 \frac{\text{Btu}/\$GNP}{\text{Year}} (t - 1960) \quad (II-17)$$

where, $t = 1980, \dots, 2000$

Since GNP is projected to increase at an annual rate of 3.2% over the 1975 to 2000 time period, the level of energy consumption by industry in the U.S. can be projected to time period "t" using the following equation:

$$(ENERGY)_t = (ENERGY/GNP)_t \times (GNP)_t \quad (II-18)$$

Values of energy, GNP, and the energy/GNP ratio are listed in Table II-10 for the years 1975, 1980, 1985, and 2000.

Projections of energy consumption for industrial process heat in the TVA region are derived from national projections, adjusted by regional earnings in manufacturing [see Eqs. (II-12) and (II-13)]. Demand for energy by industry in the U.S. is projected to increase at an annual rate of 2.6% over the reference years compared to 3.6% in the TVA region over the same time period. This regional variation in the demand for energy reflects the increasing proportion of earnings projected to originate in the region by the year 2000. Earnings in manufacturing is projected to increase at an annual rate of 3.1% in the U.S. compared to 3.9% in the TVA region.

Petroleum consumed in the petroleum refining industry is treated in the analysis as in-stream process losses during the distillation of crude oil into gasoline, distillate, and other fractions. In the analytical framework of the Reference Energy System, this energy is accounted for as an efficiency loss (7%) shown at the refining and conversion of crude oil.

TRANSPORTATION SECTOR

Transportation accounts for approximately 25% of total U.S. energy consumption, varying regionally from less than 20% in the gulf states to over 30% on the west coast. In the area serviced by TVA transportation accounts for 23% of total energy consumption. The relatively low proportion of energy consumed by transportation in the gulf states region is primarily due to the high energy requirements for the extraction of petroleum and natural gas in this region. The disproportionately high quantity of energy consumed on the west coast is due to the heavy dependence on the automobile in California. Practically all energy demanded in the transportation sector is in the

form of petroleum products with very minor amounts of electricity and natural gas. At pre-embargo fuel prices, energy consumption was expected to grow at a slightly higher rate than the demand for transportation services because of continued shifts to more energy intensive modes such as air and truck. Higher fuel prices are not expected to significantly affect the overall demand for transportation services in this scenario but will stimulate significant energy savings through equipment improvements in private ground transportation.

Automobile

In 1975 the automobile consumed 52% of the energy in the transportation sector compared to 31% projected for 2000, reflecting improved automobile fuel economy and market saturation. The total number of automobiles in the region is calculated as a function of the number of vehicles per driving age population in each state and the state population serviced by TVA. The number of vehicles per driving age population is derived from the total number of registrations¹ in each state and the state's population 16 years of age and older. The number of vehicles per driving age population in the region was 0.61 in 1975, the same as the national average. The number of registered vehicles has historically been an increasing proportion of the driving age population. This trend is not expected to continue as the market becomes saturated. It is projected that by the year 2000 85% of the population over 16 years of age will own automobiles. A constant value of 10,800 miles per vehicle is multiplied by the number of vehicles in calculating annual vehicle-miles traveled (VMT). 10,800 miles is a national average from the FHWA, adjusted by the R. L. Polk data.

Automobile gasoline consumption is computed as a function of VMT's and the fleet average fuel economy. The fleet average fuel economy is derived for each reference year based on the mix of model years on the road, the distribution of vehicle-miles with age of auto, and the fuel efficiency per model year as follows:

$$\text{COMPOSITE FUEL EFFICIENCY IN YEAR } t = \left[\frac{\text{TOTAL VEHICLE-MILES}}{\text{TOTAL FUEL REQUIREMENTS}} \right]_t$$

where, $\left[\text{TOTAL FUEL REQUIREMENTS} \right]_t =$

$$\sum_{m=t-10}^t \left[\frac{\left(\frac{\text{Miles}}{\text{Vehicle}} \right)_m \times (\text{Fraction of Total Vehicles})_m}{(\text{Fuel Economy})_m} \right] \times (\text{Total Vehicles})_t \quad (\text{II-19})$$

¹The R. L. Polk and Company estimate of registered vehicles is used rather than the Federal Highway Administration (FHWA) count. The FHWA count includes all vehicles that were operated on the roads during the calendar year. The Polk estimates, considered more reliable, measures the number of vehicles operating at a fixed point in time reflecting re-registered and scrapped vehicles.

m = Model year

t = Projection year--1980, 1985, 2000

The 1985 values of the variables in the above equation are given in Table II-11. Fuel requirements for 1980 and 2000 are computed in a similar manner. Fuel economy per model year is assumed to be 10% lower than specified in the Energy Policy and Conservation Act because of typically observed nonoptimum engine performance in older model vehicles.⁽²⁰⁾ The fleet average fuel economy projected for 1980, 1985 and 2000 is 14.9 mpg, 19.3 mpg, and 25 mpg, respectively.

Truck and Bus

The truck and bus category includes all gasoline and diesel fuel not consumed by automobiles; marine and aviation consumption of gasoline is included in ship and air transport, respectively. Thus, gasoline and diesel fuel consumed by agricultural, construction, and miscellaneous equipment is included in the truck and bus category. Trucks are by far the largest energy consumer in this category, with buses using less than 5% of the fuel consumed.

Trucking activity is subdivided into two classes--freight trucking includes all trucks over 10,000 lbs gross vehicle weight (GVW) and nonfreight trucking includes all trucks under 10,000 lbs GVW. Freight trucking activity is measured in terms of ton-miles and the fuel economy of these vehicles is measured in terms of Btu's per ton-mile. Estimates of ton-miles per truck, Btu's per ton-mile, and the fraction of gasoline versus diesel powered trucks are based on an FEA report on Trucking Activity and Fuel Consumption.⁽³⁹⁾ Nonfreight trucking activity is measured in terms of truck-miles and the fuel economy of these vehicles is measured in terms of Btu's per truck-mile. Estimates of miles per truck and the number of trucks by weight class are derived from Census of Transportation data.⁽⁴⁴⁾ The number of trucks in the TVA region is estimated from the total number of trucks in each state and the fraction of the population in that state which is serviced by TVA. Gasoline and diesel fuel consumption is then computed as a function of regional trucking activity and the energy intensiveness of the trucks (see Tables II-12 and II-13). Passenger-miles for local, intercity and school buses are estimated in proportion to the population.

Historically, freight trucking activity in the U.S. has increased in proportion to GNP, and this trend is projected to continue through the year 2000 with GNP growing at an annual rate of 3.2%. Regional freight trucking activity in 1980, 1985 and 2000 is then derived from the U.S. projections based on regional earnings. This methodology is analogous to that followed in the commercial sector.

Table II-11
AUTOMOBILE FUEL ECONOMY - 1985

Model Year	Miles Driven Annually Per Auto (10^3)	Fraction of Total Auto ¹	Fuel Economy (MPG)
1985	16.3	.083	24.8
1984	13.0	.122	23.4
1983	12.3	.109	22.1
1982	10.6	.115	20.7
1981	10.9	.121	19.4
1980	9.3	.096	18.0
1979	9.6	.087	17.1
1978	8.0	.073	16.2
1977	10.2	.045	14.4
1976	7.5	.041	13.5
Up to 1975	6.1	.108	13.5

¹Source: Reference 19.

Table II-12
TVA MODAL TRANSPORTATION PROJECTIONS
(Billions)

	1975	1980	1985	2000
Passenger-Miles				
Air	2.2	3.4	4.7	10.7
Local & Intercity Bus	1.4	1.9	2.2	3.9
School Bus	1.2	1.3	1.3	1.4
Ton-Miles				
Air	-	-	-	-
Truck (GVW over 10,000 lbs.)	16	20	25	45
Ship	25	29	33	47
Rail	26	30	34	48
Truck-Miles				
Non-freight Trucking	9	12	16	31

Table II-13
ENERGY INTENSIVENESS BY TRANSPORT MODE

	1975	1980	1985	2000
Btu/Passenger-Mile				
Air	8698	7918	7431	7431
Local & Intercity Bus	1490	1490	1490	1490
School Bus	1704	1704	1704	1704
Btu/Ton-Mile				
Air	-	-	-	-
Truck (GVW over 10,000 lbs.)	4678	4444	4210	3509
Ship	567	567	567	567
Rail	709	709	709	709
Btu/Truck-Mile	12061	11458	10855	9046
Non-freight Trucking (mpg)	(10.4)	(10.9)	(11.5)	(13.8)

$$\left(\frac{\text{TVA TRANSPORT ACTIVITY}}{\text{U.S. TRANSPORT ACTIVITY}} \right)_t = \left(\frac{\text{U.S. TRANSPORT ACTIVITY}}{\text{U.S. TRANSPORT ACTIVITY}} \right)_{1975} \times \left(\frac{\text{EARNINGS}}{\text{RATIO}} \right)_t \times \left(\frac{\text{TVA TRANSPORT ACTIVITY}}{\text{U.S. TRANSPORT ACTIVITY}} \right)_{1975} \quad (\text{II-20})$$

where TRANSPORT ACTIVITY = Ton-miles for freight trucking, rail, or ship.

Truck-miles for nonfreight trucking

Passenger-miles for air transport.

t = Projection year--1980, 1985 and 2000.

The Earnings Ratio is given in Eqs. (II-8) and (II-9) for the commercial sector where earnings in this sector is redefined to be total earnings from OBERS Projections of Regional Economic Activity.⁽¹⁷⁾ Freight trucking activity in the TVA region is projected to increase at an annual rate of 4.2%, from 16 billion ton-miles in 1975 to 45 billion ton-miles in the year 2000. Nonfreight trucking activity in the TVA region is projected to increase at an annual rate of 5.1%, from 9 billion truck-miles in 1975 to 31 billion truck-miles in the year 2000. Projections of demand for gasoline and diesel fuel are based on a 25% improvement in the fuel economy of all trucks. This efficiency improvement includes the fuel savings derived from the projected changeover to diesel engines. In 1975 23% of the motor fuels consumed by trucks and buses was in the form of diesel fuel compared to 69% projected for the year 2000.

Air Transport

Consumption of jet fuel and aviation gasoline by both commercial air carriers and general aviation is accounted for in this demand category. Demand for jet fuel and aviation gasoline in 1975 was determined for the state of Tennessee from published data.^(10,48) Consumption of jet fuel and aviation gasoline in the TVA region, excluding Tennessee, was estimated from a survey of the commercial airports serving the area. Air passenger-miles were then derived from the estimated fuel consumed in the region in 1975, given an average energy intensity for air transportation in the U.S. of 8698 Btu's per passenger-mile. Projected energy consumption is computed from Air Transportation Association of America^(34,35) projections of U. S. domestic and international air passenger-miles, adjusted by regional earnings [see Eqs. (II-20), (II-8), and (II-9)]. Air passenger miles in the TVA region are projected to increase from 2200 million passenger-miles in 1975 to 10,700 million passenger-miles in the year 2000, at an annual rate of 6.5%.

