U.S. Electricity Forecast: Results and Decomposition

Ingrid Rohmund, J. Stuart McMenamin, Frank A. Monforte, and Daniel P. Nore, Regional Economic Research, Inc

This report evaluates and quantifies the relative importance of utility DSM and other forces for efficiency gains relative to other drivers of growth. The report attempts to highlight the technologies, policy issues, and key uncertainties that are expected to have major impacts on the growth outlook.

Introduction

Future growth in electricity sales and peak demand will be influenced by a variety of market forces and policy developments over the next two decades. The role of these factors is expected to change, reflecting changes in economic and demographic profiles, continued evolution of end-use technologies, and changes in the focus of public policy and utility DSM.

Some of the key ingredients in the public policy mix are the National Appliance Energy Conservation Act of 1987 and its amendments, the Energy Policy Act of 1992, and state standards that dictate thermal efficiency levels in new construction. These laws are beginning to have a marked impact on the efficiency of the U.S. equipment and building stocks. State regulatory bodies also set public policy that will affect future electricity sales.

Regarding utility policy, the key issue is the level and mix of demand-side management (DSM) program activity and the effectiveness of these programs. The expansion of integrated resource planning (IRP) in the utility industry has spurred the growth of DSM, and many utilities are incorporating substantial amounts of DSM into their long-term resource plans.

Method

The EPRI end-use forecasting models (REEPS, COMMEND, INFORM) and supporting national data bases were used to construct a set of growth projections through 2010. To isolate the relative influence of key factors, a cascade approach was used, allowing factors to be grouped as follows:

- Customer Growth,
- Economic Factors,
- Electrification,
- Market Efficiency and Standards, and
- Utility DSM.

Project Results–Sales Forecast

Between 1960 and 1990, electricity sales in the U.S. increased from 700 to 2,700 Billion kWh. Growth was steady over this period, with an average annual gain of about 68 BkWh each year. There were many positive factors driving this expansion, but the main categories were:

- Population and work force growth
- Productivity gains and output growth
- Diffusion of significant new uses and applications of electricity y
- Strong competitive gains in space and water heating markets
- Fast regional growth in "electrified" southern climates. (See Table 1.)

These positive drivers were partially offset by factors such as the decline in household size, appliance and equipment efficiency gains, and changes in the mix of U.S. manufacturing output toward less energy-intensive industries, However, it is clear that the positive drivers strongly outweighed the negative factors, giving both strongly rising sales and increases in electricity intensity per unit of economic activity.

These same forces will remain at play in the future, but there is uncertainty as to the relative role of each factor.

Table 1. Base-Case Energy Prices

	1990	2000	2010
Electricity (¢/kWh)			
Residential	7.86	7.39	7.33
Commercial	7.37	6.79	6.63
Industrial	4.74	4.47	4.51
Natural Gas (¢/therm)			
Residential	56.82	58.67	63.60
Commercial	47.32	51.49	57.44
Industrial	28.70	32.39	39.17
Oil Prices ($/mmBtu)	5.64	4.86	6.31

Adding to this uncertainty is the emergence of new drivers, including: (a) strong federal and state efficiency standards, (b) amplified DSM activity, and (c) increased concern over environmental issues. As a result of these factors, the question facing utility management in many areas has changed from "How much growth?" to "Will there be growth?" (See Figure 1.)

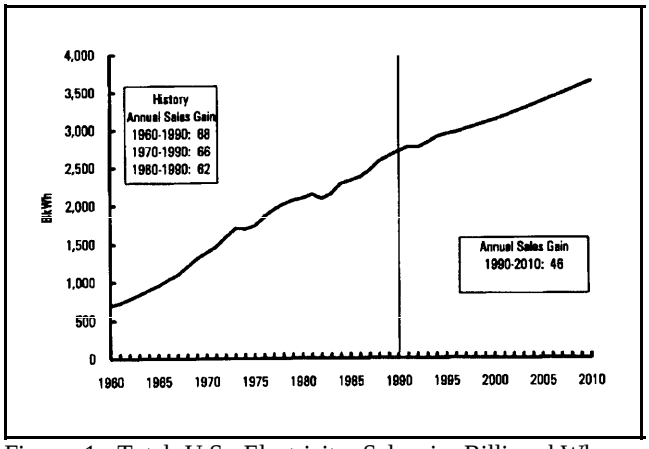

Figure 1. Total U.S. Electricity Sales in Billion kWh (BkWh)

Project Results – Forecast Drivers

The sales projection is defined by a combination of assumptions about growth of the economy, changes in end-use saturations and fuel shares, and rates of improvement in end-use equipment efficiency. To explore issues related to each of these types of factors, they are split into five "driver groups." The types of issues covered in each group are summarized below. Discussions of these drivers for each of the main sectors make up the remainder of this paper.

Customer Growth. This group of drivers includes increases in the number of residential customers, commercial floor space growth, and increases in industrial output. Equipment saturations, size, efficiency, and intensity of use are held fixed. This results in annual sales gains of about 50 BkWh between 1990 and 2010.

