Energy Vision

2020

Volume 2, Technical Document

5

Load Forecast

Volume 2, Technical Document 5

Load Forecast

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This technical document has two major sections that were originally separate information items. These were the basis for various discussions on load forecast that TVA used to develop Energy Vision 2020.

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Load Forecast

ENERGY VISION 2020 LOAD FORECAST SUMMARY – 1994

Introduction

Like many utilities, TVA forecasts the long-term energy and peak demand outlook 20 to 25 years into the future. The long-term forecast is developed from individual forecasts of residential, commercial, and industrial sales. These forecasts serve as the basis for planning the TVA power system, budgeting, and financial planning. The Energy Vision 2020 forecast is based on five elements necessary for state-of-the-art forecasting:

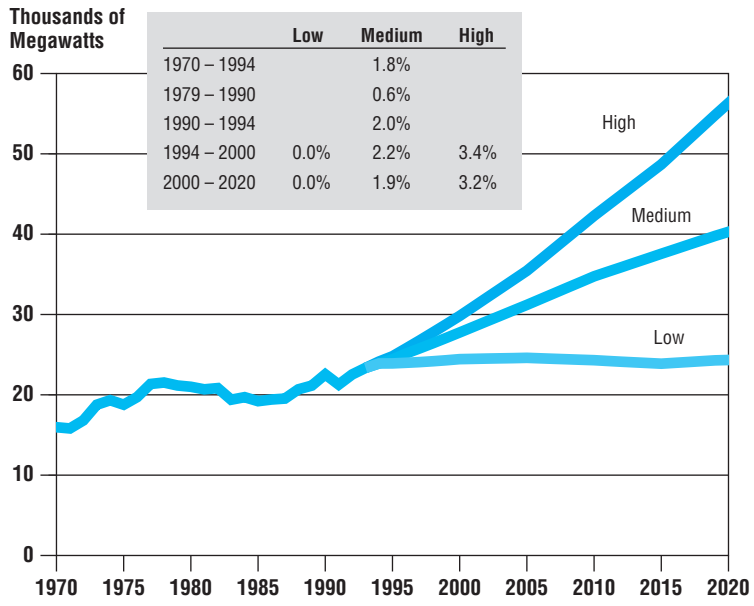
- Accuracy
- Use of best information
- Use of best methods
- Explicit treatment of uncertainty
- Continuous improvement

Summary of Results

The range of long-term peak load forecasts developed for Energy Vision 2020 is shown in *Figure T5-1*. For the medium forecast, peak loads are expected to increase 2.2 percent per year from 1994 to 2000 and 1.9 percent per year from 2000 to 2020. Recognizing the uncertainty in forecasting, TVA's high load forecast annual growth is approximately 3.3 percent from 1994 to 2020, and the low forecast is less than 1 percent from 1994 to 2020.

TVA's system energy forecast is the sum of forecasts by sector. *Figure T5-2* shows the breakdown of the medium forecast into the residential, commercial, and manufacturing sectors. Total energy requirements in 1994 were 35 percent residential, 25 percent commercial, 30 percent manufacturing, and 10 percent other sales and system losses. The commercial and manufacturing sectors are expected to increase faster than residential from 1994 to 2000. From 2000 to 2020, the directly served portion of the manufacturing sector is expected to grow less than the other sectors.

FIGURE T5-1. **System Peak Forecast**



	Low	Medium	High
1970 – 1994		1.8%	
1979 – 1990		0.6%	
1990 – 1994		2.0%	
1994 – 2000	0.0%	2.2%	3.4%
2000 – 2020	0.0%	1.9%	3.2%

Actual and projected growth of system peak needs are shown. High, medium, and low forecasts were developed to address uncertainties in the future. Under the medium forecast, peak demand is projected to be approximately 40,000 megawatts by 2020.

Historical Perspective—Forecast Accuracy

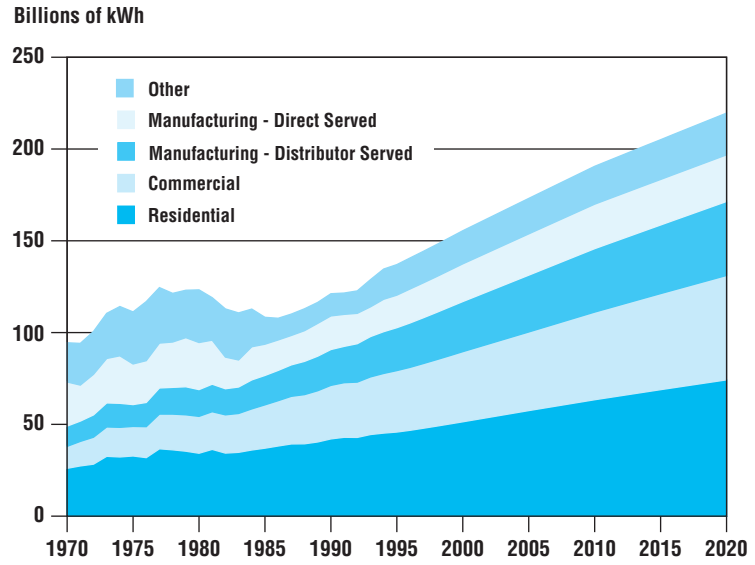
Forecasting is inherently uncertain. However, TVA's load forecast accuracy since 1985 has been within 5 percent (plus or minus) of actual loads, as shown in *Figure T5-3*. This is well within the industry standard of plus or minus 8 percent accuracy. A 1991 review of TVA forecasts by Barakat & Chamberlin, Inc. concluded that: "…on a comparative basis, TVA's forecasting procedures compare very favorably with the best-practice procedures in the United States utility industry."

FORECASTING IN THE 1970S

TVA's load forecasting has changed dramatically over the last 20 years. Until the late 1970s, forecasting at TVA consisted of examining the historical trend of energy sales and projecting future sales based on past growth. These early forecasts were based on a generally stable picture. Underlying factors such as the price of electricity and the economic situation were not considered, causing the forecasts of the 1970s to be very optimistic. TVA's 1970 and 1975 forecasts, shown in *Figure T5-4*, illustrate the error rate for these forecasts.

During and after the oil embargoes of the 1970s, the world economy experienced a long recession and steadily rising energy prices. These changes caused TVA to look to new forecasting techniques that recognized fundamental changes that were taking place in energy costs and patterns of energy use. The old methods were producing large inaccuracies and simply no longer worked.

FIGURE T5-2. **Sales by Customer Class**



ANNUAL INCREASE IN SALES %

	Residential	Commercial	Manufacturing Distributor Served	Manufacturing Direct Served	Other
1970 – 94	2.4%	4.3%	3.2%	-1.5%	-1.7%
1979 – 90	1.6%	3.6%	2.2%	-3.4%	-6.7%
1990 – 94	2.4%	3.0%	4.3%	-2.3%	4.6%
1994 – 00	1.7%	2.5%	2.8%	3.5%	4.0%
2000 – 20	1.9%	2.0%	2.0%	1.1%	1.2%

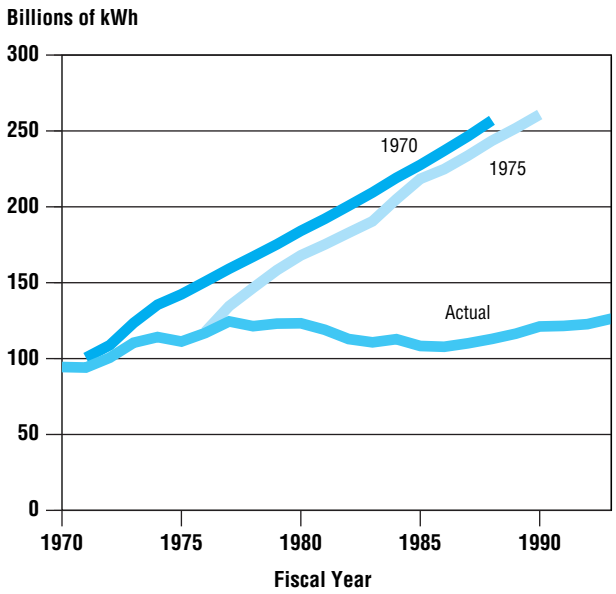
Electricity sales are shown for the customer classes of residential, commercial, and manufacturing. Electricity sales for the manufacturing customer class are divided into sales to industrial customers served by distributors and sales to industries served directly by TVA. The "other" category includes outdoor lighting sales and power sales to other federal agencies.

FIGURE T5-3. **TVA Five-Year Forecast Record**

Year Forecast Prepared	Forecast Target Year	Peak (MW)	Forecast Actual (MW)	Error (Percent)
1983	1988	22,610	20,684	9.3
1984	1989	22,546	21,149	6.6
1985	1990	21,669	21,142	2.5
1986	1991	22,348	21,810	2.5
1987	1992	21,493	22,533	-4.6
1988	1993	23,119	23,354	-1.0
Average Absolute Error				4.4

Since 1985, TVA's load forecast for five years ahead has been within 5 percent (plus or minus) of actual loads.

FIGURE T5-4. **Comparison of Historic Forecasts 1970s – System Energy**



Forecasting techniques used in the 1970s proved to be too optimistic. Earlier forecasts did not explicitly consider uncertainty in prices and economic variables.

FORECASTING IN THE 1980S AND 1990S

New approaches adopted by TVA in the late 1970s included using better quality data in the forecasts, using econometric and end-use models, and making special provisions to deal with uncertainty.

TVA's econometric models link electricity sales to several key factors in the market, such as the price of electricity, the price of natural gas, and growth in economic activity. These models are used to forecast sales growth in the residential and commercial sectors and in each industrial sector.

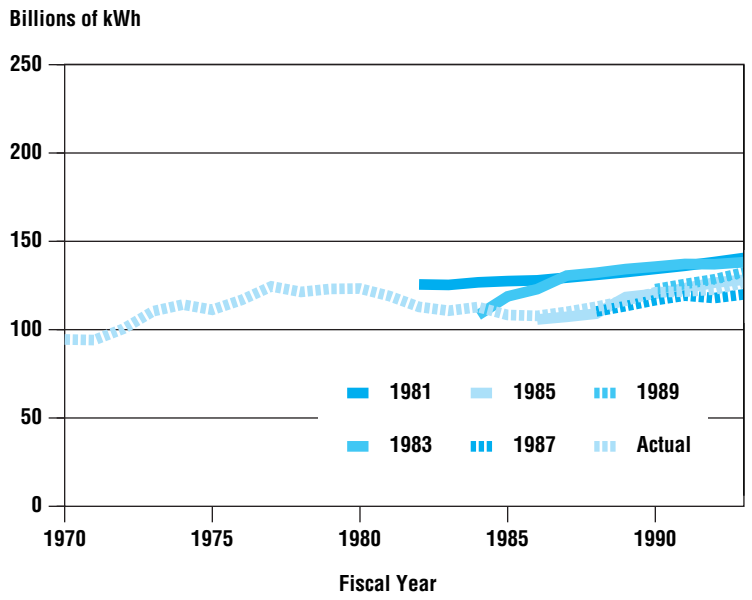
Underlying trends within each sector, such as the use of various types of equipment or processes, also play a major role in forecasting sales. To capture these trends, TVA uses a variety of state-of-the-art end-use forecasting models. For example, in the residential sector, sales are forecast for space heating, air conditioning, water heating, and several other uses. In the commercial sector, a number of end-use categories including lighting, cooling, refrigeration, and space heating are examined.

End-use and econometric models have vastly increased the amount of data used in TVA forecasting. TVA uses a cutting-edge Regional Economic Simulation Model (RESM) to forecast regional economic activity. The regional economic forecasts are based on national economic forecasts provided by DRI/McGraw-Hill.

Forecasts of the price of electricity are provided from TVA's financial modeling. In addition, during the 1980s, TVA began conducting numerous surveys of its residential and business customers. This continuing survey effort provides valuable information on TVA customer market shares, the kinds of electric equipment used, and equipment efficiency. Finally, the inaccurate forecasts of the 1970s demonstrated to utility planners that there is much uncertainty in even the best forecast. In the 1980s, TVA began to deal with this uncertainty by using high and low forecasts to bracket the medium forecast.

Figure T5-5 shows the improved accuracy of TVA forecasts developed in the 1980s. While the 1981 and 1983 forecasts had errors relating to large declines in Department of Energy (DOE) contracts, they are still more accurate than their predecessors. Since 1985—when most of the improvements were fully implemented—every load forecast has been within plus or minus 5 percent accuracy.