Railroads, Ships, and Pipelines

Consumption of diesel fuel by railroads is computed as a function of rail transport activity, measured in terms of ton-miles, and the energy intensiveness of the railroads, measured in terms of Btu's per ton-mile. Regional demand in each state is estimated for 1975 by assuming that the demand in a state is proportional to the fraction of its population serviced by TVA. Demand in the region is projected to increase in proportion to U.S. projections, adjusted by regional earnings [see Eqs. (II-20), (II-8), and (II-9)]. Rail freight ton-miles are projected to increase from 26 billion ton-miles in 1975 to 48 billion ton-miles in the year 2000 at an annual growth rate of 2.5%.

Consumption of residual oil, distillate oil and gasoline by commercial shipping and recreational boating is accounted for in the water transport category. Commercial shipping's demand for fuel oil in 1975 is computed from the demand for fuel oil by ships in the state of Tennessee, inflated by the population in the TVA region relative to the population in Tennessee. Regional energy demands for commercial shipping are derived from Tennessee data only rather than from the energy usage in each state because of the disproportionate share of port facilities in the states of Alabama and Mississippi. Demand for fuel oil by the commercial shipping industry is projected to increase in proportion to U.S. projections, adjusted by regional earnings [see Eqs. (II-20), (II-8) and (II-9)]. Commercial shipping ton-miles are projected to increase from 25 billion ton-miles in 1975 to 47 billion ton-miles in the year 2000 at an annual growth rate of 2.5%. Demand for gasoline by recreational boating in 1975 is estimated for each state in the region by assuming demand is proportional to the state population serviced by TVA. Demand for gasoline by recreational boating is projected to increase at an annual growth rate of 4.6% through 1985 based on historical data, and is reduced to 3% thereafter.

Pipeline fuel represents some 6% of total industrial consumption of natural gas (including electric utilities) in the United States. Although use of natural gas as a pipeline fuel is concentrated in the producing states, almost one-third of the total amount is consumed at compressor stations located in the northeast and north-central regions of the country. The use of natural gas to power pipeline pumping stations in the TVA region is escalated in proportion to the consumption of natural gas in the region.

III. ENERGY SUPPLIES

Historically the United States has been almost entirely dependent upon fossil fuels for its primary energy resources. With diminishing supplies of natural gas and oil this reliance is expected to decrease as new technologies such as nuclear, solar and geothermal are gradually introduced into the national energy system. The direct use of solar and geothermal energy for space heat and process heat and the use of these technologies to generate electricity is projected to supply less than 5% of the nation's energy requirement by the turn of the century, according to the President's National Energy Plan. Nuclear power is projected to play a major role in satisfying the nation's demand for electric power, meeting 41% of the load forecast for 2000 compared to 9% in 1975. In the TVA region electricity generated from nuclear plants is projected to play an even greater role than in the nation as a whole, meeting 57% of the demand for electric power in 2000.

Aside from nuclear, coal is the other energy resource expected to replace the diminishing supplies of oil and natural gas. The U.S. Bureau of Mines estimates that 219 billion tons of coal are economically recoverable from a demonstrated coal reserve of twice that amount.⁽²⁴⁾ Demand for coal is expected to reach one billion tons in 1985 and two billion tons by 2000 compared to 640 million tons in 1975. The origin of this coal, whether from underground mines in the east or new strip mines in the west, is an issue currently receiving national attention. Environmental regulations coupled with the anticipated emergence of new markets for coal (synthetic fuels) are rapidly changing the economics of coal use. Perhaps the most visible example of this has been the rapid increase in demand for western coal. The high cost of pollution control equipment, especially for sulfur removal, coupled with the tremendous jump in oil prices has brought on a boom in low sulfur western coal development. This boom is partly predicated on meeting the sulfur dioxide emissions levels contained in the New Source Performance Standards (NSPS) for the electric utility industry (1.2 lbs SO₂/10⁶ Btu). Legislation was recently enacted requiring that the Best Available Control Technology (BACT) be installed on all new coal-fired power plants. The installation of flue gas desulfurization at all new coal-fired power plants, regardless of the sulfur content of the coal, reduces the economic advantage of burning low sulfur coal. Uncertainties concerning

the relative costs of scrubbing high and low sulfur coals make the impact of this legislation on eastern and western coal production difficult to assess at this time.

In developing a projection of coal mining in the TVA region the results of the National Coal Assessment⁽²⁸⁾ study were applied in estimating production levels for 1980, 1985 and 2000. It is assumed that coal production in the TVA region will increase at the same rate as forecast for the Interior Appalachia region from the "Recent Trends" scenario in the National Coal Assessment. This results in a 3.5% growth rate from 1975 to 1985 and a 1.8% growth rate thereafter and compares favorably with the projections for Appalachia contained in the National Energy Outlook.⁽²⁵⁾

Coal production in the region was approximately 695 trillion Btu's in 1975 and was computed from county data published by the Bureau of Mines.⁽⁸⁾ Production in a county is assumed to equal total production in that county as estimated by the Bureau of Mines if the entire county is within the TVA service territory. If the entire county is not within the TVA service territory then coal production is assumed proportional to that fraction of land area in the county that is within the TVA service territory. Land area is estimated from a map of the region showing county borders. 45% of the coal in the region is produced from underground mines and 55% from strip mines. Thus,

$$[COAL]_{TVA} = \sum_i^{COUNTY} \left[(COAL)_i \times \frac{AREA_i^{TVA}}{AREA_i} \right]$$

where, $(COAL)_i$ = Coal production in region i.

$AREA_i$ = Land area in county i.

$AREA_i^{TVA}$ = Land area in county i that is serviced by TVA.

i = Counties in TVA region.

Minimal quantities of oil and natural gas were produced in the TVA region in 1975 and no substantial increase is projected over the reference years. Oil refinery capacity in the region was 43,900 barrels per day, producing approximately 75 trillion Btu's of refined petroleum products in 1975.

ELECTRIC UTILITY SECTOR

The Tennessee Valley Authority is a wholly owned corporation of the United States Government established by Act of Congress in 1933 to develop the Tennessee River System and to assist in the development of other resources in the Tennessee Valley. The production and sale of electric power are part of TVA's resource development program. TVA supplies power at wholesale to 160 municipal and cooperative distributors which in turn distribute power to about 2.5 million residential, commercial and industrial customers.

These customers are located in seven states including the entire state of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina and Virginia. TVA also serves directly 49 industrial customers with large or unusual power requirements and several Federal installations including uranium enrichment plants located at Oak Ridge, Tennessee and Paducah, Kentucky.

The Tennessee Valley Authority has traditionally depended upon hydroelectric power and coal to meet its power requirements. Electricity generated from nuclear plants is playing an increasing role in meeting the systems demand for base load electric power with gas turbines and pumped storage being used to meet the systems demand for peak power. Electricity generated from coal-steam plants met 72% of the demand for electric power in 1975, hydroelectric power satisfied 20% of demand, and electricity generated from nuclear plants and gas turbine peaking units met the remainder of the load in 1975. The generation mix shown in Table III-1 assumes interchange deliveries and receipts net to zero and that all of the power sold by TVA is generated within the system. Actual net purchases and deliveries of electric power were a positive input to the system thus accounting for the slight difference between system generation data published by TVA⁽²¹⁾ for 1975 and that appearing in Table III-1. Heat rates reported by TVA for 1975 were used to compute fossil and nuclear fuel requirements. Output from hydroelectric plants is converted to theoretical energy inputs (primary resources) based on the equivalent coal-steam electric heat rate of 9880 Btu per kWh in 1975. Electricity sales totaled 318 trillion Btu's or 112 billion kilowatt-hours in 1975, remaining approximately constant since 1973. This trend is similar to that experienced by many other utilities across the nation since the Arab oil embargo and is attributed to both energy conservation and the depressed economic conditions that have existed in the U.S.

Recent electric utility forecasts of future energy requirements have been reduced from what they were in the 1972 to 1973 time period. Higher energy prices, depressed economic conditions, and the "conservation ethic" have all been contributing factors to the low energy growth recently experienced. These factors have added a considerable degree of uncertainty to future projections. Traditionally, utilities have depended upon historical trends in forecasting future loads, but this method is rapidly being replaced by more sophisticated techniques using econometrics and detailed engineering analyses of demands. A systems approach using the latter technique is being applied in this study to project requirements for electric power. More specifically, demand for electric power is obtained from the summation of electric demands in 1980, 1985, and 2000 over all other demand categories, adjusted to include transmission, distribution and pumped storage losses.

Table III-1

TVA ELECTRIC GENERATION - BY CENTRAL STATION POWER PLANT

	Heat Rate	Millions of kWh (Percent)			
		1975	1980	1985	2000
Coal-Steam	9,880 Btu/kWh	80,602 (72%)	94,679 (58%)	66,429 (34%)	110,827 (35%)
Nuclear-Steam	10,570 Btu/kWh	7,429 (7%)	46,962 (29%)	107,891 (56%)	176,360 (56 1/2%)
Hydroelectric	9,880 Btu/kWh	22,950 (20%)	18,276 (11%)	18,276 (9%)	18,276 (6%)
Oil-fired Gas Turbine	12,950 Btu/kWh	551 (1%)	2,393 (1%)	1,195 (1/2%)	1,846 (1/2%)
Pumped Storage	-	-	1,347 (1%)	1,209 (1/2%)	5,948 (2%)
Total	-	111,532	163,657	195,000	313,257

System generating capacity in service, under construction or planned as of June 30, 1976 is shown in Table III-2 for the Tennessee Valley Authority. The mix of capacity additions projected by TVA results in a generation mix for 1985 of 34% coal-steam, and 56% nuclear-steam, with the remainder of the load being met by hydro, pumped storage and gas turbine peaking units. No capacity additions to hydropower are planned after 1980 and the electricity generated from hydro is projected to decrease from 22950 million kilowatt-hours in 1975 to 18276 million kilowatt-hours in 1980 and then remain constant at that level through the year 2000. Pumped storage is projected to play an increasing role in meeting the systems demand for peak power with four units totaling 1530 Mw expected to be operational by the end of 1978 and 5430Mw projected to be on line by the year 2000. No additional gas turbine peaking units are planned after 1980. Coal continues to be an important fuel in meeting TVA's energy requirements, although nuclear power dominates the schedule of planned additions over the next ten years as illustrated in Figure III-1.

Projections of the basic energy demand for electricity over the reference years are obtained from the summation of electric demands in all other demand categories adjusted to include transmission, distribution, and pumped storage losses. Differences in the projected demand for electricity between TVA and BNL are less than 5% in 1980 and 1985 and 12% in 2000. These discrepancies are not unreasonable in view of the inherent uncertainties and dissimilar techniques used to develop the projections. Differences in the demand for electricity are primarily attributable to the residential sector and can be explained, in part, by differences in the assumed market penetration of appliances and projected use of electricity for domestic hot water heating. The generation mix for 1980, 1985 and 2000 was derived from the TVA forecast after taking into account these reductions in demand. In 1985 these demand reductions are equivalent to one less nuclear power plant of approximately 1250 megawatts capacity. Considering the lengthy delays in construction recently encountered across the nation and the ambitious construction program underway in the region, the reduced demand for electricity projected in this study should not cause excessive base load capacity in 1985. In 2000 the projected demand reductions relative to the TVA forecast are equivalent to four fewer nuclear plants (5000 Mw) and 1000Mw less coal capacity. If the BNL load forecast is realized in 2000 it would require some readjustment in planning, but should pose no problem if rescheduling is considered within a reasonable time frame.