Economic Factors. This group of drivers includes changes in economic and demographic factors within each sector. Examples are decreasing household size in the residential sector, increasing operating hours in the commercial sector, and changing industry mix in manufacturing. Impacts of changing energy prices on equipment usage levels are also included here, but equipment saturations, fuel shares, and efficiency levels are held fixed. Under these conditions, economic factors have a net positive impact on annual sales gains, adding 4 BkWh per year between 1990 and 2010.

Electrification. This group of drivers covers changes in electric equipment saturations and fuel shares. Examples are increasing electric water heating and space heating shares in homes, increases in office equipment energy use, and penetrations of electric process technologies in manufacturing. Equipment efficiency levels are held fixed. Electrification drivers are strong positive factors, with impacts on annual sales gains of about 25 BkWh per year.

Market Efficiency and Standards. This category covers changes in equipment efficiency resulting from naturally occurring market forces and from efficiency standards for appliances, equipment, and the thermal shell of homes and buildings. Examples are greatly improved refrigerator efficiency levels in residential dwellings, improved lighting efficiency in commercial buildings, and more efficient motors in manufacturing facilities. Efficiency drivers are negative factors, with impacts on annual sales growth of about -22 BkWh between 1990 and 2010.

Utility DSM. This category covers expected impacts of utility DSM programs based on anticipated trends in the level of utility DSM activity and the impact of these efforts on customer demand for electricity. Like market efficiency drivers, utility DSM impacts are negative factors, with impacts on annual sales growth of about -12 BkWh per year between 1990 and 2000 and with extended impacts averaging -11 BkWh per year between 1990 and 2010.

Sales impacts across all sectors for each driver category are summarized in Figure 2. End-Use results from the national forecast are presented in Figure 3. Results for each sector are presented in the discussion below.

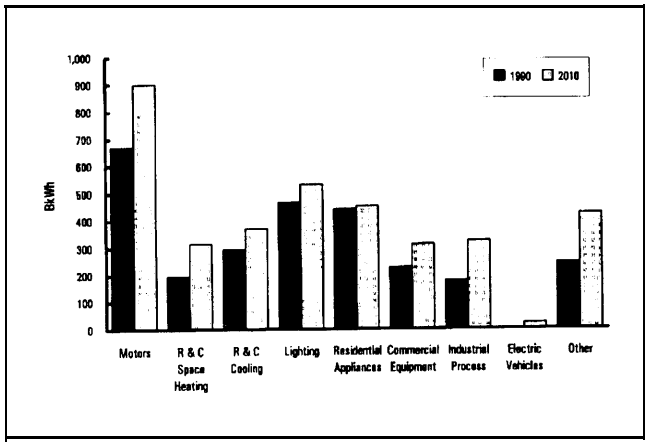

Figure 2. Sales Projection by End Use

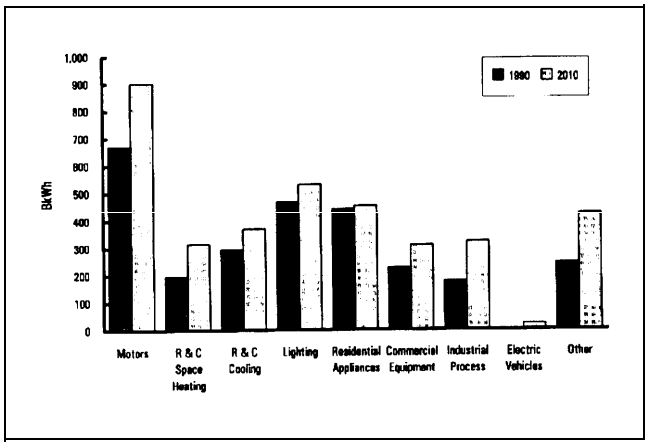

Figure 3. Impacts on Annual Sales Growth (1990 to 2010)

Residential Sector–Summary and Key Conclusions

The residential sector has generated rapid growth in terms of electricity sales and peak. Between 1970 and 1990, the sales gain for this sector has averaged about 23 BkWh per year, which is 35% of the total gain. Between 1990 and 2010, growth in this sector will slow significantly, reflecting the following key changes:

- The gain in households is expected to drop from an average of 1.6 million per year over the last two decades to about 1.1 million per year between 1990 and 2010.

- Significant efficiency improvements are expected as the result of better electric technologies, including more efficient refrigerators and freezers, more efficient air conditioning equipment, and efficiency gains in lighting and other uses.

- Utility DSM is moderate in the residential sector, focusing on space heating and cooling, water heating, and lighting. (See Figure 4.)