FIGURE T5-5. **Comparison of Historic Forecasts 1980s – System Energy**



Forecasting techniques were improved in the 1980s, resulting in a more accurate forecast. Since 1985, TVA's load forecast has been within plus or minus 5 percent accuracy.

Key Variables Affecting the Forecast

Four key variables are used in the load forecasts and in each of the residential, commercial, and industrial sectors.

- Economic activity
- Price of electricity
- TVA's level of competitive success
- Price of substitute fuels

The impact of these variables on the use of electricity is not measured by a single value. Instead, a range of values is developed from which a range of load forecasts is derived. The uncertainties section of this technical document discusses how the range of load forecasts is developed. The key variables are discussed in greater detail below.

ECONOMIC ACTIVITY

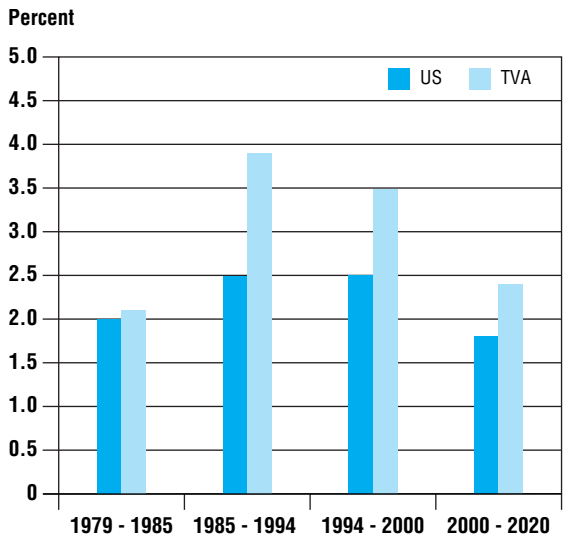
TVA produces its own forecasts of regional economic activity using a Regional Economic Simulation Model (RESM), an econometric model of the TVA region's economy. TVA's forecasts are based on forecasts of the national economy by DRI/McGraw-Hill, an internationally recognized forecasting service. However, RESM does not blindly attribute national trends to the TVA region. Instead, it recognizes differences inherent in the region's economic structure that cause it to perform differently than the United States.

The most likely outlook is for the region to continue to outperform the nation *(Figure T5-6)*. Gross Regional Product (GRP) is forecast to grow 3.5 percent annually from 1994 to 2000 and 2.4 percent from 2000 to 2020, while national Gross Domestic Product (GDP) is expected to grow at 2.5 and 1.8 percent for the respective periods. This compares favorably with the historical performance of GRP and GDP shown in *Figure T5-6*.

The region's economy is expected to grow faster than the rest of the nation's, largely due to the region's advantages in manufacturing. In 1994, about 29 percent of total product in the region was in manufacturing, as opposed to 19 percent for the United States. Manufacturing's predominance in the regional economy is due to several factors:

- A location in the South between the markets of the Northeast, Midwest, Southwest, and Florida
- A good transportation system allowing goods to be shipped to these markets by interstate, rail, and barge
- A good, low wage (for the United States) workforce
- Relatively low-cost, abundant resources including water, electricity, and land

FIGURE T5-6. **Gross Product Comparison – TVA vs. U.S. Average Annual Growth Rates**



This figure shows the most likely outlook is for the Tennessee Valley to continue to outperform the nation. This is largely due to the region's advantages in manufacturing. Manufacturing output in the Tennessee Valley is expected to surpass national average growth rates, continuing the trend since 1985.

Because of these advantages, the regional economic model forecasts manufacturing in the region to outperform manufacturing in the United States, continuing the trend since 1985. Before 1985, manufacturing was adversely affected by exceptionally high oil and energy prices, high interest rates, and the high value of the dollar compared to other currencies. These factors have returned to relatively low levels and are expected to remain relatively low in the future. Given the region's dependence on manufacturing, this sets up favorable conditions for the region's economic growth.

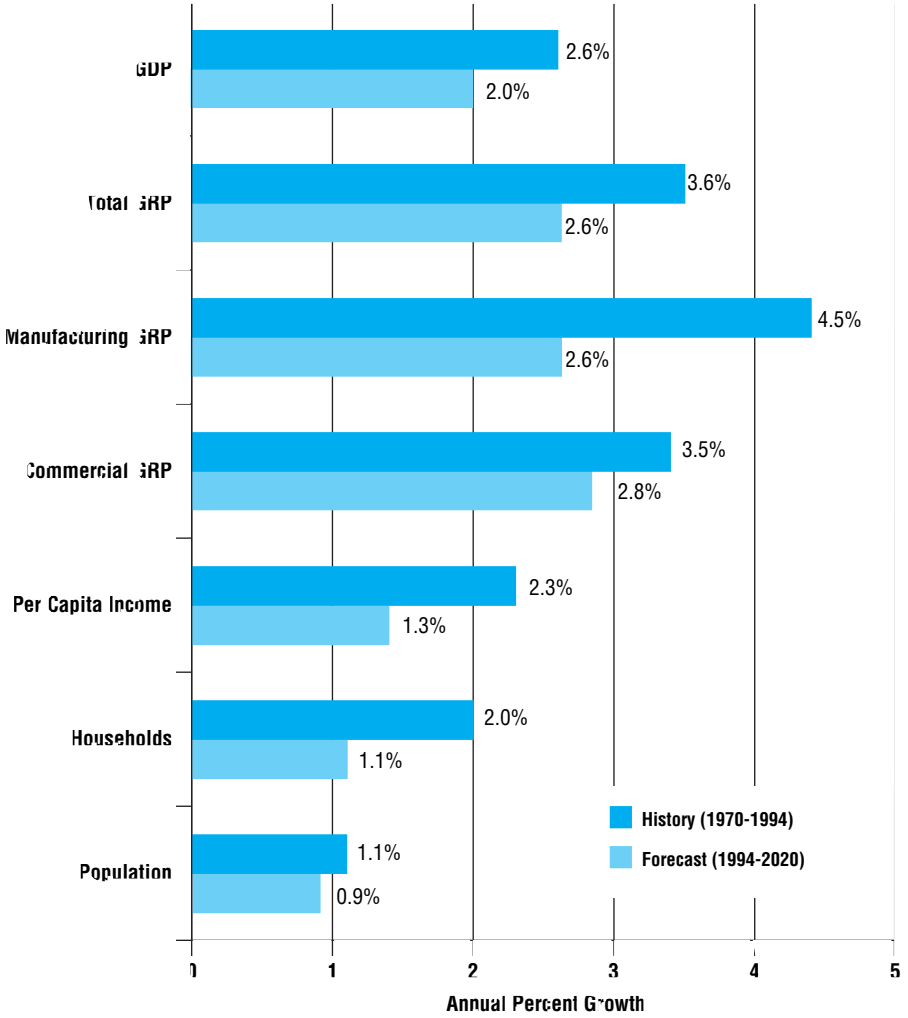
Within the manufacturing sector of the regional economy, several industries are showing favorable growth trends. Durable goods production has expanded while, at the same time, nondurables have held up better than in the rest of the United States. Although there are several examples of newer durable industries growing in the TVA region, such as machinery and furniture, the prime example is motor vehicles. Employment in the motor vehicle industry has grown much faster in the region than the nation, with considerable potential for continuing expansion.

Over the rest of the decade, the region's performance is expected to be similar to that of the 1985-1994 period as newer manufacturing industries continue to expand and national economic conditions remain favorable. Beyond the year 2000, manufacturing is expected to continue to provide enough impetus for the region to expand at a somewhat faster rate than the United States, but the region's growth is expected to be slower than before 2000 as the region's newer manufacturing industries reach maturity. The region does not have particular advantages in the commercial sector as it does for manufacturing. Thus, with the slowing of manufacturing growth, the overall regional economy is expected to grow at a rate closer to the nation's economic growth.

From the economic forecast, several variables are used as drivers to the load forecasts. For the residential sector, population, households, and per capita income drive the load forecast in the Valley. For the commercial and industrial sector, output or Gross Regional Product are key drivers. The historical and predicted growth rates for the medium forecast of the economic variables are shown in *Figure T5-7*.

To account for uncertainty, high and low regional economic forecasts are derived by using corresponding national forecasts and the TVA low and high electricity price forecasts. In addition,

FIGURE T5-7. **Economic Outlook – History and Forecast**



Economic forecasts for the TVA region are developed as part of the load forecast process. Historical and predicted growth rates for economic variables are shown for the medium regional economic forecast. Economic growth is expected to slow from the 1970-1994 rates.

explicit assumptions are made concerning national and international developments. The high scenario assumes that the region will develop a commercial sector that more closely matches that of the nation. On the other hand, the low scenario assumes that the Valley is more affected by foreign competition and that the commercial sector does not develop further.

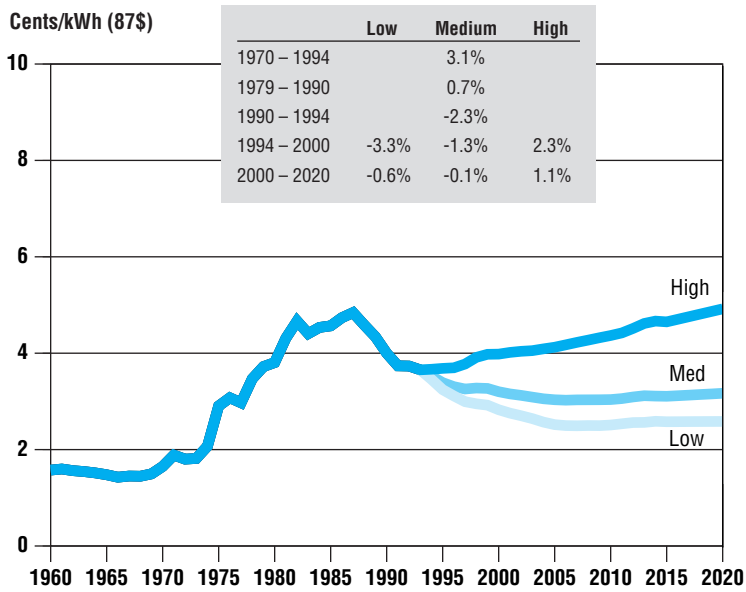
Additional information on the economic forecasts is available from TVA in a report titled "Economic Outlook."

PRICE OF ELECTRICITY

TVA has not increased electricity prices since 1987 and is committed to no rate increases through 1997. This has been achieved through a combination of efforts including controlling costs, refinancing debt, and efficiency improvements. Holding rates constant is expected to continue to have a positive impact on electricity sales.

The real wholesale price of electricity (excluding inflation) is expected to decline 1.3 percent per year from 1994 to 2000 and decline further at 0.1 percent per year from 2000 to 2020 as shown in the medium forecast in *Figure T5-8*. For the low

FIGURE T5-8. **Wholesale Price of Electricity**



	Low	Medium	High
1970 – 1994		3.1%	
1979 – 1990		0.7%	
1990 – 1994		-2.3%	
1994 – 2000	-3.3%	-1.3%	2.3%
2000 – 2020	-0.6%	-0.1%	1.1%

The wholesale price of electricity without inflation is expected to decline through 2020 under the low and medium forecasts.

forecast, the price of electricity will decrease by 3.3 percent per year from 1994 to 2000 and 0.6 percent per year from 2000 to 2020. For the high forecast, the price of electricity will grow at 2.3 percent per year from 1994 to 2000 and 1.1 percent per year from 2000 to 2020.

Forecasts of the price of electricity are based on estimates of the total revenue required to operate and maintain the power system. Forecasts of total revenue requirements are based on estimates of key costs such as fuel, operations and maintenance, depreciation, and interest costs. Therefore, the high and low electric price forecasts are derived from variations in the same factors: fuel, operations and maintenance, depreciation, and interest costs.