Figure III-1. Projected electric generation in the TVA region.

Table III-2

GENERATING CAPACITY ON JUNE 30, 1976

In Service					
<i>TVA Hydro Plants</i>	<i>No. Units</i>	<i>Installed Capacity - kW</i>	<i>TVA Combustion Turbine Plants</i>	<i>No. Units</i>	<i>Installed Capacity - kW</i>
Apalachia	2	78,900	Allen	20	620,800
Blue Ridge	1	20,000	Colbert	8	476,000
Boone	3	75,000	Gallatin	4	325,200
Chatuge	1	10,000	Johnsonville	16	1,088,000
Cherokee	4	129,300	Total	48	2,510,000
Chickamauga	4	111,000	Alcoa Dams (12)		423,715
Douglas	4	115,000	Corps of Engineers Dams (8)		853,000
Fontana	3	238,500	Total System in Service		<u>27,071,480</u>
Fort Loudoun	4	135,590			
Fort Patrick Henry	2	36,000			
Great Falls	2	31,860			
Guntersville	4	101,700			
Hiwassee	2	117,100			
Kentucky	5	175,000	Browns Ferry Nuclear Unit 3	1	1,152,000
Melton Hill	2	72,000	Scheduled Commercial Operation—1977		
Nickajack	4	100,350			
Norris	2	100,800	Sequoyah Nuclear	2	2,441,160
Nottely	1	15,000	Scheduled Commercial		
Ocoee #1	5	18,000	Operation—1978-1979		
Ocoee #2	2	21,000			
Ocoee #3	1	28,800			
Pickwick	6	220,040	Raccoon Mountain Pumped Storage	4	1,530,000
South Holston	1	35,000	Scheduled Commercial		
Tims Ford	1	45,000	Operation—1978		
Watauga	2	50,000			
Watts Bar	5	153,300			
Wheeler	11	356,400	Watts Bar Nuclear	2	2,539,800
Wilbur	4	10,700	Scheduled Commercial		
Wilson	21	629,840	Operation—1979-1980		
Total	109	3,231,180			
<i>TVA Coal-Fired Plants</i>					
Allen	3	990,000	Bellefonte Nuclear	2	2,664,000
Bull Run	1	950,000	Scheduled Commercial		
Colbert	5	1,396,500	Operation—1980-1981		
Cumberland	2	2,600,000			
Gallatin	4	1,255,200	Proposed Hartsville Nuclear	4	5,148,000
John Sevier	4	846,500	Scheduled Commercial		
Johnsonville	10	1,485,200	Operation—1983-1984		
Kingston	9	1,700,000	Proposed Phipps Bend Nuclear	2	2,574,000
Paradise	3	2,558,200	Scheduled Commercial		
Shawnee	10	1,750,000	Operation—1984-1985		
Watts Bar	4	240,000			
Widows Creek	8	1,977,985	Proposed Yellow Creek Nuclear	2	2,678,000
Total	63	17,749,585	Scheduled Commercial		
			Operation—1985-1986		
<i>TVA Nuclear Plants</i>				19	<u>20,726,960</u>
Browns Ferry	2	2,304,000			

Source: 1976 Power Annual Report, Tennessee Valley Authority⁽²¹⁾

IV. TVA REFERENCE ENERGY SYSTEMS

Reference Energy Systems for the TVA region defined for the years 1975, 1980, 1985, and 2000 are exhibited in a series of energy flow diagrams, Figures IV-1 through IV-4. These reference systems provide a compact framework for the representation of the entire energy system including resource extraction, refinement, conversion, transportation, and utilization. In the residential and commercial sectors the flow diagrams are function oriented (e.g., the heating of a certain number of homes), while in the industrial and resource sectors the RES's are process oriented (e.g., the electrolysis of alumina or mining of coal). Thus, these network representations of regional energy flows incorporate the major features of the energy system through individual activities or processes to provide a framework for assessing new technologies or policies.

The values on the left-hand side of the diagrams under the heading EXTRACTION represent resources into the system. The values on the right-hand side under the heading DEMAND CATEGORY represent basic energy demands in terms of a disaggregated set of end uses. The energy flowing through each stage of the RES is shown above the line representing the activity. In the demand categories, the numbers in parentheses represent the relative effectiveness or efficiency of the processes as described in Section II. On the supply side, these efficiencies represent losses from electrical conversion and transmission, petroleum refining, gas processing and distribution, and coal cleaning.

The Evaluation Of New Technologies

In the remainder of this section, the manner in which the Reference Energy System can be applied to technology assessments will be briefly outlined. The regional variability of the energy system and the diversity of technologies being considered make a formal methodology for assessments inappropriate. More preferable are the basic ground rules presented here.

Underlying all evaluations is the Reference Energy System and associated data as they provide a baseline against which new technologies can be measured. The place of a new technology should be noted on the perturbed Reference Energy System for the time frame of interest. The impact of the new technology in terms of resource consumption may be evaluated by modifying the energy flow paths to incorporate the new technology. Alternative paths through the network reflect the

substitutability of resources and technologies for one another. A choice is necessary among the technologies to be replaced, and each choice will be determined by the purpose of the assessment and the energy priorities at the time the analysis is performed. In many cases it is convenient to represent a resource change in terms of imported oil since this measure will be of obvious importance in the foreseeable future.

In the case of space heating, the quantity of electricity required to allow for the introduction of heat pumps into a given fraction of the homes presently heated by natural gas may be computed by accounting for differences in efficiencies between the two technologies. Any savings in primary resources brought about by this technology shift from gas to heat pumps can be computed by following the network flow back to the left-hand side of the diagram, accounting for additional fuels required as input to electric generation. The amount of electricity required for air conditioning displayed in the RES under the heading UTILIZING DEVICE may be computed in terms of primary resource requirements for air conditioning by moving from right to left in the network, allowing for efficiencies encountered including losses incurred in the generation of electric power. The following is a partial list of parameters to be considered in a technology assessment:(27)

- Implementation dates
- Degree of implementation (fraction of demand satisfied by the new technology)
- Regional limitations (e.g., solar heating and cooling would have considerable regional variation)
- Primary input fuel
- Economic data
 - Capital cost
 - Operating and maintenance cost
 - Fuel cost
 - Fixed charge rate (e.g., 15%). This includes the cost of money, depreciation, taxes, and insurance.

For systems that may not be competitive in terms of dollar cost but that have significant environmental or conservation benefits, the analysis should emphasize the cost of achieving those benefits.

Allowances for moderate conservation are either explicitly or implicitly incorporated in the energy systems in appropriate demand categories where the technology currently exists. These reductions in per capita energy demand are brought

about either through regulation or price-induced cutbacks in energy consumption. Improvements in fuel economy for automobiles as mandated by law are taken into account in projecting gasoline consumption, for example. Conservation in industry is reflected as a reduced growth rate for industrial process heat. Again, it should be emphasized that the Reference Energy Systems in this report are base case scenarios representing reasonable energy use patterns and are not meant to reflect either a forecast based entirely on historical growth rates or a projection allowing for the introduction of new technologies and strong conservation measures.

As a numerical example of the perturbation analysis discussed, the impacts of a conservation strategy applied to petroleum consumption in the industrial sector will be evaluated. It is assumed that by the year 1985 oil to industrial process heat will be reduced by 15% per unit of output. This reduction is applied to the level of crude oil imports to the region in 1985. The oil to industrial process heat with no conservation, as shown in Table IV-1, is from the 1985 Reference Energy System (Figure IV-3). The oil savings is computed by reducing oil input to industrial process heat by 15% and dividing this result by the refining efficiency, 0.93. Thus a 15% reduction in oil requirements to industrial process heat reduces crude imports to the region by 9.4×10^{12} Btu (equivalent to about 2440 bbl/day). The cost savings are calculated by assuming that the price of oil in 1985 will be \$14.50/bbl or \$2.50 per million Btu. Then the dollar savings is

$$9.4 \times 10^{12} \text{ Btu} \times \$2.50/10^6 \text{ Btu} = \$23.5 \text{ million}$$

Table IV-1
IMPACT OF INDUSTRIAL OIL CONSERVATION, 1985

Region	Oil to Process Heat With No Conservation	Oil Savings	Oil to Process Heat With Conservation
TVA	58.0	9.4	48.6

Figure IV-1. TVA reference energy system, year 1975.

Figure IV-3. TVA reference energy system, year 1985.

Figure IV-4. TVA reference energy system, year 2000.

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APPENDIX A
SUMMARY OF ENERGY DEMAND AND FUEL MIX

Projections of energy demand and fuel mix are summarized in Tables A-1 through A-4 for the Tennessee Valley Authority for the years 1975, 1980, 1985, and 2000. In the tables, the electricity delivered to each end use is indicated and the resources to generate electrical energy are tabulated in the row entitled "Electric Utility." Losses incurred in the extraction of resources are accounted for in the rows entitled "Methane Production," "Coal Production," and "Refinery Use."

Table A-1
Summary of Energy Demand and Fuel Mix, 1975
Region: Tennessee Valley Authority

							(10 ¹² Btu)
	<u>Methane</u>	<u>Oil</u>	<u>Coal & Wood</u>	<u>LPG</u>	<u>Nuclear</u>	<u>Hydro</u> ^a	<u>Electric</u> ^b <u>Direct Use</u>
RESIDENTIAL:							
Space Heat	57.94	10.64	21.45	17.38			142.94
Water Heat	15.94			2.12			42.16
Air Cond.							14.61
Cooking	3.27		.36	.77			10.48
Appl. & Light	2.14						30.21
SUBTOTAL	79.29	10.64	21.81	20.27			240.40
COMMERCIAL:							
Space Heat	15.92	3.25	2.84	2.28			28.12
Water Heat	1.32	.30		.13			2.79
Cooking	2.63						2.99
Air Cond.							10.48
Mis. Electric							32.98
Outdoor Lighting							2.96
SUBTOTAL	19.87	3.55	2.84	2.41			80.32
INDUSTRIAL:							
Aluminum	7.32		15.62				60.00
Iron							
Steel	1.68						2.56
Process Heat	183.91	34.37	44.75				263.03
Electric Drive							77.11
Feedstocks	41.27	125.69	20.64				187.60
Uranium Enrich.							74.54
SUBTOTAL	234.18	160.06	81.01				664.84
TRANSPORTATION							
Automobile		277.07					277.07
Truck & Bus		187.52					187.52
Rail & Transit		18.36					18.36
Air		19.14					19.14
Pipelines	12.13						12.13
Ship		17.57					17.57
SUBTOTAL	12.13	519.66					531.79
ELEC. UTILITY							
		7.12	797.33		78.49	227.03	755.77 ^c
Methane Prod.							
Coal Prod.			27.96				27.96
Refinery Use		5.25					5.25
Agriculture	3.54	.91	.02	2.99		2.31	9.77
Mining	7.66	5.01	1.07			2.26	16.00
TOTAL RESOURCES CONSUMED							
	356.67	712.20	932.04	25.67	78.49	227.03	2332.10

^a Hydroelectric output is converted to theoretical energy inputs based on the equivalent coal-steam electric heat rate.

^b Gives energy consumed as electricity at 3412.8 Btu/KWH. For fuels consumed in producing electricity see row labeled "Electric Utility."

^c Taken as total resources consumed by utilities less electricity delivered to end use.

Table A-2
Summary of Energy Demand and Fuel Mix, 1980
Region: Tennessee Valley Authority

								(10 ¹² Btu)
	<u>Methane</u>	<u>Oil</u>	<u>Coal & Wood</u>	<u>LPG</u>	<u>Nuclear</u>	<u>Hydro^a</u>	<u>Electric^b</u>	<u>Total Direct Use</u>
RESIDENTIAL:								
Space Heat	58.94	9.22	17.03	19.22			43.52	147.93
Water Heat	16.37			2.37			28.21	46.95
Air Cond.							16.45	16.45
Cooking	3.01		.20	.65			7.23	11.09
Appl. & Light	2.19						34.57	36.76
SUBTOTAL	80.51	9.22	17.23	22.24			129.98	259.18
COMMERCIAL:								
Space Heat	16.59	4.03	3.08	2.82			6.34	32.86
Water Heat	1.51	.32		.16			1.43	3.42
Cooking	2.73						.48	3.21
Air Cond.							14.63	14.63
Mis. Electric							43.80	43.80
Outdoor Lighting							3.85	3.85
SUBTOTAL	20.83	4.35	3.08	2.98			70.53	101.77
INDUSTRIAL:								
Aluminum	10.30		21.25				52.20	83.75
Iron								
Steel	2.25						1.18	3.43
Process Heat	218.30	41.74	65.49				4.37	329.90
Electric Drive							116.74	116.74
Feedstocks	54.27	162.82	29.60					246.69
Uranium Enrich.							135.60	135.60
SUBTOTAL	285.12	204.56	116.34				310.17	916.19
TRANSPORTATION:								
Automobile		310.95						310.95
Truck & Bus		211.42						231.42
Rail & Transit		21.27						21.27
Air		26.92						26.92
Pipelines	14.09							14.09
Ship		20.66						20.66
SUBTOTAL	14.09	611.22						625.31
ELEC. UTILITY								
Methane prod.		30.25	923.20		485.67	178.21	(517.18)	1100.15 ^c
Coal. Prod.			32.83					32.83
Refinery Use		6.41						6.41
Agriculture	3.84	1.09		5.26			2.79	10.98
Mining	9.90	6.36	1.55				3.71	21.52
TOTAL RESOURCES CONSUMED	414.29	873.46	1094.23	28.48	485.67	178.21		3074.34

^a Hydroelectric output is converted to theoretical energy inputs based on the equivalent coal-steam electric heat rate.

^b Gives energy consumed as electricity at 3412.8 Btu/KWH. For fuels consumed in producing electricity see row labeled "Electric Utility."

^c Taken as total resources consumed by utilities less electricity delivered to end use.

Table A-3
Summary of Energy Demand and Fuel Mix, 1985
Region: Tennessee Valley Authority

							(10 ¹² Btu)
	<u>Methane</u>	<u>Oil</u>	<u>Coal & Wood</u>	<u>LPG</u>	<u>Nuclear</u>	<u>Hydro</u> ^a	Total <u>Direct Use</u>
RESIDENTIAL:							
Space Heat	59.90	9.99	14.28	18.15		52.97	155.29
Water Heat	17.63			1.78		33.24	52.65
Air Cond.						18.91	18.91
Cooking	2.42			.48		8.74	11.64
Appl. & Light	2.24					41.86	44.10
SUBTOTAL	82.19	9.99	14.28	20.41		155.72	282.59
COMMERCIAL:							
Space Heat	18.43	4.95	2.70	2.97		9.20	38.25
Water Heat	1.71	.39		.13		1.94	4.17
Cooking	2.79					.62	3.41
Air Cond.						19.95	19.95
Mis. Electric						57.19	57.19
Outdoor Lighting						4.91	4.91
SUBTOTAL	22.93	5.34	2.70	3.10		93.81	127.88
INDUSTRIAL:							
Aluminum	14.11		29.09			71.49	114.69
Iron							
Steel	2.84					1.48	4.32
Process Heat	238.16	45.59	88.58			12.92	385.25
Electric Drive						137.64	137.64
Feedstocks	66.11	207.76	40.92				314.79
Uranium Enrich.						136.24	136.24
SUBTOTAL	321.22	253.35	158.59			359.77	1092.93
TRANSPORTATION:							
Automobile		269.32					269.32
Truck & Bus		284.42					284.42
Rail & Transit		24.18					24.18
Air		34.93					34.93
Pipelines	15.58						15.58
Ship		23.94					23.94
SUBTOTAL	15.58	636.79					652.37
ELEC. UTILITY		14.56	647.74		1115.79	178.21	(618.31) 1337.99 ^c
Methane Prod.							
Coal Prod.			25.52				25.52
Refinery Use		6.80					6.80
Agriculture	4.19	1.09		3.54		3.42	12.24
Mining	12.18	7.93	1.71			5.59	27.41
TOTAL RESOURCES CONSUMED	450.29	935.85	850.54	27.05	1115.79	178.21	3565.73

^a Hydroelectric output is converted to theoretical energy inputs based on the equivalent coal-steam electric heat rate."

^b Gives energy consumed as electricity at 3412.8 Btu/KWH. For fuels consumed in producing electricity see row labeled "Electric Utility."

^c Taken as total resources consumed by utilities less electricity delivered to end use.

Table A-4
Summary of Energy Demand and Fuel Mix, 2000
Region: Tennessee Valley Authority

	<u>Methane</u>	<u>Oil</u>	<u>Coal & Wood</u>	<u>LPG</u>	<u>Nuclear</u>	<u>Hydro^a</u>	<u>Electric^b</u>	(10 ¹² Btu) Total Direct Use
RESIDENTIAL:								
Space Heat	62.63	11.66	6.63	17.69			73.10	171.71
Water Heat	17.95			1.11			46.22	65.28
Air Cond.							30.79	30.79
Cooking							12.36	12.36
Appl. & Light	1.95						63.01	64.96
SUBTOTAL	82.53	11.66	6.63	18.80			225.48	345.10
COMMERCIAL:								
Space Heat	24.85	8.75	1.91	3.50			21.36	60.37
Water Heat	2.13	.38		.12			4.35	7.18
Cooking	2.90						1.19	4.09
Air Cond.							39.16	39.16
Mis. Electric							113.20	113.28
Outdoor Lighting							9.50	9.50
SUBTOTAL	29.88	9.33	1.91	3.62			188.84	233.58
INDUSTRIAL:								
Aluminum	34.54		58.95				145.51	239.00
Iron								
Steel	3.97						2.08	6.05
Process Heat	310.38	54.77	195.10				41.38	601.63
Electric Drive							217.14	217.14
Feedstocks	115.56	375.58	86.67					577.81
Uranium Enrich.							136.61	136.61
SUBTOTAL	464.45	430.35	340.72				542.72	1778.24
TRANSPORTATION:								
Automobile		276.44						276.44
Truck & Bus		446.53						446.53
Rail & Transit		34.03						34.03
Air		79.51						79.51
Pipelines	21.26							21.26
Ship		34.47						34.47
SUBTOTAL	21.26	870.98						892.24
ELEC. UTILITY								
		21.00	1080.66		1770.24	178.21	(977.41)	2072.70 ^c
Methane Prod.								
Coal Prod.			44.33					44.33
Refinery Use		9.92						9.92
Agriculture	5.92	1.50		4.93			6.41	18.76
Mining	21.21	13.12	3.32				13.96	51.61
TOTAL RESOURCES CONSUMED	625.25	1367.86	1477.57	27.35	1770.24	178.21		5446.48

^a Hydroelectric output is converted to theoretical energy inputs based on the equivalent coal-steam electric heat rate.

^b Gives energy consumed as electricity at 3412.8 Btu/KWH. For fuels consumed in producing electricity see row labeled "Electric Utility."

^c Taken as total resources consumed by utilities less electricity delivered to end use.

APPENDIX B

FUEL MIX TABLES

The projections of energy demand and fuel mix for the reference years are developed on the worksheets included in this Appendix. The following parameters are specified in these "Fuel Mix Tables" for each demand category: Fuel Demand (D_i), Total Fuel Demand (D), Relative Effectiveness (e_i), Basic Energy Demand (E), Degree of Saturation (S), Unit Basic Energy Demand (E_u), Fuel Fraction (f_i), and Basis. These terms are defined below. In the base year the Fuel Demand, Relative Effectiveness, Basis, and degree of Saturation are initially specified with other variables being derived. The Basic Energy Demand is independent of the fuels employed to satisfy that demand and is forecast into the future from the projected Basis and any changes that may be postulated in Saturation and Unit Basic Energy Demand. By specifying the Fuel Fraction and Relative Effectiveness, the Fuel Demands are derived from the Basic Energy Demand for each future reference year, thus defining the fuel mix. The projection methodology is further outlined in Section II. The parameters discussed above and computed in the Fuel Mix Tables are defined as follows:

1. Fuel Demand, D_i = the quantity of a fuel, i , actually consumed in a specific demand category, such as space heating, automotive transport, or aluminum production.
2. Total Fuel Demand, D = the total fuel required to satisfy the requirements of a specific demand category. Electricity is considered as a fuel in this sense and $D = \sum D_i$.
3. Relative Effectiveness, e_i = the relative effectiveness with which fuel, i , is used in a demand category. This parameter depends on the utilization technology employed. See discussion in Section II.
4. Basic Energy Demand, E = the amount of energy that would be required in a specific demand category, assuming a relative effectiveness, e_i , of 100% for each fuel employed. Thus, for a given demand category where quantities of fuels, D_i , are consumed with actual Relative Effectiveness, e_i , $E = \sum_i e_i D_i$

5. Degree of Saturation, S = the fraction of the potential demand for a particular energy use actually being fulfilled at a given time. For example, if 95% of all households have refrigerators, and potentially all houses can have one refrigerator, $S = 0.95$.
6. Saturated Basic Energy Demand = the Basic Energy Demand that would exist in a category if there was 100% saturation, $= E/S$.
7. Unit Basic Energy Demand, E_u = the Basic Energy Demand per unit (e.g., per household, per lb of Aluminum Produced, etc.).
8. Fuel Fraction, f_i = fraction of the Saturated Basic Energy Demand that is satisfied by using the i'th fuel, $f_i = \frac{e_i D_i}{E/S}$ and $\sum_i f_i = S$