TVA'S LEVEL OF COMPETITIVE SUCCESS

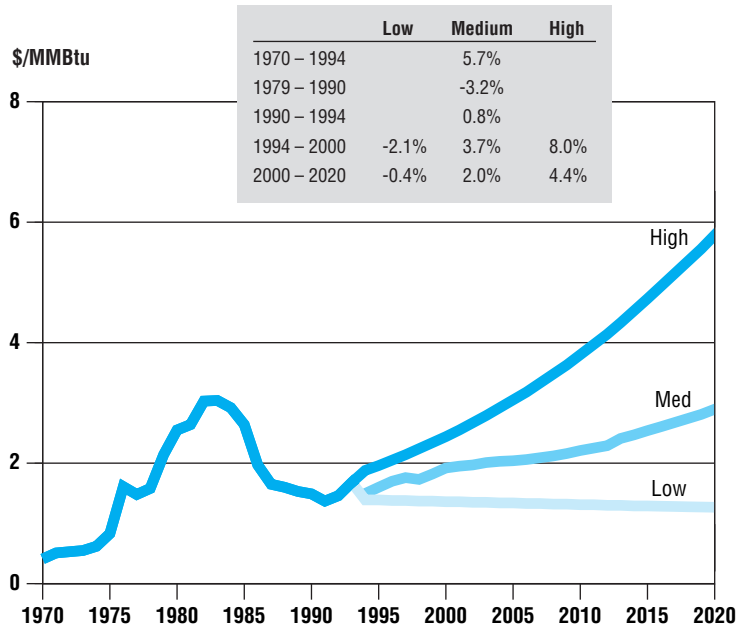
In recent years, the electric utility industry has undergone a fundamental change. The world of regulated monopoly is being replaced by a world of competitive pressures. Wholesale open access (the right of wholesale customers to buy power from generating utilities other than the one whose lines serve them) can be mandated by the Federal Energy Regulatory Commission (FERC). Retail firms, such as large industrial customers, are looking for the same privilege, and retail open access is beginning to be mandated by some state regulatory bodies. In a more competitive market, TVA's success as a generating company will be greatly affected by whether TVA is successful in being a low-cost producer.

TVA has incorporated different competitive scenarios into its forecasts. In the medium forecast, TVA's price of electricity is expected to remain competitive with other utilities. Market and regulatory changes would have less impact in the medium case than in the high or low cases. As a result, the net impact of competition in the medium forecast is that TVA will retain its current customers.

The prospect of increasingly competitive markets increases the uncertainty in the forecast. If TVA operates at lower costs than the competition and regulations permit, TVA may have opportunities to gain customers. This is termed high competitive success. Likewise, if TVA is a higher cost producer than its competitors, it is likely to lose customers—described as low competitive success. Both cases assume that deregulation of the electric market continues. The high and low forecasts recognize the risks and opportunities of increased competition.

TVA analyzed competitive impacts for all sales. The effort was aimed at looking at the market rather than specific customers. In the low competitive success case, TVA will lose customers to competing electric utilities. In order to estimate the potential for losing sales to competition, TVA's customer survey—complet-

FIGURE T5-9. **Natural Gas Acquisition Price**



	Low	Medium	High
1970 – 1994		5.7%	
1979 – 1990		-3.2%	
1990 – 1994		0.8%	
1994 – 2000	-2.1%	3.7%	8.0%
2000 – 2020	-0.4%	2.0%	4.4%

Natural gas prices without inflation are expected to increase 3.7 percent annually through 2000 and 2 percent per year from 2000 to 2020 under the medium forecast.

ed by many of TVA's distributors and directly served customers—was used to identify the amount of load that appeared to be at high risk.

In the high competitive success case, TVA will gain customers from its competition. To estimate the potential for this gain in the wholesale markets, loads of municipal and cooperative distributors in neighboring regions were used. The chance of gaining any distributor was partly influenced by the wholesale price paid by that distributor. Because a very large percentage of TVA's sales are wholesale compared to neighboring utilities, the potential gain in the wholesale market in the high competitive success case was smaller than the potential loss in the low competitive success case.

For directly served customers, less specific information on nearby opportunities was available. Because TVA is surrounded by states with large industrial loads, a judgment was made that potential gain is higher than potential loss of industrial loads.

Wholesale and retail gains in load were assigned the highest probability for the low electric price forecast, making TVA more competitive. A more complete discussion of all uncertainties in the forecast can be found in the uncertainty section.

PRICE OF SUBSTITUTE FUELS

The potential for substitution between electricity and fossil fuels, primarily oil and natural gas, will depend on relative prices and technological factors. Changes in the TVA price of electricity compared to the price of natural gas and other fuels will influence consumers' choices of appliances—either electric, gas, or other fuels. While other substitutions are possible, natural gas prices are the benchmark for determining substitution impacts in the load forecasts.

In preparing the medium natural gas price forecast, TVA relied on forecasts by Energy Ventures Analysis, Inc., Jofree Corporation, and ICF Resources. The forecast for natural gas prices is higher than for electricity. Natural gas prices in real terms are forecast to increase at 3.7 percent from 1994 to 2000 and at 2.0 percent from 2000 to 2020 as shown in *Figure T5-9*.

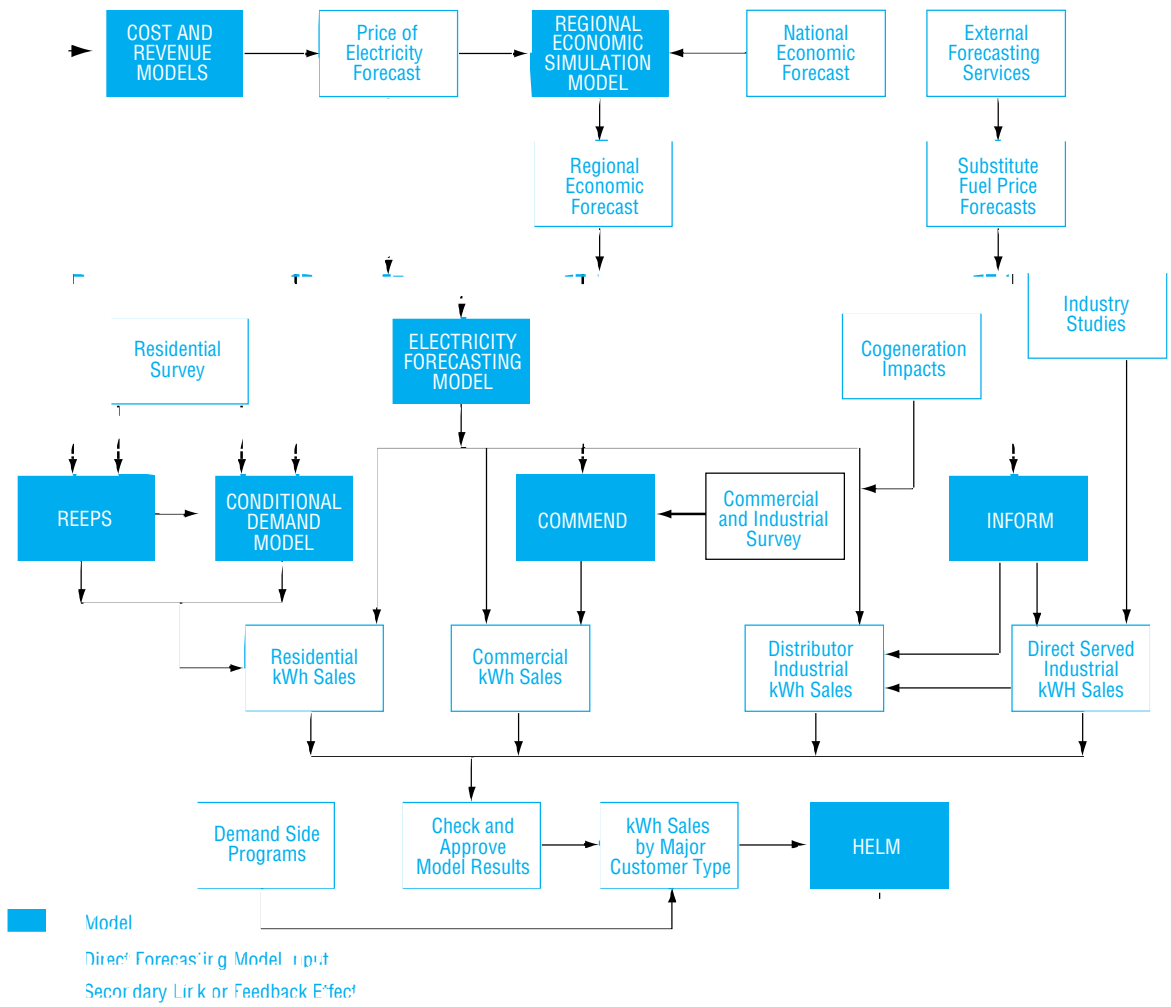
The high and low forecasts for gas prices were derived using several nationally recognized forecasters such as Gas Research Institute, American Gas Association, DRI/McGraw-Hill, and the Energy Information Administration. The high forecast is for growth rates of 8.0 percent per year from 1994 to 2000 and 4.4 percent per year from 2000 to 2020. The low is for -2.1 percent per year and -0.4 percent per year over the same periods.

TVA Uses the Best Methods Available

TVA stays abreast of issues and procedures relating to energy forecasting and continually incorporates new information into its forecasting process. The use of multiple forecasting models makes it possible to avoid blind spots that could result with a single model. At TVA, several advanced forecasting models and techniques have been incorporated to form a complete forecasting system from data collection to evaluation of forecast uncertainties. To deal with uncertainty, the forecast does not rely on a single estimate, but provides decision-makers with a range of forecasts. An overview of the TVA forecasting process is shown in *Figure T5-10*.

The system forecast is built up from its major sectors: residential, commercial, and industrial. The outputs of several models for each sector are systematically compared, and trends

FIGURE T5-10. **Overview of TVA's Load Forecasting Process**



The load forecasting process is illustrated by this flow chart which shows how information is gathered and evaluated to form the basis of the forecast. Multiple models or computer simulations are used to ensure that all possibilities and impacts are considered.

in key parameters, such as saturation rates and unit energy consumption, are examined.

Large customers that have significant electricity requirements are analyzed individually. In addition, each major industry group, such as paper or machinery, is reviewed annually for changes in technology, finances, competitive structure, etc. Ranges of values for key variables are developed in order to measure the varying impacts on TVA sales.

Econometric modeling is used extensively. The strengths of this approach include the explicit estimation of the historical response of electricity consumption to electricity prices, natural gas prices, and income. Each of TVA's primary customer sectors is considered individually in the models to allow for changing shares of energy use.

End-use models are used to measure how much energy consumption will occur from given end uses such as residential air conditioners, office lighting, and industrial motors. These models can reflect how energy use is changing within sectors. While econometric models are tied to historical data, end-use models allow forecasters to incorporate expected future events

such as the introduction of mandated efficiency standards or the arrival of new technologies.

Conditional demand and qualitative choice analysis is a hybrid of econometric and end-use modeling. TVA uses this analysis in the residential sector and is developing a commercial conditional demand model. This analysis is useful in estimating the relationship between electricity consumption and demographic characteristics. These models incorporate the best of econometric and end-use models and allow for a more detailed analysis of each sector.

Best methods available include the following models, which are used in the Energy Vision 2020 forecast:

- Residential Conditional Demand Model (RCDM)
- Residential Energy End-Use Planning System (REEPS)
- Electricity Forecasting Model (EFM)
- Commercial Energy End-Use Model (COMMEND)
- Industrial Energy End-Use Model (INFORM)
- Regional Economic Simulation Model (RESM)
- Financial Model used in price of electricity (FINESSE)
- Hourly Electric Load Model (HELM)

RESIDENTIAL SECTOR FORECASTING MODELS

Residential Conditional Demand Model (RCDM)

This model is based on econometric analysis of data from TVA's residential surveys, which is used to estimate unit energy consumption of major appliances, along with price and income elasticities. This allows individual components of the residential model to be forecast. The estimates of unit energy consumption are used in conjunction with saturation forecasts by appliance types to produce forecasts of total residential sector electricity use. The estimates of unit energy consumption are also used in calibrating Residential Energy End-Use Planning System (REEPS), using TVA service territory data.

Residential Energy End-Use Planning System (REEPS)

REEPS is an end-use econometric model of electricity consumption developed with the Electric Power Research Institute (EPRI). REEPS forecasts residential energy consumption by end-use, fuel type, and market segment in order to forecast market potential and saturation of residential end uses by fuel type and market segment. This model also analyzes the impacts of mandated or utility-sponsored demand-side management programs. REEPS generates aggregate forecasts for the entire residential sector by calculating a weighted sum of all residential market segments. Thus, TVA can evaluate forecast impacts on each market segment, rather than simply assessing behavior of the "average" household.

Electricity Forecasting Model (EFM)

This is an aggregate time series econometric model. For the residential sector, consumption per customer is the major variable. The independent variables are average real price of electricity, average real price of natural gas, and real annual per capita income. By multiplying sales per customer by the projected number of residential customers, a forecast for the total sector is derived.