PROJECTED FUEL MIX

Sector: Residential

Region: TENNESSEE VALLEY AUTHORITY

Category: Space Heating

	B 1975				B 1980				B 1985				B 2000			
	f_i	e_i	S_i	D_i	f_i	e_i	S_i	D_i	f_i	e_i	S_i	D_i	f_i	e_i	S_i	D_i
DIRECT FUEL USE																
Methane-Mobile Home				1.80				3.26				3.58				3.83
Single-Family Detached	.32			50.62	.30			49.66	.28			49.87	.25			51.60
Single-Family Attached		.75	.63	4.19		.75	.64	4.65		.76	.65	4.94		.77	.68	5.52
Multi-Family Low Rise	.37			1.03	.35			1.03	.33			1.13	.30			1.25
Multi-Family High Rise				.30				.34				.38				.43
Distillate Oil-																
Mobile Home				.33				.52				.61				.73
Single-Family Detached				9.42				7.88				8.46				9.79
Single-Family Attached	.05	.63	.63	.67	.04	.63	.64	.63	.04	.64	.65	.71	.04	.65	.68	.87
Multi-Family Low Rise				.17				.14				.16				.20
Multi-Family High Rise				.05				.05				.05				.07
Coal-																
Single-Family Detached				11.86				9.01				5.99				
Single-Family Attached	.07	.70	.63	.85	.05	.70	.63	.72	.03	.70	.63	.50				
Multi-Family Low Rise				.21				.16				.12				
Multi-Family High Rise				.06				.05				.04				
Wood-																
Single-Family Detached	.05	.70	.63	8.47	.04	.70	.64	7.09	.04	.71	.65	7.63	.03	.72	.68	6.63
LPG-Mobile Home	.24			1.60	.22			2.85	.19			2.88	.15			2.72
Single-Family Detached	.08			15.07	.08			15.77	.07			14.80	.06			14.68
Single-Family Attached		.63	.63	.54		.63	.64	.47		.64	.65	.36		.65	.68	.22
Multi-Family Low Rise	.04			.13	.03			.10	.02			.08	.01			.05
Multi-Family High Rise				.04				.03				.03				.02
Electricity-Mobile Home	.39			1.02	.44			2.19	.49			2.92	.56			4.12
Single-Family Detached	.43			31.29	.49			37.16	.54			44.77	.62	1.09	1.00	61.51
Single-Family Attached		1.027	1.00	2.45		1.048	1.00	3.23		1.061	1.00	4.04				5.74
Multi-Family Low Rise	.47			.60	.53			.71	.58			.93	.65			1.30
Multi-Family High Rise				.17				.23				.31				.43
TOTAL FUEL DEMAND, D,																
10^{12} Btu				142.94				147.93				155.29				171.71
BASIS, 10^3 Units																
Mobile Home				87				171				207				263
Single-Family Detached				1632				1735				1921				2361
Single-Family Attached				184				219				254				331
Multi-Family Low Rise				83				89				107				138
Multi-Family High Rise				39				47				57				75
				2025				2261				2546				3168
BASIC ENERGY DEMAND, E,																
10^{12} Btu																
Mobile Home				2.66				5.22				6.32				8.02
Single-Family Detached				74.74				79.46				87.98				108.12
Single-Family Attached				5.35				6.37				7.39				9.63
Multi-Family Low Rise				1.31				1.41				1.70				2.18
Multi-Family High Rise				.38				.46				.57				.74
UNIT BASIC DEMAND, E_u ,																
10^6 Btu/Household																
Mobile Home				30.5				30.5				30.5				30.5
Single-Family Detached				45.8				45.8				45.8				45.8
Single-Family Attached				29.1				29.1				29.1				29.1
Multi-Family Low Rise				15.8				15.8				15.8				15.8
Multi-Family High Rise				9.9				9.9				9.9				9.9

PROJECTED FUEL MIX

Sector: Residential

Region: TENNESSEE VALLEY AUTHORITY

Category: Space Heating

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels, electric resistance heat, and heat pumps.

DATA SOURCES: D_i (for 1975): Annual energy requirements per housing unit for five building types from Ref. (1) adjusted for average annual population weighted heating degree days in the TVA region.

e_i : Fossil fuel burner efficiencies from Ref. (6). No burner loss assumed for electric resistance heat. Seasonal performance factor for heat pumps, assumed to be 1.60, is weighted in proportion to the number of heat pumps to obtain an average efficiency for all electric heating. The apparent relative shell effectiveness of an electrically heated home set at 1.00. Shell effectiveness of other buildings reflects reduced insulation and other building practices typical of conventional housing units.

f_i : Fuels for space heating as reported by TVA.

BASIS OF PROJECTIONS: The basic demands derived for 1975 are escalated in proportion to the number of households. Total number of households and number of electrically heated homes projected based on data reported by TVA. Space heating from fossil fuels projected to proportionally decrease with coal meeting less than 1% of demand in 2000. Housing units constructed after 1985 assumed to meet ASHRAE 90-75 standards. Retrofitting in one-half of all residential buildings constructed prior to 1975 such that they meet ASHRAE 90-75 standards by 2000.

PROJECTED FUEL MIX

Sector: Residential

Region: TENNESSEE VALLEY AUTHORITY

Category: Water Heating

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.25	.61	15.94	.23	.61	16.37	.22	.61	17.63	.18	.61	17.95
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
LPG	.03	.55	2.12	.03	.55	2.37	.02	.55	1.78	.01	.55	1.11
ELECTRICITY	.62	1.00	24.10	.65	1.00	28.21	.68	1.00	33.24	.76	1.00	46.22
TOTAL FUEL DEMAND, D, 10 ¹² Btu			42.16			46.95			52.65			65.28
BASIS, 10 ³ Households			2025			2261			2546			3168
SATURATION, S,	.90			.91			.92			.95		
BASIC ENERGY DEMAND, E, 10 ¹² Btu			34.99			39.50			44.97			57.78
UNIT BASIC DEMAND, E _u , 10 ⁶ Btu/Household			19.2			19.2			19.2			19.2

REFERENCE TECHNOLOGIES: Gas and oil burners, electric resistance heat.

DATA SOURCES: D_i and f_i (for 1975): Btu/Household requirements from Ref(1); fuels for water heating derived from Bureau of Census data (Ref 2). e_i :

These are apparent relative efficiencies derived from Btu/Household requirements assuming electric units have an apparent efficiency of 1.00.

BASIS OF PROJECTIONS:

The basic demands derived for 1975 are escalated in proportion to the number of households projected for the reference years. The fuel mix is projected according to the changes forecast for space heat.

PROJECTED FUEL MIX

Sector: Residential

Region: TENNESSEE VALLEY AUTHORITY

Category: Air Conditioning

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY, Room	.395	1.75	6.71	.36	2.00	5.98	.32	2.25	5.32	.25	3.00	3.88
Central	.268	2.50	7.90	.35	2.75	10.47	.44	3.00	13.59	.70	3.00	26.91
TOTAL FUEL DEMAND, D, 10 ¹² Btu			14.61			16.45			18.91			30.79
BASIS, 10 ³ Households			2025			2261			2546			3168
SATURATION, S, Room	.395			.36			.32			.25		
Central	.268			.35			.44			.70		
BASIC ENERGY DEMAND, E, 10 ¹² Btu, Room			11.74			11.96			11.97			11.64
Central			19.75			28.79			40.77			80.73
UNIT BASIC DEMAND, E _u , 10 ⁶ Btu/Household												
Room			14.7			14.7			14.7			14.7
Central			36.4			36.4			36.4			36.4

REFERENCE TECHNOLOGIES: Vapor compression cycle operating on electricity.

DATA SOURCE: D_i and f_i (for 1975): Energy demand for room and central A/C in the U.S. from a report by ORNL (Ref 3). Regionalized energy demand proportional to equivalent full load operating hours in the TVA service area (1200 hours as derived from Ref 41) relative to the U.S. (1000 hours from Ref 1). Market saturation of A/C derived from Census of Housing and Annual Housing Survey data (References 2 and 42).

e_i : The efficiency in this demand category is the coefficient of performance for air conditioning equipment. The 1975 values for central units are taken from ASHRAE Guide and Data Book, American Society of Heating, Refrigeration, and Air Conditioning Engineers, 1969, p. 514. The 1975 values for room A/C are estimated from a report by ORNL (Ref 41). The coefficient of performance is increased in future reference years to reflect the use of the more efficient devices that are on the market today.

BASIS OF PROJECTIONS: The basic demands derived for 1975 are escalated in proportion to the market saturation and the number of households projected in the reference years.

PROJECTED FUEL MIX

Sector: Residential

Region: TENNESSEE VALLEY AUTHORITY

Category: Cooking

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.17	.41	3.27	.14	.41	3.01	.10	.41	2.42			
Jet Fuel												
Gasoline												
LPG	.04	.41	.77	.03	.41	.65	.02	.41	.48			
Residual oil												
Wood, Coal	.02	.44	.36	.01	.44	.20						
Other												
ELECTRICITY	.77	1.00	6.08	.82	1.00	7.23	.88	1.00	8.74	1.00	1.00	12.36
TOTAL FUEL DEMAND, D, 10 ¹² Btu			10.48			11.09			11.64			12.36
BASIS, 10 ³ Households			2025			2261			2546			3168
SATURATION, S,												
BASIC ENERGY DEMAND, E, 10 ¹² Btu			7.89			8.82			9.93			12.36
UNIT BASIC DEMAND, E _u , 10 ⁶ Btu/Household			3.9			3.9			3.9			3.9

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels, electric resistance heat.

DATA SOURCES: D_i and f_i (for 1975): Btu/Household requirements from Ref. (1). Fuel fraction derived from Census of Housing and Annual Housing Survey data (References 2 and 42).

e_i : Apparent relative efficiencies for methane and LPG are derived from Btu/Household requirements assuming electric units have an efficiency of 1.00. Apparent relative efficiency of wood and coal set equal to that in the residential space heating category.

BASIS OF PROJECTIONS: The basic demand for 1975 is escalated in proportion to the number of households projected in the reference years. The fuel fraction is projected in proportion to the increasing market penetration of electric ranges and the corresponding decreasing use of methane, LPG, wood, and coal for cooking. The shift observed from 1970 to 1975 (References 2 and 42) is assumed to continue such that by the year 2000 electric ranges have completely saturated the market.

PROJECTED FUEL MIX

Sector: Residential

Region: TENNESSEE VALLEY AUTHORITY

Category: Appliances &
Lighting

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.01	.36	2.14	.01	.36	2.19	.01	.36	2.24	.01	.36	1.95
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	.50	1.00	28.07	.55	1.00	34.57	.59	1.00	41.86	.71	1.00	63.01
TOTAL FUEL DEMAND, D, 10^{12} Btu			30.21			36.76			44.10			64.96
BASIS, 10^3 Households			2025			2261			2546			3168
SATURATION, S,	.51			.56			.60			.72		
BASIC ENERGY DEMAND, E, 10^{12} Btu			28.84			35.36			42.67			63.71
UNIT BASIC DEMAND, E_u , 10^6 Btu/Household			27.93			27.93			27.93			27.93

REFERENCE TECHNOLOGIES: Vapor compression cycle in refrigeration; AC induction motor in appliances; 1975 mix of lighting and of vacuum tube, transistor and integrated circuits in electronic equipment.

DATA SOURCES: D_i and f_i (for 1975): Summarized in Table . Btu/household requirements from Ref. (1). The saturation factor is derived from 1970 census data (Ref. 2) escalated to 1975.

e_i : Only non-electric appliances are gas clothes dryers. e_i is an apparent relative efficiency derived from Btu/household requirements assuming electric appliances have an apparent efficiency of 1.00.

BASIS OF PROJECTIONS: The basic demands derived for 1975 are escalated in proportion to the projected market penetration of appliances derived from Ref. (1), and the number of households projected in the reference years. In 2000 new residential electrical devices not yet in use are assumed to use as much energy as small appliances did in 1970 (1.6×10^6 Btu/Household).

PROJECTED FUEL MIX
Region: TENNESSEE VALLEY AUTHORITY

Sector: Commercial
Category: Space Heating

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.50	.49	15.92	.42	.49	16.59	.38	.49	18.43	.29	.49	24.85
Jet Fuel												
Gasoline												
Fuel oil	.10	.48	3.25	.10	.48	4.03	.10	.48	4.95	.10	.48	8.75
LPG	.07	.48	2.28	.07	.48	2.82	.06	.48	2.97	.04	.48	3.50
Coal & wood	.08	.44	2.84	.07	.44	3.08	.05	.44	2.70	.02	.44	1.91
Other												
ELECTRICITY	.25	1.018	3.83	.34	1.039	6.34	.41	1.060	9.20	.55	1.081	21.36
TOTAL FUEL DEMAND, D, 10 ¹² Btu			28.12			32.86			38.25			60.37
BASIS, 10 ⁶ square feet			680			844			1036			1830
SATURATION, S,	1.00			1.00			1.00			1.00		
BASIC ENERGY DEMAND, E, 10 ¹² Btu			15.60			19.36			23.77			41.98
UNIT BASIC DEMAND, E _u , Btu/sq. ft.			23,000			23,000			23,000			23,000

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels, electric resistance heat, and heat pumps.

DATA SOURCES: D_i and f_i (for 1975): Annual heating requirements per square foot for five commercial building types from Ref. (1), adjusted for population weighted degree day data for the TVA region. Fuel mix estimated relative to residential space heating.

e_i : Fossil fuel burner efficiencies from Ref. (6). No burner loss assumed for electric resistance heat. Seasonal performance factor for heat pumps, assumed to be 1.60, is weighted in proportion to the number of heat pumps to obtain an average efficiency for all electric heating. Relative effectiveness, e_i , is the product of the burner efficiency and the apparent relative shell effectiveness. The apparent relative shell effectiveness of an electrically heated building set at 1.00. Shell effectiveness of other buildings reflects reduced insulation and other practices typical of conventional buildings.

BASIS OF PROJECTIONS: The basic energy demand for 1975 is escalated in proportion to projected commercial floor space. Commercial floor space is escalated in proportion to projected output in the commercial sector in the U.S. from the BNL input-output model assuming a 3.2% GNP growth rate. Total U.S. output in the commercial sector is regionalized to the TVA service area based on projected regional earnings in the commercial sector. 75% of new construction is assumed to have electric heating.

PROJECTED FUEL MIX

Sector: Commercial

Region: TENNESSEE VALLEY AUTHORITY

Category: Water Heating

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.40	.70	1.32	.37	.70	1.51	.34	.70	1.71	.24	.70	2.13
Jet Fuel												
Gasoline												
Fuel oil	.07	.54	.30	.06	.54	.32	.06	.54	.39	.05	.54	.58
LPG	.03	.54	.13	.03	.54	.16	.02	.54	.13	.01	.54	.12
Coal												
Other												
ELECTRICITY	.45	1.00	1.04	.50	1.00	1.43	.55	1.00	1.94	.70	1.00	4.35
TOTAL FUEL DEMAND, D , 10^{12} Btu			2.79			3.42			4.17			7.18
BASIS, 10^6 square feet			680			844			1036			1830
SATURATION, S ,	.95			.96			.97			1.00		
BASIC ENERGY DEMAND, E , 10^{12} Btu			2.20			2.75			3.42			6.22
UNIT BASIC DEMAND, E_u , Btu/sq. ft.			3400			3400			3400			3400

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels and electric resistance heat.

DATA SOURCES: D_i and f_i (for 1975): Annual hot water requirements per square foot for five building types from Ref. (1). Fuel mix estimated relative to residential water heating. e_i : The relative efficiencies are held in the same ratio as is given in Ref. (6), p. 18.

BASIS OF PROJECTIONS: The basic energy demand for 1975 is escalated in proportion to projected commercial floor space. Changes in the fuel mix are projected relative to residential hot water heating.

PROJECTED FUEL MIX

Sector: Commercial

Region: TENNESSEE VALLEY AUTHORITY

Category: Cooking

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.75	.41	2.63	.70	.41	2.73	.65	.41	2.79	.50	.41	2.90
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	.25	1.00	.36	.30	1.00	.48	.35	1.00	.62	.50	1.00	1.19
TOTAL FUEL DEMAND, D , 10^{12} Btu			2.99			3.21			3.41			4.09
BASIS, 10^6 meals			1309			1452			1596			2168
SATURATION, S ,	1.00			1.00			1.00			1.00		
BASIC ENERGY DEMAND, E , 10^{12} Btu			1.44			1.60			1.76			2.38
UNIT BASIC DEMAND, E_u , Btu/meal			1100			1100			1100			1100

REFERENCE TECHNOLOGIES: Gas burner device and electric resistance heat.

DATA SOURCES: D_i and f_i (for 1975): Assume energy required to cook a meal is 75% that of the residential sector and twenty percent of all meals are in commercial establishments. e_i : Taken as equal to the apparent relative efficiencies in the residential cooking category.

BASIS OF PROJECTIONS: The basic energy demand is escalated in proportion to the number of meals served. The number of meals served is projected as a function of growth in population and the increasing proportion of meals eaten in commercial establishments, projected to increase from 20% in 1975 to 25% in 2000.

PROJECTED FUEL MIX

Sector: Commercial

Region: TENNESSEE VALLEY AUTHORITY

Category: Air Conditioning

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	.72	2.50	10.48	.81	2.50	14.63	.90	2.50	19.95	1.00	2.50	39.16
TOTAL FUEL DEMAND, D, 10 ¹² Btu			10.48			14.63			19.95			39.16
BASIS, 10 ⁶ square feet			680			844			1036			1830
SATURATION, S,	.72			.81			.90			1.00		
BASIC ENERGY DEMAND, E, 10 ¹² Btu			26.20			36.57			49.88			97.91
UNIT BASIC DEMAND, E _u , 10 ³ Btu/sq. ft.			53.5			53.5			53.5			53.3

REFERENCE TECHNOLOGIES: Vapor compression cycle.

DATA SOURCES: D_i and f_i (for 1975): Annual energy requirements per square foot per building type from Ref. (1). Regionalized to the TVA service area based on equivalent full load operating hours (1200) in the region from Ref. (41). Market penetration of A/C is BNL estimate.

e_i : The efficiency in this demand category is the coefficient of performance for air conditioning equipment.

BASIS OF PROJECTIONS: The basic demands derived for 1975 are escalated in proportion to the market saturation and the number of households projected in the reference years.

PROJECTED FUEL MIX

Sector: Commercial

Region: TENNESSEE VALLEY AUTHORITY

Category: Lighting, Appliances
& Refrigeration

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	1.00	1.00	32.98	1.00	1.00	43.80	1.00	1.00	57.19	1.00	1.00	113.28
TOTAL FUEL DEMAND, D, 10 ¹² Btu			32.98			43.80			57.19			113.28
BASIS, 10 ⁶ square feet			680			844			1036			1830
SATURATION, S,	1.00			1.00			1.00			1.00		
BASIC ENERGY DEMAND, E, 10 ¹² Btu			32.98			43.80			57.19			113.28
UNIT BASIC DEMAND, E _u , Btu/sq. ft.			48,500			51,900			55,200			61,900

REFERENCE TECHNOLOGIES: Electric energy and vapor compression cycle.

DATA SOURCES: D_i and f_i (for 1975): Annual energy requirements per square foot per building type for lighting, appliances, refrigeration, auxiliary space conditioning equipment, and computers from Ref. (1). e_i : Taken as one since there is only one energy source employed.

BASIS OF PROJECTIONS: The basic energy demand for 1975 is escalated in proportion to projected commercial floor space and changes in the unit basic energy demand. Energy requirements for computers and refrigerating equipment increase by a factor of 1.5 by 1985 and 2.0 by 2000.

PROJECTED FUEL MIX

Sector: Commercial

Region: TENNESSEE VALLEY AUTHORITY

Category: Outdoor Lighting

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	1.00	1.00	2.96	1.00	1.00	3.85	1.00	1.00	4.91	1.00	1.00	9.50
TOTAL FUEL DEMAND, D , 10^{12} Btu			2.96			3.85			4.91			9.50
BASIS, Multiple of 1975			1.000			1.301			1.659			3.209
SATURATION, S ,												
BASIC ENERGY DEMAND, E , 10^{12} Btu			2.96			3.85			4.91			9.50
UNIT BASIC DEMAND, E_u ,												

REFERENCE TECHNOLOGIES: Incandescent lamp.

DATA SOURCES: D_i (for 1975): Electricity sales to outdoor lighting as reported by TVA for 1975. e_i and f_i : Taken as unity since there is only one energy source employed.BASIS OF PROJECTIONS: Electricity sales to outdoor lighting as projected by TVA for 1980 and 1985.
Electricity sales to outdoor lighting in the year 2000 is a BNL estimate.

PROJECTED FUEL MIX

Sector: Agriculture

Region: TENNESSEE VALLEY AUTHORITY

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.31	.64	3.54	.30	.64	3.84	.29	.64	4.19	.26	.64	5.92
Jet Fuel												
Gasoline												
Distillate oil	.09	.68	.91	.09	.68	1.09	.08	.68	1.09	.07	.68	1.50
Residual oil												
Coal	.0	.70	.02									
LPG	.28	.68	2.99	.27	.68	3.26	.26	.68	3.54	.23	.68	4.93
ELECTRICITY	.32	1.00	2.31	.34	1.00	2.79	.37	1.00	3.42	.44	1.00	6.41
TOTAL FUEL DEMAND, D, 10^{12} Btu			9.77			10.98			12.24			18.76
BASIS, Multiple of 1975			1.000			1.132			1.278			2.013
SATURATION, S,	1.00			1.00			1.00			1.00		
BASIC ENERGY DEMAND, E, 10^{12} Btu			7.24			8.20			9.25			14.57
UNIT BASIC DEMAND, E_u ,												

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels, electric resistance heat, and a/c induction motors and pumps.

DATA SOURCES: D_i and f_i (for 1975): Demand for energy and fuel mix in the U.S. from the National Energy Accounts (Ref. 43). Regionalized based on farm acreage in the TVA service area relative to total U.S. acreage.

e_i : Relative efficiencies set equal to those used for industrial process heat.

BASIS OF PROJECTIONS: The basic energy demand derived for 1975 is escalated in proportion to projected agricultural output in the U.S. from the BNL input-output model assuming a 3.2% GNP growth rate. U.S. agricultural output is regionalized to the TVA service area based on projected regional earnings in agriculture.