COMMERCIAL SECTOR FORECASTING MODELS

Commercial Energy End-Use Model (COMMEND)

COMMEND, widely used by utilities and regulatory agencies, was developed by Electric Power Research Institute. It forecasts energy consumption by building types and end uses. COMMEND allows its user to assess the impacts of energy price changes, technology, efficiencies, and economic growth. It also identifies and evaluates demand-side management opportunities. The model allows up to 20 building types to be addressed, each with a variety of end uses.

Electricity Forecasting Model (EFM)

EFM is an econometric forecasting model for the commercial sector. EFM divides the commercial sector into six subsectors—(1) regulated industries, (2) wholesale/retail trade, (3) finance/insurance and real estate, (4) service, (5) government, and (6) unclassified. Electricity demand is derived for each sector based on Gross Regional Product, employment, the real price of electricity, and the real price of natural gas.

INDUSTRIAL SECTOR FORECASTING MODELS

Industrial Energy End-Use Model (INFORM)

INFORM is an industrial end-use model developed by the Electric Power Research Institute. TVA began using this model in 1992. The model categorizes energy sales by subsector and end use.

Electricity Forecasting Model (EFM)

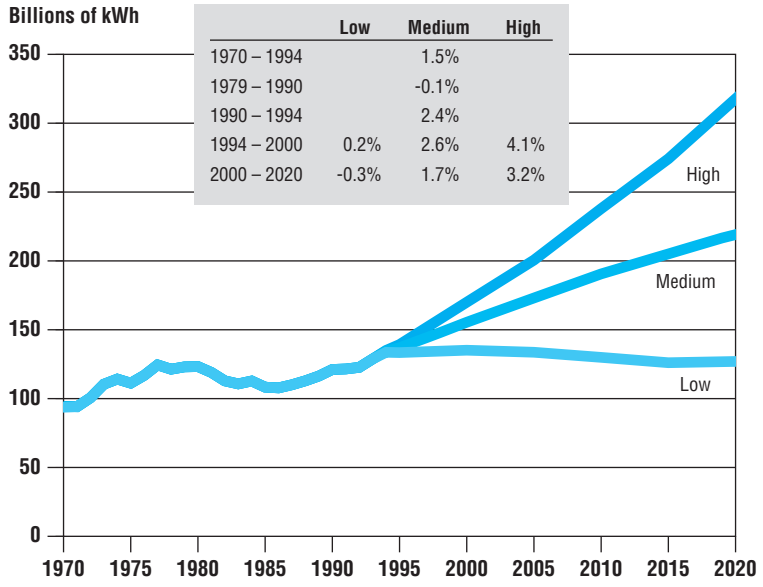
EFM is an econometric forecasting model for the industrial sector. It is divided into subsectors for food, machinery, paper, textiles, chemicals, primary metals, other nondurable goods, and other durable goods. The dependent variable is energy use, and the independent variables are Gross Regional Product, employment, the real price of electricity, and the real price of natural gas.

OTHER FORECASTING MODELS

Regional Economic Simulation Model (RESM)

RESM is an econometric model of the TVA region that maps out the regional economy with its major linkages and feedbacks and its relations to the United States economy. This model uses state-of-the-art methods comparable to those of the major nation-

FIGURE T5-11. **System Energy Requirements**



	Low	Medium	High
1970 – 1994		1.5%	
1979 – 1990		-0.1%	
1990 – 1994		2.4%	
1994 – 2000	0.2%	2.6%	4.1%
2000 – 2020	-0.3%	1.7%	3.2%

Actual and projected growth of electricity needs are shown. High, medium, and low forecasts were developed to reflect future uncertainty. Energy requirements are projected to be 219.7 billion kilowatt-hours by 2020 under the medium forecast.

Financial Model (FINESSE)

This model, developed in-house by TVA, estimates TVA's total revenue requirements over time. The forecast of revenue requirements is based on forecasts of the individual cost components. These cost components include the load forecast, capital costs, additions and improvements (A&I) costs, interest rates, fuel costs, and operating and maintenance (O&M) costs.

Hourly Electric Load Model (HELM)

HELM was developed in partnership with TVA, Electric Power Research Institute, and ICF Resources during the early 1980s. It produces an hourly load or peak load forecast based on forecasts of energy consumption. HELM analyzes the load-shape impacts of many changing conditions, including conservation and load management programs, rate design alternatives, market penetrations of new electricity-using technologies, changes in the mix of customers or end uses, and alternative weather conditions.

al forecasters. Several professional papers have been presented on the model including presentations at the Electric Power Research Institute (EPRI) forecasting conference in 1991.

The two major inputs, or key assumptions, to RESM are the national economic forecast from DRI/McGraw-Hill and industrial electricity prices.

RESM is a highly disaggregated model which uses two-digit standard industrial classification (SIC) detail. With regard to the manufacturing sector, there are equations for chemicals, apparel, primary metals, etc. For the commercial sector there are equations for eating and drinking establishments, health services, hotels, etc. This allows for linkages between industries—for instance, wholesale trade is linked to retail trade.

RESM does not simply capture trends, but rather, it captures the differences inherent in the regional economic structure that leads the region to perform differently than the nation as a whole.

Further details on the forecast methodology and accuracy may be found in "Economic Forecasting Methodology and Validation" included in this document.

Load Forecast Results

The medium forecast for total system energy for Energy Vision 2020 is 155.5 billion kilowatt-hours in 2000 and 219.6 billion kilowatt-hours in 2020, as shown in *Figure T5-11*. The medium load forecast is based on the medium forecasts of all the variables discussed in the previous section. The medium forecast assumes the TVA region will experience moderate economic growth of 2.7 percent annually through 2020. It assumes that TVA can maintain its "no rate increase" policy through 1997 and thereafter maintain competitive rates. It is also assumed TVA is able to successfully defend its current market if a less-regulated and more competitive marketplace develops, as expected. Finally, the medium forecast assumes any inroads made by natural gas are not severe, due to TVA's ability to maintain its price versus the price of natural gas.

The Energy Vision 2020 high load forecast is for 170 billion kilowatt-hours in 2000, 238 billion kilowatt-hours in 2010, and 317.5 billion kilowatt-hours in 2020. The primary factor influencing the high load forecast is high economic growth. Competitive success and continued relatively low electric prices also contribute to TVA's success in the high forecast. The

Energy Vision 2020 low load forecast is for 135.1 billion kilowatt-hours in 2000, 129.9 billion kilowatt-hours in 2010, and 126.3 billion kilowatt-hours in 2020, with growth generally less than 1 percent. Low annual economic growth is a major influence in the low load forecast. The low economic scenario can be summarized as follows: the recovery falters and, in the long term, the United States and the TVA region become less competitive globally, interest rates become unstable, and inflation rises. In short, the TVA region has manufacturing output growth of 0.2 percent and commercial output growth of 1.3 percent through 2020.

RESIDENTIAL SECTOR FORECAST

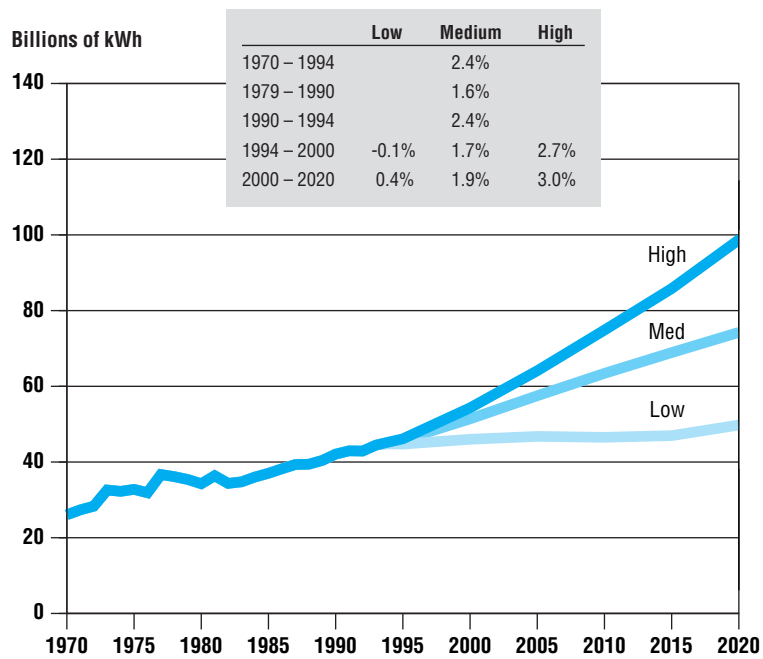
Long-term sales forecasts for the residential customer sector are shown in *Figure T5-12*. In the medium forecast, residential sales are forecast to be 51.4 billion kilowatt-hours in 2000, 63.4 billion kilowatt-hours in 2010, and 74.3 billion kilowatt-hours in 2020. Corresponding growth rates are 1.7 percent per year from 1994 to 2000 and 1.9 percent per year from 2000 to 2020. For the high residential sales forecast, the percent per year growth is 2.7 percent from 1994 to 2000 and 3.0 percent from 2000 to 2020. The low forecast is -0.1 percent from 1994 to 2000 and 0.4 percent from 2000 to 2020.

The residential forecasts are influenced by six factors: per capita income, population, residential electric prices, residential gas prices, household types, and efficiencies, as shown in *Figure T5-13*.

Residential End-Use Energy Forecast

The residential forecast is developed from forecasts of end uses of electricity. Major end uses include space heating, space cooling, water heating, refrigerators, freezers, and cooking. The share of residential electricity sales attributable to each of these end uses and miscellaneous use is shown in *Figure T5-14*. The largest increase in the share of total residential electricity use is for the "other" category, which moves from 31.5 percent to 41.1 percent. The miscellaneous category includes a number of appliances, such as dishwashers,

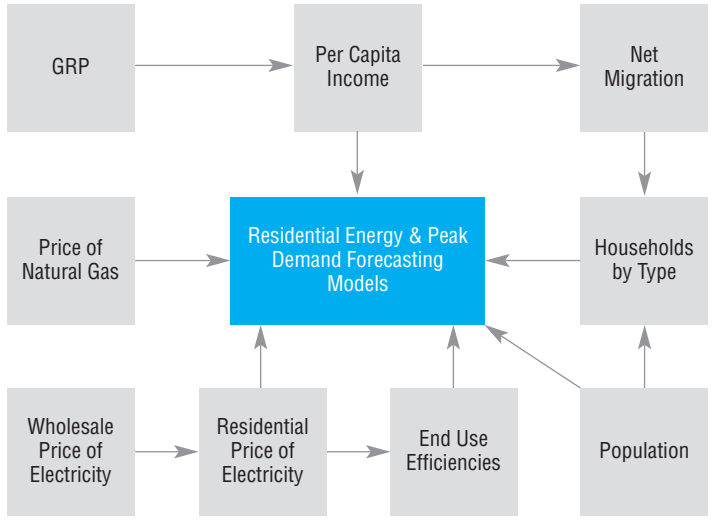
FIGURE T5-12. **Total Residential Sales**



	Low	Medium	High
1970 – 1994		2.4%	
1979 – 1990		1.6%	
1990 – 1994		2.4%	
1994 – 2000	-0.1%	1.7%	2.7%
2000 – 2020	0.4%	1.9%	3.0%

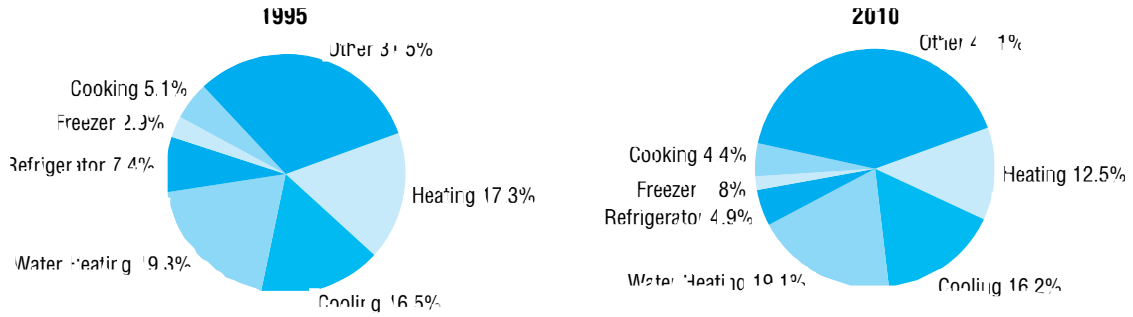
Residential sales are expected to increase to 74.3 billion kilowatt-hours by 2020 under the medium forecast.