PROJECTED FUEL MIX
Region: TENNESSEE VALLEY AUTHORITY

Sector: Mining

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.43	.64	7.66	.41	.64	9.90	.39	.64	12.18	.35	.64	21.21
Jet Fuel												
Gasoline												
Distillate oil	.21	.68	3.59	.20	.68	4.54	.19	.68	5.58	.16	.68	9.13
Residual oil	.09	.68	1.42	.08	.68	1.82	.08	.68	2.35	.07	.68	3.99
Coal	.07	.70	1.07	.07	.70	1.55	.06	.70	1.71	.06	.70	3.32
Other												
ELECTRICITY	.20	1.00	2.26	.24	1.00	3.71	.28	1.00	5.59	.36	1.00	13.96
TOTAL FUEL DEMAND, D, 10 ¹² Btu			16.00			21.52			27.41			51.61
BASIS, Multiple of 1975			1.000			1.365			1.765			3.427
SATURATION, S,	1.00			1.00			1.00			1.00		
BASIC ENERGY DEMAND, E, 10 ¹² Btu			11.32			15.45			19.98			38.79
UNIT BASIC DEMAND, E _u ,												

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels, electric resistance heat, and a/c induction motors.

DATA SOURCES: D_i and f_i (for 1975): Demand for energy and fuel mix in the U.S. from the National Energy Accounts (Ref. 43). Regionalized based on value added in mining for the TVA service area relative to value added in mining for the U.S.

e_i : Relative efficiencies set equal to those used for industrial process heat.

BASIS OF PROJECTIONS: The basic energy demand derived for 1975 is escalated in proportion to projected output from mineral industries in the U.S., estimated using the BNL input-output model assuming a 3.2% GNP growth rate. Mineral industries output is regionalized to the TVA service area based on projected regional earnings in mining.

PROJECTED FUEL MIX

Sector: Industry
Category: Aluminum

Region: TENNESSEE VALLEY AUTHORITY

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.12	.64	7.32	.12	.64	10.30	.12	.64	14.11	.14	.64	34.54
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal - For Carbon Electrodes	.30	.75	15.62	0.29	0.75	21.25	0.29	0.75	29.09	.28	.75	58.95
Other												
ELECTRICITY - Electrolysis Drive	.40	.52	30.03	0.39	0.52	41.21	.39	.52	56.44	.37	.52	112.35
	.18	1.0	7.03	0.20	1.0	10.99	.20	1.0	15.05	.21	1.0	33.16
TOTAL FUEL DEMAND, D, 10 ¹² Btu			60.00			83.75			114.69			239.00
Basis, 10 ⁹ lbs. Primary Al.			1.144			1.57			2.15			4.28
10 ⁹ lbs. Scrap			0.289			0.52			0.71			2.11
10 ⁹ lbs. Total			1.433			2.09			2.86			6.39
SATURATION, S,												
BASIC ENERGY DEMAND, E, 10 ¹² Btu			39.05			54.95			75.25			157.90
UNIT BASIC DEMAND, E _u , Btu/lb.		27,000			26,000			26,000			25,000	

REFERENCE TECHNOLOGIES: Electrolytic smelting, carbon cathodes and pot linings.

DATA SOURCES: D_i and f_i (for 1975): Energy totals for methane, coal, and electricity are BNL estimates for smelting and other primary and secondary processes plus foundry operations. Production level based on capacity data (Ref. 8). e_i :

The efficiency for methane use is taken from Ref. (6) for process steam production. The electrolytic efficiency is based on a minimum theoretical requirement of 27.3 million Btu per ton. Oxidation of carbon at the anode is accounted for in the losses to coal.

BASIS OF PROJECTIONS:

The total 1975 U.S. production from the Bureau of Mines is escalated at 5.6% per year to 1985 and 4.9% thereafter. The 1975-1985 rate is from Ref. (18); the 1985-2000 rate is based on the 2000 total U.S. production forecast in Ref. (19). TVA production is adjusted, relative to U.S. production, by the ratio of TVA to U.S. earnings in manufacturing in the projected year divided by the TVA to U.S. earnings in 1970 (Ref. 17). Scrap represents 25% of the total through 1985 and is increased to 33% thereafter.

PROJECTED FUEL MIX

Sector: Industry

Region: TENNESSEE VALLEY AUTHORITY

Category: Steel

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	0.55	0.64	1.68	0.55	0.64	2.25	0.55	0.64	2.84	0.55	0.64	3.97
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY												
Electric Furnace	0.45	1.00	0.88	0.45	1.00	1.18	0.45	1.00	1.48	0.45	1.00	2.08
TOTAL FUEL DEMAND, D , 10^{12} Btu			2.56			3.43			4.32			6.05
BASIS, 10^3 short tons			383.4			514.4			647.6			906.6
SATURATION, S ,												
BASIC ENERGY DEMAND, E , 10^{12} Btu			1.96			2.62			3.30			4.62
UNIT BASIC DEMAND, F_u , 10^3 Btu/ton			5100			5100			5100			5100

REFERENCE TECHNOLOGIES: Electric furnace.

DATA SOURCES: D_i and f_i (for 1975): Energy requirements for the electric furnace from Ref. (6) and and AUI estimates. Production level from survey of plants in TVA region and AUI estimates.

e_i : Reference (6), p. 18.

BASIS OF PROJECTIONS: Production is escalated in proportion to AUI steel projections for the U.S., adjusted by the ratio of TVA to U.S. earnings in primary metals in the projected year divided by the TVA to U.S. earnings in 1970 (Ref. 17).

PROJECTED FUEL MIX

Sector: Industrial

Region: TENNESSEE VALLEY AUTHORITY

Category: Process Heat

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.68	.64	183.91	.64	.64	218.30	.59	.64	238.16	.48	.64	310.38
Jet Fuel												
Gasoline												
Fuel oil	.14	.68	34.37	.13	.68	41.74	.12	.68	45.59	.09	.68	54.77
Coal	.18	.70	44.75	.21	.70	65.49	.24	.70	88.58	.33	.70	195.10
Other												
ELECTRICITY				.02	1.00	4.37	.05	1.00	12.92	.10	1.00	41.38
TOTAL FUEL DEMAND, D_i , 10^{12} Btu			263.03			329.90			385.25			601.63
BASIS, Multiple of 1975			1.000			1.2663			1.4985			2.4005
SATURATION, S_i ,												
BASIC ENERGY DEMAND, E_i , 10^{12} Btu			172.40			218.31			258.35			413.84
UNIT BASIC DEMAND, E_u ,												

REFERENCE TECHNOLOGIES: Burner devices for fossil fuels, electric.

DATA SOURCES: D_i (for 1975): Industrial Process Heat demand represents the balance of unaccounted fuels to the industrial sector. Energy demand in the industrial sector is computed as the product of

$$\left[\frac{\text{ENERGY DEMAND BY INDUSTRY}}{\$ \text{ VALUE ADDED}} \right]_{\text{ESC}} \times \left[\text{VALUE ADDED} \right]_{\text{TVA}}$$

where energy per dollar value added in the East South Central census region (ESC) is assumed to approximate that in the TVA region. TVA fuel fractions are assumed to be the same as Tennessee.

 e_i :

Ref. (6), p. 18.

 f_i :

Apparent fractions based on 1975 data.

BASIS OF PROJECTIONS:

A 2.6% growth rate from 1975 to 2000 in the U.S. is based on two assumptions: 1) The average GNP growth rate in real dollars will be 3.2% between 1975 and 2000; 2) The ratio of energy consumed by industry to GNP will continue declining at the rate observed historically between 1960 and 1975. The 2.6% national growth rate is increased to 4.8% from 1975 to 1980, 3.4% from 1980 to 1985, and 3.2% thereafter for the TVA region. This is based on the ratio of TVA to U.S. manufacturing earnings in the projected year divided by the TVA to U.S. earnings in 1970 (Ref. 17).

PROJECTED FUEL MIX

Sector: Industry

Region: TENNESSEE VALLEY AUTHORITY

Category: Electric Drive

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	1.00	1.00	77.11	1.00	1.00	116.74	1.00	1.00	137.64	1.00	1.00	217.14
TOTAL FUEL DEMAND, D , 10^{12} Btu			77.11			116.74			137.64			217.14
BASIS, Multiple of 1975			1.000			1.514			1.785			2.816
SATURATION, S ,												
BASIC ENERGY DEMAND, E , 10^{12} Btu			77.11			116.74			137.64			217.14
UNIT BASIC DEMAND, E_u ,												

REFERENCE TECHNOLOGIES: AC induction motor.

DATA SOURCES: D_i (for 1975): Adjusted to provide the balance of unaccounted electric demand as reported by TVA. e_i and f_i : Taken as unity since there is only one energy source employed.

BASIS OF PROJECTIONS: Electricity sales projected to 1985 as reported by TVA. Sales to distributors projected at 5.5% from 1985 to 2000. Sales direct to industry from 1985 to 2000 as reported by TVA.

PROJECTED FUEL MIX

Sector: Industry

Region: TENNESSEE VALLEY AUTHORITY

Category: Petrochemical
Feedstocks, Asphalt, &
Road Oil 2000

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane	.22	1.00	41.27	.22	1.00	54.27	.21	1.00	66.11	.20	1.00	115.56
Jet Fuel												
Gasoline												
Distillate oil	.67	1.00	125.69	.66	1.00	162.82	.66	1.00	207.76	.65	1.00	375.58
Residual oil												
Coal	.11	1.00	20.64	.12	1.00	29.60	.13	1.00	40.92	.15	1.00	86.67
Other												
ELECTRICITY												
TOTAL FUEL DEMAND, D, 10 ¹² Btu			187.60			246.69			314.79			577.81
BASIS, Multiple of 1975			1.000			1.315			1.678			3.080
SATURATION, S,												
BASIC ENERGY DEMAND, E, 10 ¹² Btu			187.60			246.69			314.79			577.81
UNIT BASIC DEMAND, E _u ,												

REFERENCE TECHNOLOGIES: Undefined.

DATA SOURCES: D_i (for 1975): Regional energy demand is proportional to regional value added relative to U.S. value added in SIC 28. e_i : These are taken as unity since the resources are used for their material input rather than their energy content. f_i : Apparent fractions from the East South Central Census Region (Ref. 30).

BASIS OF PROJECTIONS: The basic energy demand derived for 1975 is escalated in proportion to projected U.S. output in SIC 28 from the BNL input-output model assuming a 3.2% GNP growth rate (Ref. 40). U.S. output in SIC 28 is regionalized to the TVA service area based on projected regional earnings in chemicals and allied products.

PROJECTED FUEL MIX

Sector: Industry

Region: TENNESSEE VALLEY AUTHORITY

Category: Uranium Enrichment

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY	1.00	1.00	74.54	1.00	1.00	135.68	1.00	1.00	136.24	1.00	1.00	136.61
TOTAL FUEL DEMAND, D , 10^{12} Btu			74.54			135.68			136.24			136.61
BASIS, Multiple of 1975			1.000			1.820			1.828			1.833
SATURATION, S ,												
BASIC ENERGY DEMAND, E , 10^{12} Btu			74.54			135.68			136.24			136.61
UNIT BASIC DEMAND, E_u ,												

REFERENCE TECHNOLOGIES: Gaseous diffusion.

DATA SOURCES: D_i (for 1975): Electricity sales data as reported by TVA. e_i and f_i : Taken as unity since there is only one energy source employed.

BASIS OF PROJECTIONS: Electricity sales projections as reported by TVA.

PROJECTED FUEL MIX

Sector: Transportation

Region: TENNESSEE VALLEY AUTHORITY

Category: Automobile

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline	1.00	.20	277.07	1.00	.22	310.95	1.00	.29	269.32	1.00	.37	276.44
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY												
TOTAL FUEL DEMAND, D, 10 ¹² Btu			277.07			310.95			269.32			276.44
BASIS, 10 ⁹ vehicle-miles			30.002			37.08			41.60			55.31
SATURATION, S,												
BASIC ENERGY DEMAND, E, 10 ¹² Btu			55.41			68.41			78.10			102.28
FUEL EFFICIENCY (Btu/vehicle-mile) mpg	(9235)		13.53	(8386)		14.9	(6474)		19.3	(4998)		25.0

REFERENCE TECHNOLOGIES: Internal combustion engine.

DATA SOURCES: D_i and f_i (for 1975): Reference 10. e_i : Estimated at 20% for 1975.

BASIS OF PROJECTIONS: Fuel efficiency of new model cars reduced by 10% from that mandated by the Energy Policy and Conservation Act (Ref. 20). Fleet economy derived from age distribution of vehicles (Ref. 19), vehicle-miles per model year, and fuel economy per model year. Vehicle-miles per year assumed to remain at the 1975 level of 10,800 miles/vehicle (FHWA estimate corrected for re-registered and scrapped vehicles). The ratio of vehicles to driving age population is projected to increase in proportion to growth in the U.S. fleet, from .61 in 1975 to .85 in 2000.

PROJECTED FUEL MIX
Region: TENNESSEE VALLEY AUTHORITY

Sector: Transportation
Category: Truck & Bus

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline	.77	.20	144.39	.69	.21	159.68	.56	.22	159.28	.31	.27	138.42
Diesel	.23	.20	43.13	.31	.21	71.74	.44	.22	125.14	.69	.27	308.11
Residual oil												
Coal												
Other												
ELECTRICITY												
TOTAL FUEL DEMAND, D, 10 ¹² Btu			187.52			231.42			284.42			446.53
BASIS, 10 ⁹												
BUS Passenger-Miles			2.6			3.2			3.5			5.3
FREIGHT TRUCKING												
Ton-Miles (GVW over 10,000 lbs.)			16			20			25			45
NON-FREIGHT TRUCKING												
Truck-Miles			9			12			16			31
BASIC ENERGY DEMAND, E, 10 ¹² Btu			37.50			48.60			62.57			120.56
ENERGY INTENSIVENESS												
BUS Btu/Passenger-Mile			1580			1577			1569			1547
FREIGHT TRUCKING												
Btu/Ton-Mile			4678			4444			4210			3909
NON-FREIGHT TRUCKING												
Btu/Truck-Mile (mpg)			12,061 (10.4)			11,458 (10.9)			10,855 (11.5)			9046 (13.8)

REFERENCE TECHNOLOGIES: Internal combustion engine.

DATA SOURCES: D_i and f_i (for 1975): Number of trucks per state from FHWA (Ref. 10); number of trucks per state within TVA region proportional to TVA population per state. Miles per truck held at 1972 levels. Ton-miles per truck and percent of gasoline versus diesel trucks derived from FEA data (Ref. 39). Percent of trucks by weight class extrapolated from 1967 and 1972 Census of Transportation data (Ref. 44). Bus passenger-miles proportional to population.

e_i : Miles per gallon for non-freight trucking, BNL estimate. Btu/ton-mile from Ref. 39.

BASIS OF PROJECTIONS: Freight trucking ton-miles escalated at the same rate as GNP, 3.2%, adjusted by total regional earnings. Non-freight trucking truck-miles escalated at 6.1% from 1975 to 1980; 5.3% from 1980 to 1985, and 4.6% from 1985 to 2000. These regional growth rates were derived from national projections (Ref. 39) adjusted by total regional earnings. The energy intensiveness of freight trucking, Btu/ton-mile, and non-freight trucking, Btu/truck-mile, are reduced by 25% over the reference years.

PROJECTED FUEL MIX

Sector: Transportation

Region: TENNESSEE VALLEY AUTHORITY

Category: Railroads

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline												
Distillate oil	1.00	.30	18.36	1.00	.30	21.27	1.00	.30	24.18	1.00	.30	34.03
Residual oil												
Coal												
Other												
ELECTRICITY												
TOTAL FUEL DEMAND, D_i , 10^{12} Btu			18.36			21.27			24.18			34.03
BASIS, 10^9 ton-miles			25.9			30.0			34.1			48.0
SATURATION, S_i												
BASIC ENERGY DEMAND, E_i , 10^{12} Btu			5.51			6.38			7.25			10.21
ENERGY INTENSIVENESS, Btu/ton-mile			709			709			709			709

REFERENCE TECHNOLOGIES: Diesel engine.

DATA SOURCES: D_i (for 1975): Diesel fuel consumption derived from Bureau of Mines data (Ref. 11).
 e_i : Estimated at 30%.

BASIS OF PROJECTIONS: Diesel fuel escalated at the U.S. growth rate (2%) adjusted by the ratio of TVA to U.S. total earnings in the projected year divided by the TVA to U.S. total earnings in 1970 (Reference 17 and BNL estimates).

PROJECTED FUEL MIX

Sector: Transportation

Region: TENNESSEE VALLEY AUTHORITY

Category: Air

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel	0.98	0.30	18.74	0.99	0.33	26.62	0.99	0.35	34.63	1.00	0.35	79.51
Gasoline	0.02	0.30	0.40	0.01	0.33	0.30	0.01	0.35	0.30			
Distillate oil												
Residual oil												
Coal												
Other												
ELECTRICITY												
TOTAL FUEL DEMAND, D, 10 ¹² Btu			19.14			26.92			34.93			79.51
BASIS 10 ⁹ , Passenger- miles			2.2			3.4			4.7			10.7
SATURATION, S,												
BASIC ENERGY DEMAND, E, 10 ¹² Btu			5.74			8.88			12.23			27.83
ENERGY INTENSIVENESS, Btu/passenger-mile			8698			7910			7431			7431

REFERENCE TECHNOLOGIES: Aircraft gas turbines (Turbofan).

DATA SOURCES: D_i (for 1975): Jet fuel consumption in Tennessee determined from Bureau of Mines data. Aviation gasoline consumption in Tennessee from Ref. (10). Jet fuel and aviation gasoline consumption in TVA region (excluding Tennessee) determined from a survey of commercial airports.

e_i : Estimated efficiencies for aircraft gas turbines.

f_i : Apparent fraction based on 1975 data.

BASIS OF PROJECTIONS: U.S. domestic and international passenger-miles from ATAA (Ref. 34 and 35) adjusted to include general aviation. TVA air passenger-miles proportional to U.S. air passenger-mile projections, adjusted upward by the ratio of TVA to U.S. total earnings projections (Ref. 17) normalized to 1970.

PROJECTED FUEL MIX

Sector: Transportation

Region: TENNESSEE VALLEY AUTHORITY

Category: Ships

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Methane												
Jet Fuel												
Gasoline	.18	.20	3.23	.20	.20	4.04	.21	.20	5.06	.23	.20	7.88
Distillate oil	.82	.20	14.34	.80	.20	16.62	.79	.20	18.88	.77	.20	26.59
Residual oil												
Coal												
Other												
ELECTRICITY												
TOTAL FUEL DEMAND, D, 10 ¹² Btu			17.57			20.66			23.94			34.47
BASIS, 10 ⁹ Ton-Miles			25.3			29.3			33.3			46.9
SATURATION, S,												
BASIC ENERGY DEMAND, E, 10 ¹² Btu			3.51			4.13			4.79			6.89
ENERGY INTENSIVENESS Btu/Ton-Mile			567			567			567			567

REFERENCE TECHNOLOGIES: Steam and internal combustion engines.

DATA SOURCES: D_i (for 1975): Fuel oil consumption derived from Bureau of Mines data (Ref. 11).
Gasoline consumption from FHWA data (Ref. 10). e_i : Estimated at 20%. f_i : Apparent fraction based on 1975 data.

BASIS OF PROJECTIONS: Gasoline escalated at 4.6% through 1985 based on historical data and reduced to 3% thereafter. Fuel oil escalated at the U.S. growth rate (2%) adjusted by the ratio of TVA to U.S. total earnings in the projected year divided by the TVA to U.S. total earnings in 1970 (Ref. 17 and 23).

PROJECTED FUEL MIX

Sector: Electric Utility

Region: TENNESSEE VALLEY AUTHORITY

	1975			1980			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE												
Oil-Fired Gas Turbine	.01	.264	7.12	.01	.27	30.25	.01	.28	14.56	.01	.30	21.00
Coal Steam	.72	.345	797.33	.59	.35	923.20	.34	.35	647.74	.36	.35	1080.66
Hydroelectric	.20	.345	227.03	.11	.35	178.21	.09	.35	178.21	.06	.35	178.21
Nuclear Steam	.07	.323	78.49	.29	.33	485.67	.56	.33	1115.79	.57	.34	1770.24
TOTAL FUEL DEMAND, D, 10 ¹² Btu			1109.97			1617.33			1956.30			3050.11
Interdivisional			2.08			2.08			2.08			2.08
Σ Electric from Other Demand Categories			354.20			517.18			618.31			977.41
BASIS, Total Demand			356.28			519.26			620.39			979.49
GENERATION = $\frac{\text{DEMAND}}{\text{TRANS. \& Distr. Losses}}$		356.28/.936			519.26/.94			620.39/.94			979.49/.94	
PUMPED STORAGE LOSSES						1.53			1.38			6.77
BASIC ENERGY DEMAND, E, 10 ¹² Btu			380.64			553.93			661.37			1048.78

REFERENCE TECHNOLOGIES: Coal is consumed in steam electric plants with no topping cycle. Oil is consumed in gas turbine peaking units. Nuclear fuel is consumed in light water reactors.

DATA SOURCES: D_i for (1975) The basic energy demand for electricity is obtained from the summation of electrical demands in all other demand categories adjusted to include transmission, distribution, and pumped storage losses. Total demand include purchases and sales to other utilities and interchange power deliveries and receipts.

f_i : Oil-fired gas turbine held in proportion to data as reported by TVA. Hydro and nuclear steam as reported by TVA. Coal-steam meets remainder of load in 1975.

e_i : Coal steam-electric, oil fired gas-turbine and nuclear steam plants converted at an average heat rate of 9880 Btu/KWh, 12950 Btu/KWh and 10570 Btu/KWh, respectively; as reported by TVA in the 1976 Power Annual Report. Hydroelectric output is converted to theoretical energy inputs based on the equivalent coal-steam electric heat rate.

BASIS OF PROJECTIONS: The basic energy demand for electricity is obtained from the summation of electric demands in all other demand categories adjusted to include transmission, distribution, and pumped storage losses. The fraction of the basic energy demand satisfied by gas turbine units is held in proportion to data projected by TVA. Hydro and pumped storage as projected by TVA. In 1980, LWR as projected by TVA; coal-steam meets remainder of projected load. In 1985, nuclear capacity reduced from TVA projections by 1250 MW; coal-steam meets remainder of projected load. In 2000, nuclear capacity reduced from TVA projections by 5000 MW; coal-steam meets remainder of projected load.