FIGURE T5-13. **Residential Sector Influence Diagram**



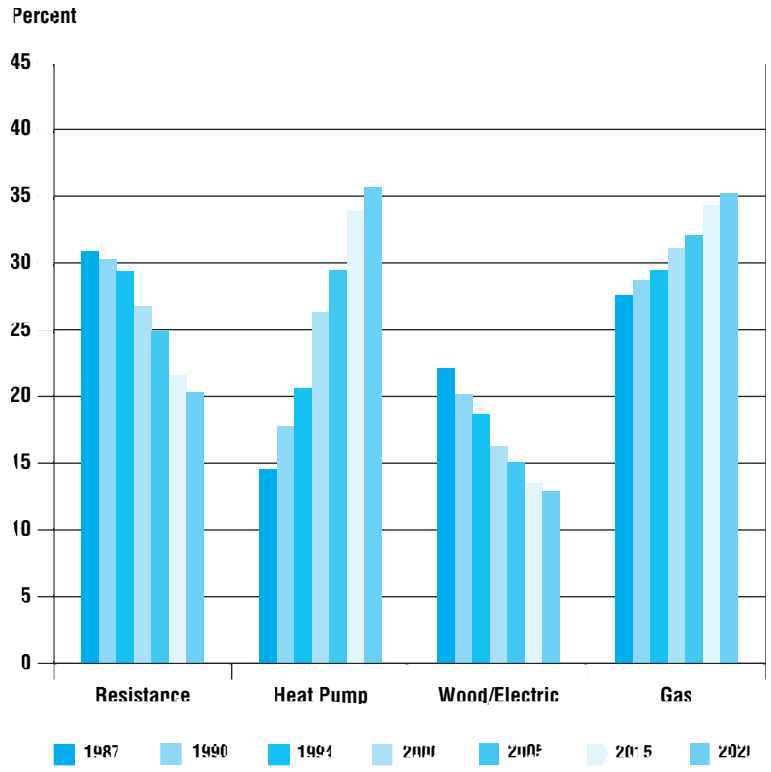
Residential forecasts are influenced by six factors: per capita income, population, residential electric prices, residential gas prices, household types, and efficiencies.

FIGURE T5-14. **Percent of Residential Sales by End Use**



TVA anticipates changes in the way residential consumers use electricity through 2010. The largest increase in the share of total residential electricity use is for the "other" category. The largest decrease in the share of total residential electricity use is for the heating category.

FIGURE T5-15. **Residential Space Heating Saturations**



Electric heat pumps and natural gas heating units are expected to continue to gain favor with consumers at the expense of resistance electric heating and wood-burning stoves.

clothes washers, clothes dryers, and the increasing use of electronic equipment in the home, for which room for growth remains as incomes increase. The heating share drops the most as total heating energy rises only slightly over the forecast period.

Residential Saturations

Major factors in the changing end-use energy forecasts are changes in the saturation of appliances. Saturation is defined as the percentage of total households that have a particular appliance. In the long term, consumers switch to more efficient end-use appliances, as well as those using fuels that are declining relatively in price. Changes in space heating saturations are shown in *Figure T5-15*. Heat pumps are substituted for resistance heat, especially in areas where natural gas is not available. Heat pumps increase in saturation from 21 percent of total households in 1994 to 26 percent in 2000 and 36 percent in 2020. These heat pumps provide both heating and cooling. Electric resistance space heat declines from 29 percent in 1994 to 27 percent in 2000 and 20 percent in 2020. Natural gas used for space heating increases from 30 percent in 1994 to 31 percent in 2000 and 35 percent in 2020. Electric backup for wood heat is expected to decline due to the decline in wood as a primary heating fuel. The gains by

both heat pumps and gas furnaces are at the expense of the dwindling wood heat market and declining resistance heat.

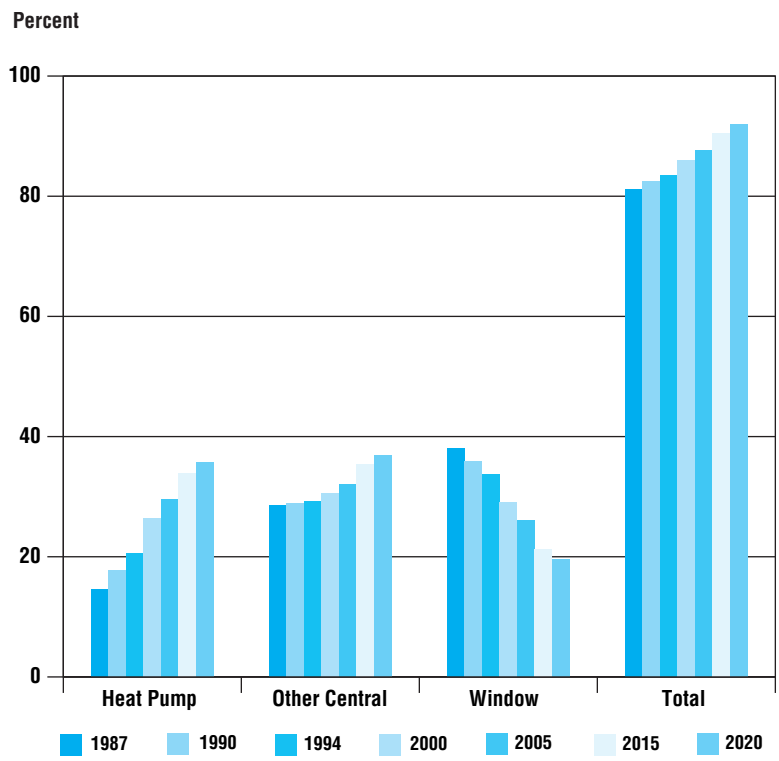
Central air conditioning other than heat pumps increases from 29 percent in 1994 to 31 percent in 2000 and 37 percent in 2020, as shown in *Figure T5-16*. Window air conditioning saturation drops from 33 percent to 20 percent by 2020. Total air conditioning saturation increases from 84 percent in 1994 to 92 percent by 2020.

Residential water heating is dominated by electricity. The saturation of electric resistance water heating decreases slightly from 77 to 75 percent. Natural gas water heating saturation increases moderately from 22 to 25 percent over the same period. Declining electricity prices support the electric water heating market share in spite of increasing competition from natural gas.

Residential Efficiency Improvements

Another major factor in changing end-use energy forecasts is improvement in efficiency of the appliances. These improvements reduce the amount of fuel needed to provide a given level of service. As a result, forecasts of efficiency improvements will reduce the forecast of electricity sales. End-use efficiency improvements for the residential customer class are shown in *Figure T5-17*. The efficiency improvements are in terms of the percentage reduction in energy use by the years 2000 and 2020. For example, heat pump efficiency increases by 12 percent over current levels by 2020, air conditioning efficiency increases by 11.2 percent, and water heating decreases by 7 percent. Efficiency improvements estimates incorporate requirements of the Energy Policy Act of 1992.

FIGURE T5-16. **Residential Space Cooling Saturations**



Air conditioning saturation is projected to increase to 92 percent by 2020.

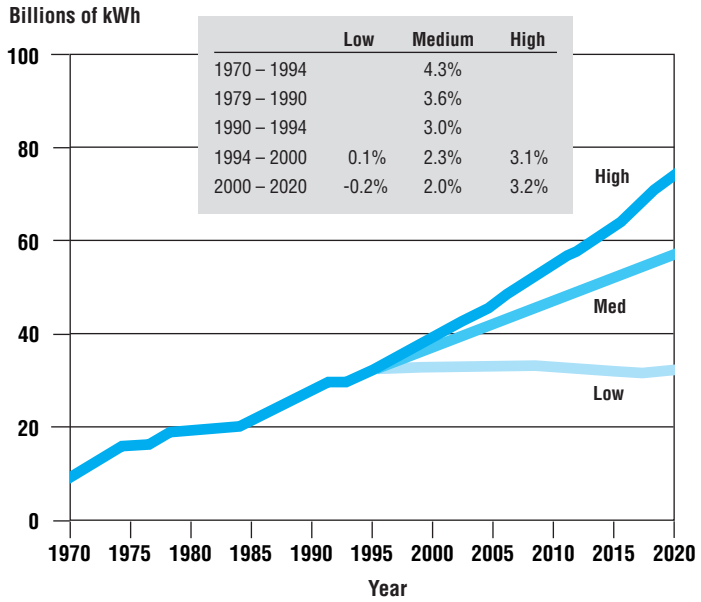
FIGURE T5-17. **Residential Efficiency Improvements 1995–2020**

Water Heating	-7.0%
Resistance Heating	0.0%
Central Air Conditioning	11.2%
Heat Pump Heating	12.0%
Heat Pump Cooling	13.6%
Freezer	20.2%
Refrigeration	59.4%

Total Residential Improvements 7.2%

Efficiency improvements in home appliances and heating and cooling equipment will affect future load by reducing the amount of energy needed to provide a given level of service. Because direct electric heating is 100 percent efficient, little opportunity exists for efficiency improvements in water heating and resistance heating. The declining efficiency for water heating is a result of consumers becoming less concerned with the insulation levels of their water heaters as electricity prices fall.

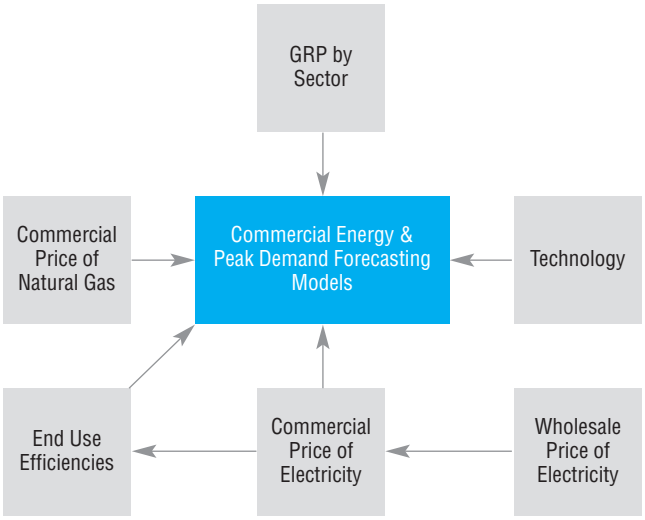
FIGURE T5-18. **Total Commercial Sales**



	Low	Medium	High
1970 – 1994		4.3%	
1979 – 1990		3.6%	
1990 – 1994		3.0%	
1994 – 2000	0.1%	2.3%	3.1%
2000 – 2020	-0.2%	2.0%	3.2%

Commercial sales are expected to be 56.9 billion kilowatt-hours in 2020 for the medium forecast.

FIGURE T5-19. **Commercial Sector Influence Diagram**



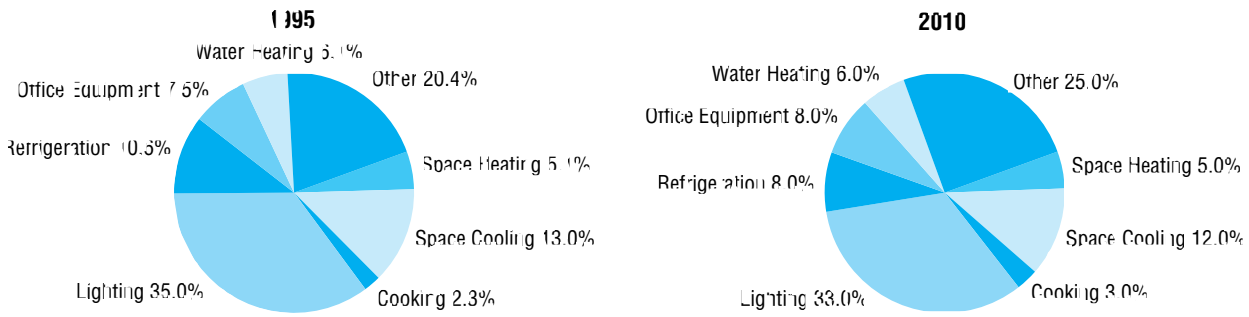
The commercial sector sales forecast is driven by economic activity (in terms of GRP by sector), the price of electricity, the price of competing fuels, efficiency improvements, and technology.

COMMERCIAL SECTOR FORECAST

Long-term sales forecasts for the commercial sector are shown in *Figure T5-18*. In the medium forecast, commercial kilowatt-hours sales are expected to be 38.2 billion kilowatt-hours in 2000 and 56.9 billion kilowatt-hours in 2020. Corresponding growth rates are 2.3 percent per year from 1994 to 2000 and 2.0 percent per year from 2000 to 2020. For the high commercial sales forecast, the growth rates are 3.1 percent from 1994 to 2000 and 3.2 percent from 2000 to 2020. The corresponding sales growth in the low forecast is 0.1 percent from 1994 to 2000 and -0.2 percent from 2000 to 2020.

The commercial sector sales forecast is driven by economic activity, the price of electricity, the price of competing fuels, efficiency improvements, and technology, as indicated in *Figure T5-19*.

FIGURE T5-20. **Percent of Commercial Sales by End Use**



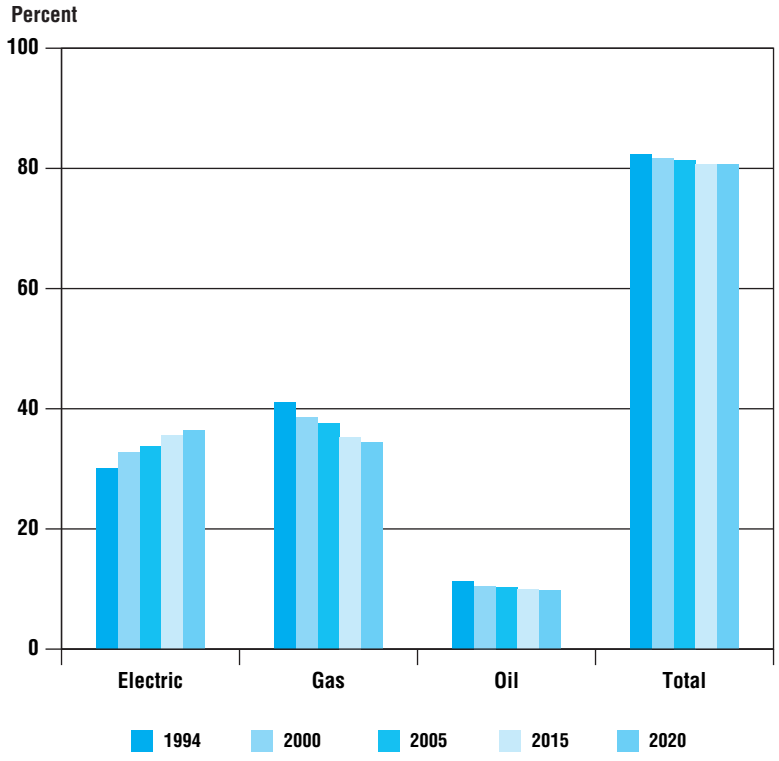
Commercial sales for cooking, office equipment, and miscellaneous uses are expected to increase through the next 15 years.

Commercial End-Use Energy Forecasts

In the commercial sector, the major end uses are space cooling, lighting, space heating, refrigeration, and office equipment. The share of commercial electricity sales attributable to each of these end uses is shown in *Figure T5-20*. Cooking, office equipment, and miscellaneous uses show increasing shares of the total energy consumption between 1994 and 2010.

As in the residential sector, end-use energy forecasts are influenced by two major factors, the saturations of each appliance and improvements in efficiency of the appliances.

FIGURE T5-21. **Commercial Space Heating Saturations**



Electric heating for commercial customers is expected to increase through 2020 at the expense of gas and oil. Rising gas and oil prices will influence this change.

Commercial Saturations

Space heating saturations by fuel type are shown for the commercial sector in *Figure T5-21*. The saturation of electric space heat increases from 30 percent in 1994 to 36 percent in 2020. Natural gas saturation declines from 41 percent in 1994 to 34 percent in 2020 as gas prices increase. Oil, liquefied petroleum (LP) gas, and other fuels used for space heating decline from 11 to 10 percent.

Other saturations also impact commercial sales. The total saturation of air conditioning increases from 66 percent in 1994 to 71 percent in 2020. The saturation of electric water heating is 43 percent in 1994 and 53 percent in 2020. Over the same period, natural gas water heating saturation declines slightly from 36 to 31 percent, and oil water heating declines from 3 to 1 percent. The saturation of electric lighting is very nearly 100 percent.

FIGURE T5-22. **Commercial Efficiency Improvements 1995–2020**

Resistance Heating	0.0%
Space Cooling	6.6%
Refrigeration	4.9%
Lighting	8.4%
Heat Pump Heating	12.8%
Office Equipment	22.3%

Total Commercial Improvements 9.4%

Efficiency improvements in commercial lighting and space cooling will have significant impact on commercial energy usage since lighting and cooling currently consume about half of the energy used in the commercial sector.

Commercial Efficiency Improvements

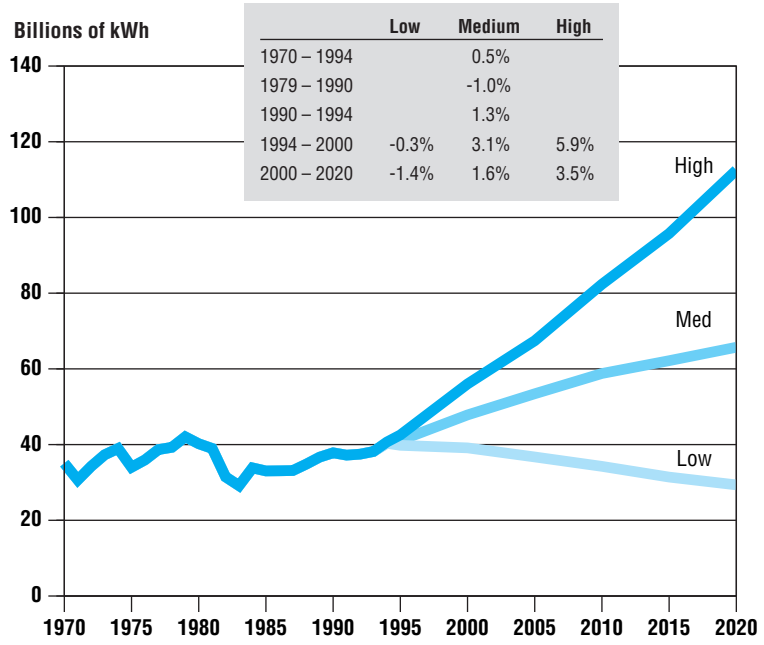
The impact of efficiency improvements and alternative technologies on the commercial long-term sales forecast is shown in *Figure T5-22*. The major impact is in the improvement in efficiency in lighting of 8.4 percent from 1995-2020 and the improvement in space cooling of 6.6 percent over the same period. Efficiency improvements in lighting and cooling have large impacts because lighting and space cooling consumed 48 percent of the energy in the commercial sector in 1994. The impact of efficient office equipment, primarily more efficient computers, is also significant. Efficient office equipment and lighting also generate less heat and reduce cooling requirements. The efficiency improvements comply with the provisions of the Energy Policy Act of 1992.

MANUFACTURING SECTOR FORECAST

The medium manufacturing sales forecast, shown in *Figure T5-23*, has growth rates of 3.1 percent per year from 1994 to 2000 and 1.6 percent per year from 2000 to 2020. The medium forecast of manufacturing kilowatt-hours sales is reasonably bounded by the high and low forecasts, which have 1994 to 2020 growth rates of 5.9 and -0.3 percent per year, respectively.

Manufacturing sales are forecast for individual industry groups or standard industrial classification (SIC) codes. In each industry group the sales are influenced by the five major factors shown

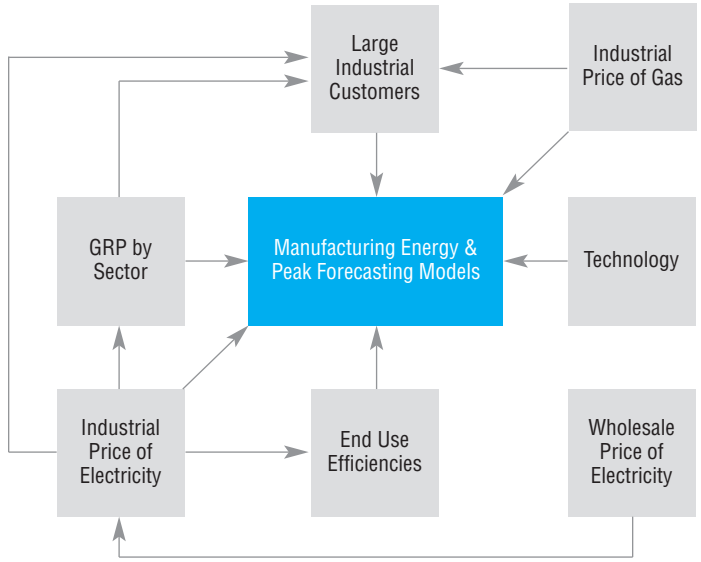
FIGURE T5-23. **Total Manufacturing Sales**



	Low	Medium	High
1970 – 1994		0.5%	
1979 – 1990		-1.0%	
1990 – 1994		1.3%	
1994 – 2000	-0.3%	3.1%	5.9%
2000 – 2020	-1.4%	1.6%	3.5%

Energy sales to manufacturing customers are expected to increase to over 65 billion kilowatt-hours by 2020.

FIGURE T5-24. **Manufacturing Sector Influence Diagram**



Factors affecting sales to manufacturing customers include economic activity (in terms of GRP by sector), price of electricity, price of industrial gas, efficiency improvements, and technology.

in *Figure T5-24*: economic activity, price of electricity, price of industrial gas, efficiency improvements, and technology.

These inputs are used in the industrial forecast models to forecast manufacturing sales. In addition, a general survey of business conditions is made for each major industry group. This survey includes major products, technology, and business conditions specific to an industry group. Also, each industry is considered from an international, national, and regional perspective, emphasizing the competitive situation, new products, environmental concerns, and other related issues.

The forecasts of manufacturing by industry groups are shown in *Figure T5-25*.

FIGURE T5-25. **Manufacturing Sales by Industry Group**

	Billions of kWh			Average Annual Growth Rate	
	1979	1994	2020	1979-1994	1994-2020
Food	1.5	2.8	5.7	4.3%	2.8%
Textiles & Apparel	1.9	2.4	3.3	1.6%	1.2%
Paper	2.2	4.8	8.6	5.3%	2.3%
Chemicals	11.7	9.5	11.2	-1.4%	0.6%
Primary Metals	17.1	6.4	9.1	-6.3%	1.4%
Machinery	3.0	4.4	6.9	2.6%	1.8%
Other Durables	2.8	5.6	9.1	4.7%	1.9%
Other Nondurables	1.9	3.9	11.9	4.9%	4.4%
Total Manufacturing	42.1	39.8	65.8	0.4%	2.0%

Electric sales to manufacturing customers are expected to reach 65.8 billion kilowatt-hours by 2020. Other nondurables, food processing, and paper manufacturing are expected to lead in average annual growth rates among Valley industries.

Distributor Served Industries

Manufacturing sales by the 160 power distributors within the TVA service area were 23.1 billion kilowatt-hours in 1994. These sales accounted for 58 percent of the total manufacturing sales in 1994 and are expected to increase to 61 percent in 2020. Distributor served sales have experienced 2.8 percent growth since 1979 in contrast to the -3.0 percent growth in TVA directly served sales. This trend is expected to continue with a 2.2 percent growth in distributor served industry sales through 2020. *Figure T5-26* shows the kilowatt-hours and average annual growth rates for distributor served industry sales.

FIGURE T5-26. **Distributor Served Industrial Sales**

	Billions of kWh			Average Annual Growth Rate	
	1979	1994	2020	1979-1994	1994-2020
Food	1.5	2.8	5.0	4.2%	2.3%
Textiles & Apparel	1.9	2.4	3.3	1.6%	1.2%
Paper	0.8	1.1	1.7	2.1%	1.7%
Chemicals	2.6	2.7	2.9	0.3%	0.3%
Primary Metals	1.5	2.2	2.2	2.6%	0.0%
Machinery	2.5	3.7	5.7	2.6%	1.7%
Other Durables	2.6	4.5	7.8	3.7%	2.1%
Other Nondurables	1.9	3.7	11.7	4.5%	4.5%
	15.3	23.1	40.3	2.8%	2.2%

Distributor manufacturing sales are expected to reach 40.3 billion kilowatt–hours by 2020. The growth leader is expected to be other nondurables at 4.5%.

Other nondurables are expected to be the leader in growth with 4.5 percent annual growth rate through 2020. Nondurables consist primarily of printing and publications, miscellaneous plastics, and petroleum products, among other industries. The food industries are expected to follow with 2.3 percent annual growth rate.

Directly Served Industries

The directly served industrial class consists of relatively large customers served directly by TVA. They account for 42 percent of manufacturing sales and 13 percent of total TVA sales. These sales are spread among 54 companies and are concentrated in 3 industries—primary metals, paper, and chemicals. A close look at each customer is required because these customers have a significant impact on TVA sales.

The forecast for directly served industries is built up on a company-by-company basis. The outlook for the company and the industry is developed from several sources of information. This includes specific company information, industry outlooks, and national economic industry forecasts.

Forecasts for major directly served industries are shown in *Figure T5-27*. Total energy sales for directly served industries are expected to increase from 16.8 billion kilowatt-hours in 1994 to 25.4 billion kilowatt-hours in 2020. Historically, total directly served sales have declined by 3.5 percent per year, largely based on the decline in primary metals and to a lesser degree in chemicals. From 1994 to 2020, directly served industry sales are expected to increase 1.6 percent per year.

FIGURE T5-27. **Directly Served Industrial Sales**

	Billions of kWh			Average Annual Growth Rate	
	1979	1994	2020	1979-1994	1994-2020
Primary Metals	15.6	4.2	6.9	-8.4%	1.9%
Chemicals	9.0	6.9	8.2	-1.8%	0.7%
Chlorine	3.4	4.2	4.7	1.4%	0.4%
Fibers	2.2	2.0	3.0	-0.1%	1.6%
Other Chemicals	3.4	0.7	0.5	-10.0%	-1.3%
Paper	1.4	3.7	6.9	6.7%	2.4%
Other	0.7	2.0	3.4	7.3%	2.1%
Total Direct Served	26.7	16.8	25.4	-3.0%	1.6%

Energy sales to industries served directly by TVA are expected to increase to 25.4 billion kilowatt-hours annually by 2020.

Cogeneration

Cogeneration is the production of electricity by an industry for its own use. Cogeneration by directly served industries is forecast to increase from 2.3 billion kilowatt-hours in 1994 to 3.1 billion kilowatt-hours in 2000 and to 6.1 billion kilowatt-hours by 2020. It is expected that cogeneration will continue to increase as long as it proves beneficial to industries or the environment. Presently, customers most likely to produce their own electricity are those with process steam needs, in particular, operations involving paper, chemicals, and textiles. For example, energy produced during the recovery cycle of the paper manufacturing process is often sufficient to meet the energy needs of the pulp industry. In addition, the lumber industry is becoming increasingly interested in cogeneration because landfills, in many cases, are either charging more for dumping waste sawdust or refusing to accept it.

Load Forecast Uncertainty

A load forecast is inherently uncertain for two reasons. First, there is uncertainty in the future values of the key variables that determine the level of future electricity consumption. For the Energy Vision 2020 forecast these variables are:

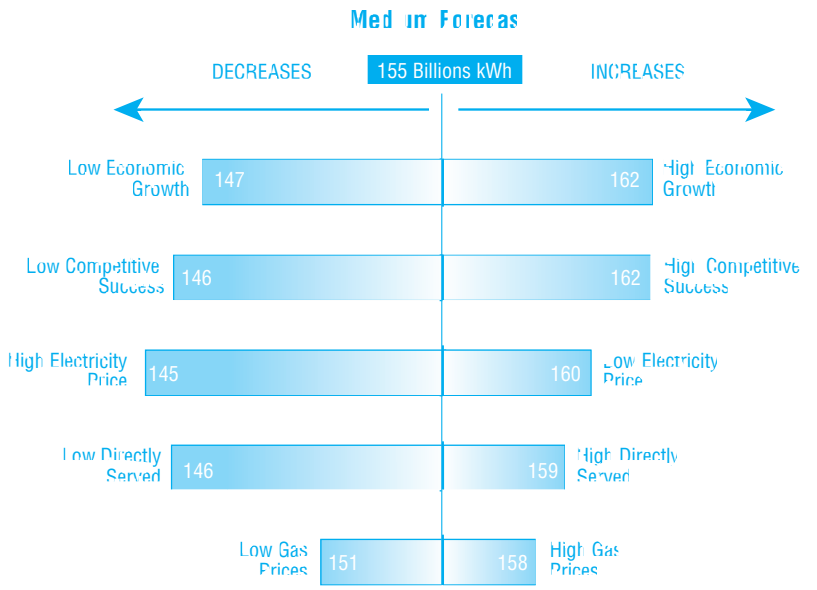
- Economic activity
- Price of electricity
- Competitive success
- Directly served load
- Price of substitute fuels

The second reason for load uncertainty is due to the relationships between the key variables and future electricity consumption. Customer preferences and behaviors will change over time. Therefore, the relationships between them and the consumption of electricity will change.

In the Energy Vision 2020 forecast, TVA has dealt with uncertainty using the following methods.

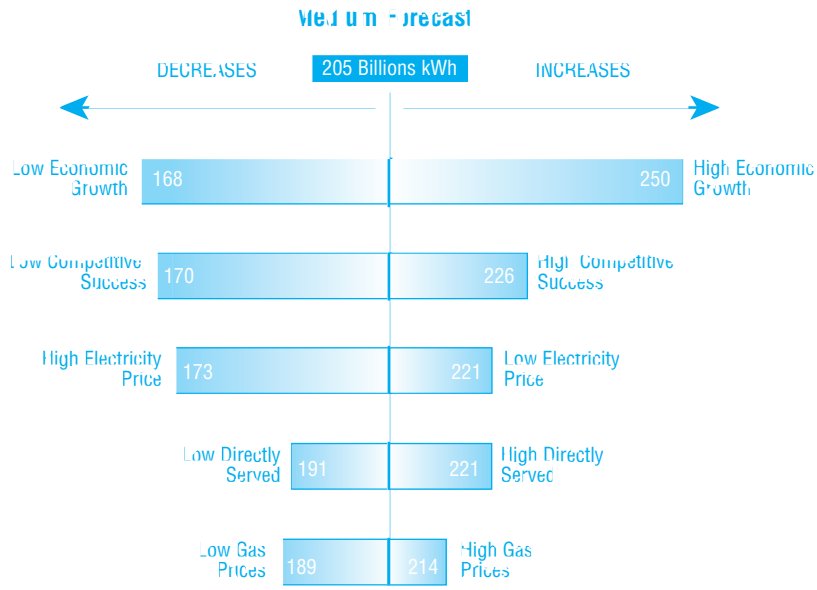
1. Evaluating alternative levels (high, medium, and low) of the key variables for their impacts on future electricity consumption. This process is based on probability and results in a wide range of alternative load forecasts.
2. Use of several quantitative models to evaluate the relationship between the major variables and their impact on future electricity consumption. Both econometric and economic end-use models are used.

FIGURE T5-28. **Variation of the System Energy Forecast Assuming High and Low Conditions for Key Uncertainties in 2000**



Uncertainty about the future requires a broad review of key variables and their impacts on system energy requirements. Load growth is most affected by economic activity, competition, and the price of electricity.

FIGURE T5-29. **Variation of the System Energy Forecast Assuming High and Low Conditions for Key Uncertainties in 2015**



Uncertainty about the future requires a broad review of key variables and their impacts on system energy requirements. Load growth is most affected by economic activity, competition, and the price of electricity.

ALTERNATIVE LEVELS OF KEY VARIABLES

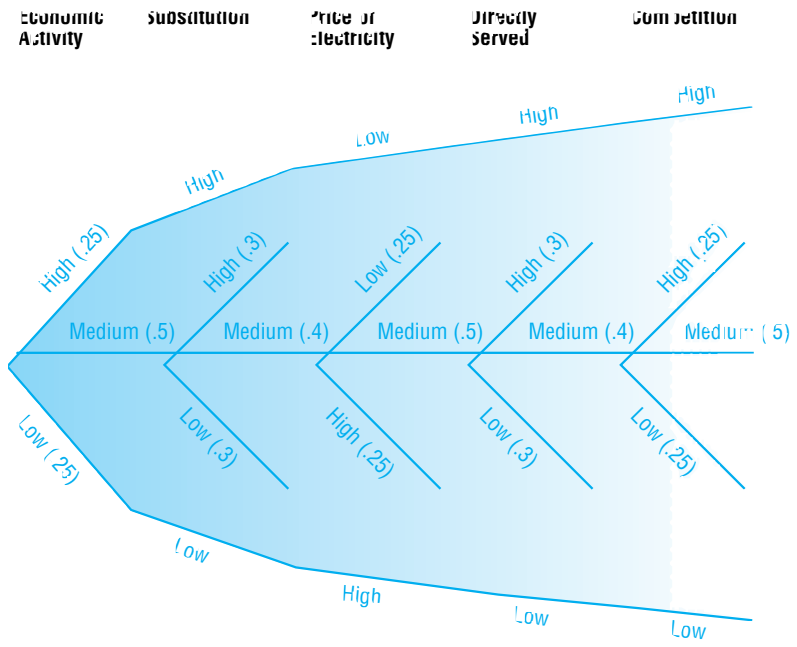
The high, medium, and low load forecasts reflect changes in the key variables which, in turn, impact load growth. The medium load forecast is based on the medium or expected level of each key variable. The high and low levels of each key variable are quantified, and models are used to determine the high and low sales levels.

The incremental impacts above or below the medium sales forecast are shown for each key variable for 2000 and 2015 in *Figures T5-28* and *T5-29*. For example, *Figure T5-28* shows that the impact on system energy requirements in the year 2000 of going from the medium to the high level of economic activity would be to increase system energy requirements by 7 billion kilowatt-hours. In 2015, as shown in *Figure T5-29*, the incremental impact of going from the medium to the high level of economic activity would be to add 45 billion kilowatt-hours—raising the forecast from 205 billion kilowatt-hours to 250 billion kilowatt-hours.

As shown in *Figures T5-28* and *T5-29*, considerable uncertainty exists in the key variables and their impacts on system energy requirements. Economic activity, competition, and the price of electricity have the greatest impact on possible changes in load growth. In 2000 the range of sales due to uncertainty in economic activity is 15 billion kilowatt-hours, increasing to 82 billion kilowatt-hours in 2015. The range on electricity price impacts is 15 billion kilowatt-hours in 2000 and 48 billion kilowatt-hours in 2015. The range on competitive success is 16 billion kilowatt-hours in 2000 and 56 billion kilowatt-hours in 2015.

The range of load growth impacts from the low to the high levels of economic activity, competition, and electricity prices does not include any impacts on the directly served sector since this sector reacts differently to changes in econom-

FIGURE T5-30. **Alternate Load Forecasts**



High and low load forecasts are developed by determining the probabilities assigned to alternative levels of the key variables, what is the likelihood that economic activity, for example, will be high or low for any given forecast period.

ic activity and electricity prices. The range of incremental impacts on net system requirements from the directly served sector is 13 billion kilowatt-hours in 2000 and 30 billion kilowatt-hours in 2020. The incremental impact of substitution of electricity for natural gas based on changes in natural gas prices has a range of 7 billion kilowatt-hours in 2000 and 25 billion in 2020.

PUTTING THE NUMBERS TOGETHER – SELECTING THE HIGH AND LOW FORECASTS

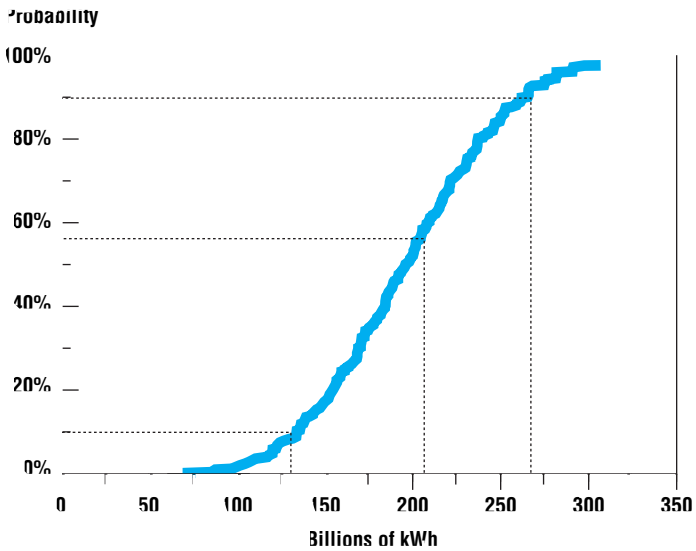
Selecting the high and low forecasts involves organizing the alternative load growth scenarios with a tree diagram *(Figure T5-30)*. There are five alternative branches in the tree—one for each of the five major determinants of load growth: economic activity, substitution (price of natural gas), price of electricity, directly served industry, and competitive success. Combinations of these five major determinants of electricity consumption produce alternative load forecasts. For example, high economic activity, high competitive success, high price of natural gas (high substitution), low price of electricity, and high directly served industry would produce the highest load forecast as represented by the top branch of the tree. Conversely, the alternative levels of the determinants of electricity consumption represented by the bottom branches of the tree would produce the lowest load forecast.

The numbers in parentheses represent the probabilities assigned to the alternative levels of the key variables. For example, high economic growth is assigned a .25 probability, medium economic growth is assigned a .50 probability, and low economic growth is assigned a .25 probability. Some of the variables are not independent. An explanation of the detailed probability assessment will be furnished upon request.

The probabilities associated with the possible forecast outcomes are used as a guideline in selecting those forecasts that will be evaluated explicitly in the decision process. A cumulative probability distribution, shown in *Figure T5-31*, indicates the distribution of probabilities associated with the entire range of possible forecasts. The cumulative probability distribution helps select a set of three forecasts that sufficiently bound the range of uncertainty. The cumulative probability distribution indicates the probability that the actual load will be less than the forecast load. TVA's high load forecast has a 90 percent probability that the actual load will be less than the forecast load. The medium forecast has a 50 percent probability that the actual load will be less than the forecast load, and the low load forecast has a 10 percent probability.

As indicated by the cumulative probability distribution, there are several potential forecasts that will be either greater than the high load forecast (90 percent) or lower than the low forecast (10 percent). Conditions that would result in load growth greater than the high load forecast, for example, are lower electricity prices. One condition that could result in load growth being lower than the low forecast would be lower natural gas prices.

FIGURE T5-31. **Forecast Probability Distribution – 2015**



High, medium, and low load forecasts have assigned probabilities that the actual load will be less than the forecast load. In the high load forecast, for example, there is a 90 percent probability that the actual load will be lower than projected.

Continuous Improvement

TVA recognizes that the world is rapidly changing and its processes and products must continually be assessed to maintain credible load forecasts. TVA therefore contracted with Barakat & Chamberlin, Inc., to evaluate the TVA load forecasting system in 1991. Barakat & Chamberlin, Inc., concluded that, "on a comparative basis, TVA's forecasting procedures compare very favorably with the best-practice procedures in the United States utility industry." Several of Barakat & Chamberlin's recommendations have been incorporated into the TVA load forecast:

- In 1992 TVA began using an industrial end-use model.
- A commercial conditional demand model is being developed.
- TVA is updating residential conditional demand studies.
- The uncertainty analysis has been expanded to include additional factors.
- Industry surveys are made continually to monitor closely the important industrial sectors of the TVA market.

ECONOMIC FORECASTING METHODOLOGY AND VALIDATION

TVA produces its own forecasts of regional economic activity. These forecasts are based on forecasts of the national economy developed by an internationally recognized forecasting service, DRI/McGraw Hill. TVA uses its regional economic forecasts for budget planning, the planning of locks and other navigation facilities, and economic development activities. These forecasts are publicly distributed throughout the Tennessee Valley and are used by four regional universities as the basis for their own publicly released economic forecasts of their local areas. (The regional universities that use the TVA forecasts as the driver in their own local area economic model forecasts are: Eastern Kentucky University, Mississippi State University, the University of Alabama in Huntsville, and Western Carolina University.) The regional economic forecasts are also the major "key assumption" to TVA's load forecasts.

These forecasts are based on five elements necessary for state-of-the-art forecasting: accuracy, use of best information, use of best methods, explicit treatment of uncertainty, and continuous improvement.

Accuracy

Figure T5-32 summarizes the accuracy of TVA's five-year forecast for Gross Regional Product (the sum of the value in dollars of all final goods and services produced) and DRI's forecasts for Gross National Product. (DRI has been used for national forecasts since 1988. Prior to that, the WEFA Group forecasts were used. However, both companies' long-term forecasts of gross national product have been very similar over the years.) These forecasts were made annually during the 1980s. For example, a regional and a national forecast for 1985 (the target year in *Figure T5-32*) were done at the start of 1981, with 1980 as the latest his-

FIGURE T5-32. **TVA Economic Forecast Five–Year Forecast Error**

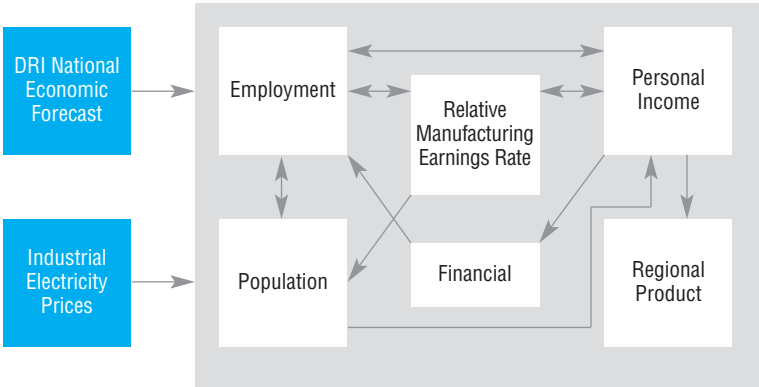
		Gross Product in Billions of Dollars					
		REGIONAL			NATIONAL		
Year of Forecast	Target Year	GRP Forecast	GRP Actual	Forecast Error	GNP Forecast	GNP Actual	Forecast Error
1980	1985	$105.3	$91.5	15.1%	$4,746	$4,054	17.1%
1981	1986	$114.5	$98.1	16.7%	$5,164	$4,278	20.7%
1982	1987	$114.6	$106.6	7.5%	$5,149	$4,545	13.3%
1983	1988	$117.5	$114.9	2.3%	$5,196	$4,908	5.9%
1984	1989	$124.1	$124.1	0.0%	$5,519	$5,267	4.8%
1985	1990	$127.4	$130.7	-2.5%	$5,673	$5,568	1.9%
1986	1991	$143.4	$137.6	4.2%	$6,116	$5,741	6.5%
1987	1992	$145.8	$149.1	-2.3%	$6,171	$6,026	2.4%
1988	1993	$161.7	$159.6	1.3%	$6,862	$6,348	8.1%
1989	1994	$174.7	$172.7	1.1%	$6,863	$6,727	2.0%
Average Absolute Error (1988-1994):				2.0%			4.5%
Average Absolute Error (1985-1994):				5.3%			8.3%

This chart summarizes the accuracy of TVA's five-year economic forecasts for the region and the nation.

torical year (the year of forecast in *Figure T5-32*). Likewise, forecasts for 1994 were done at the beginning of 1990, with 1989 as the latest historical year. *Figure T5-32* shows the percentage of error between the forecasted value and actual data (expressed as a positive—forecast was too high—or negative—forecast was too low—value) for both the regional and national forecasts.

Figure T5-32 indicates that the performance of TVA regional economic forecasts has improved over time and that the performance has been favorable compared to that of the national economic forecasts. For the forecasted years of 1988 through 1994, the average error in the regional forecasts for total gross product was good, within plus or minus 2 percent.

FIGURE T5-33. **Regional Economic Simulation Model Flowchart**



Major inputs into the Regional Economic Simulation Model are the national economic forecast and TVA industrial electricity prices.

The regional economic forecast performance has improved due to the better performance of the national forecasts and to improvements in the TVA economic forecasting process, including the validation procedures. TVA does reviews of long-term forecasting performance (as per the example above), as well as annual reviews of new economic data. Economic forecasts over the historical period are also done annually to test TVA's economic model performance versus actual data.

To improve the process, TVA began a program with universities around the Valley to share economic information in 1985. Currently, there are 11 university partners: The University of Alabama in Huntsville, Eastern Kentucky University, Western Kentucky University, Mississippi State University, Western Carolina University, East Tennessee State University, Middle Tennessee State University, Tennessee State University, The University of Memphis, The University of Tennessee at Martin, and Virginia Polytechnic and State University. TVA's regional economic forecasts are allocated to economic subregions of the Valley. The universities then review both the regional forecast and the forecasts for their subregions on an annual basis. All of this information is incorporated into the economic forecasting process and used to validate the regional economic forecasts.

The TVA regional economic forecast used for the Energy Vision 2020 process has been favorably reviewed by the regional universities. Further, the latest State of Tennessee long-term economic forecast, developed by The University of Tennessee at Knoxville, is consistent with it. The University's independently forecast average annual rate of growth for Tennessee total gross product of 3.8 percent from 1993 through 2002 compares well with the TVA forecast rate for regional total gross product growth of 3.5 percent for the same period. (See Murray, Matthew N., "The Long-Term Outlook for Tennessee: Three Trends Will Determine the State's Economic Future," *Survey of Business*, Center for Business and Economic Research, The University of Tennessee, Knoxville, (Winter 1994), pg. 39, for information on the university forecast.)

Use of Best Information

TVA strives to use the best information available for its economic forecasting. As stated previously, the national economic forecasts are purchased from DRI/McGraw-Hill. DRI forecasts are well recognized and widely used. Among DRI clients are a great number of utilities, federal and state agencies, universities, and Fortune 500 companies. DRI forecasts are quoted by the *Wall Street Journal* and other major business publications and used in Congressional hearings and legal cases.

The source historical economic data for the regional forecasts come from the federal government: the Bureau of Economic Analysis and the Bureau of the Census, U.S. Department of Commerce, and the Bureau of Labor Statistics, U.S. Department of Labor. The federal government has improved these data over the years. Further, TVA has improved its use of these data to get a better and more current picture of the region-

al economy. For example, by using the monthly state employment data from the Bureau of Labor Statistics, TVA can estimate regional employment in a more timely manner than by using estimates from other sources.

TVA has also improved its information by supplementing the data discussed above with information from other sources, including detailed employment and payroll data from state employment agencies, information on industry trends from trade journals and federal government publications, and information from the regional universities (discussed above) about the status of their local economies and industries.

Use of Best Methods

TVA uses its Regional Economic Simulation Model to produce its regional economic forecasts. The model uses state-of-the-art statistical methods comparable to those of the major economic forecasters in the country. TVA has been a leader in the utility industry in the use of econometric forecasting models that have now become the industry standard.

As seen in *Figure T5-33*, the two major inputs to RESM are the DRI national economic forecasts and TVA industrial electricity prices. RESM does not merely allocate national trends, but captures the differences inherent in the regional economic structure that affect regional performance. RESM is updated on an annual basis and has a high degree of industry detail (for example, chemicals, apparel, etc., in manufacturing; food stores, health services, etc., in the commercial sector). This allows for interindustry linkages—for instance, wholesale trade is linked to retail trade. (See Gonzalez, Juan E., "The TVA Regional Economic Simulation Model," *Proceedings: Eighth Electric Utility Forecasting Symposium*, (EPRI TR-100396), Electric Power Research Institute, Palo Alto, California, April 1992, pp. 39-1 to 39-11, for a more detailed discussion of RESM.)

Explicit Treatment of Uncertainty

Forecasting is inherently uncertain. First, there is uncertainty in the major inputs to the regional forecast. Many events, especially those that are not economic in nature, such as the Gulf War or the breakup of the Soviet Union, may throw the national economy from its expected growth path. Likewise, there is uncertainty related to the TVA electricity price forecasts. In addition, there is uncertainty as to how the regional economic structure will change over time.

To deal with uncertainty, TVA supplements its modeling with industry analyses and studies of specific major issues such as the effects of changes in the value of the dollar or interest rates on the Valley economy. This is an effort to continually improve TVA's understanding of the Valley economy and its ability to produce accurate economic forecasts.

Further, TVA deals with uncertainty by producing high and low regional economic forecasts that provide a range of possible future economic outcomes. These are derived by using DRI national high and low economic forecasts and TVA low and high electricity price forecasts, respectively. Also, explicit assumptions are made as to possible events that are not considered most likely, but are feasible developments from emerging historical events. Thus, in the current high economic forecast, the assumption is made that the region will develop a commercial sector that more closely matches that of the nation. Likewise in the low forecast, the assumption is made that several of the Valley's manufacturing industries experience large negative effects due to foreign competition.

Continuous Improvement

TVA is continuously improving its economic forecasting process. Specific efforts have been discussed previously for accuracy, use of best information, use of best methods, and explicit treatment of uncertainty. For example, TVA has made efforts to improve accuracy by working with regional universities. Efforts to improve information include supplementing data from various sources. In using the best methods, the Regional Economic Simulation Model is updated on an annual basis to improve estimates. Finally, to improve the treatment of uncertainty, TVA supplements its modeling with industry analyses and studies of specific major issues.