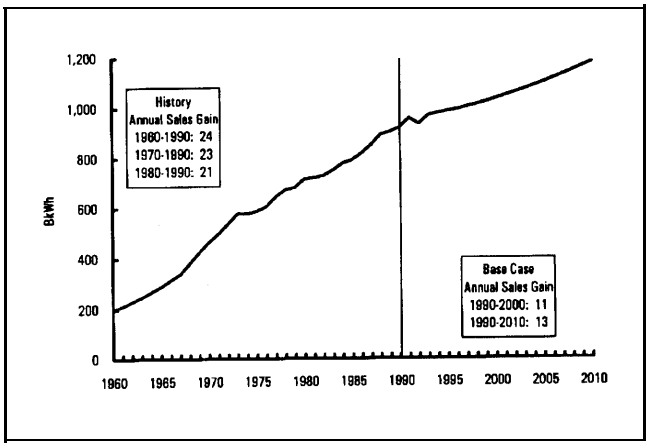

Figure 4. Residential Electricity Sales (Billion kWh)

Decomposition of Residential Projection

Residential electricity sales increases are expected to be below historical levels. The average annual gain of 13 BkWh per year between 1990 and 2010 is about one-half of the average gains between 1970 and 1990. This gain is equivalent to an annual growth rate of about 1.2% per year measured relative to 1990 sales. The 10-year projection is slightly lower at 11 BkWh per year, which also implies a growth rate of 1.2% relative to 1990 sales.

Customer Growth. The key driver of residential sales is the number of households. Changes in fertility, longevity, immigration, and household headship rates all impact household growth. In the Customer Growth step, annual household gains are about 1.1 million per year. With saturations, appliance size, efficiency, and usage held fixed, this would imply annual sales gains of about 11 BkWh per year.

Economic Factors. The main positive economic factor is increasing income levels, which leads to increases in appliance size and usage. The main negative driver is declining household size, which results in reduced usage levels for most appliances. Real electricity prices are also a factor, through impacts on appliance and equipment usage. With saturations and efficiency held fixed, the net impact of these factors on annual sales gains is about 3 BkWh per year.

Electrification. Forces for electrification are strong positive drivers in the residential sector. Continued saturation increases for many appliances are expected to combine with continued competitive gains in the space heating and water heating markets. The impact of these drivers on annual sales gains is about 11 BkWh per year.

Market Efficiency. Strong efficiency gains are expected for some residential appliances, most notably refrigerators, freezers, air conditioning equipment, and heat pumps. These changes result from continuation of efficiency improvements that have already occurred as well as further improvements mandated by federal and state standards. The impact of these drivers on annual sales gains is about -10 BkWh per year.

Utility DSM. Residential DSM programs impact building shell efficiency, appliance efficiency, and the saturation of conservation measures and devices. Significant impacts are expected for space heating and cooling, water heating, and lighting. The net effect is a reduction of annual sales gains of about 3 BkWh per year between 1990 and 2000. This impact accounts for 22% of the combined market efficiency and DSM savings. Between 1990 and 2010, the extended DSM impact averages slightly more than 2 BkWh per year, reflecting the assumption of smaller impacts in the retrofit and replacement markets beyond 2000. (See Figures 5 and 6.)

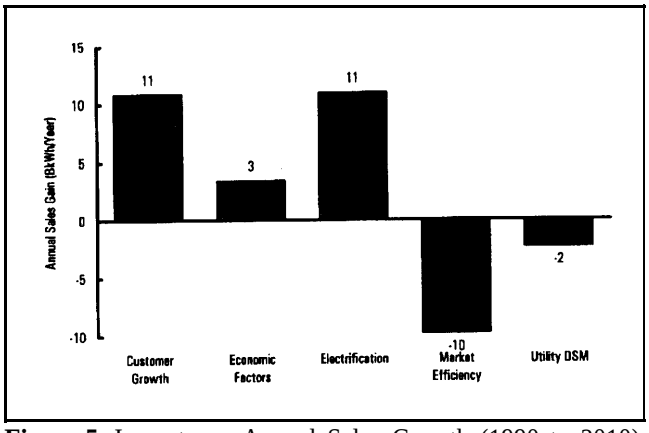

Figure 5. Impacts on Annual Sales Growth (1990 to 2010)

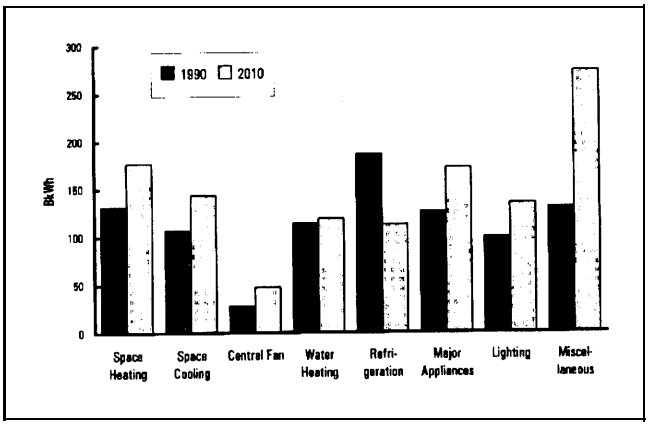

Figure 6. Residential Sales by End Use: 1990 and 2010 (BkWh)

Residential End-Use Results

The following discussion takes an end-use perspective and describes the impact of various drivers on some of the main residential end uses.

Heating. Strong growth in electric space heating sales will be driven by customer growth and increased saturations of heat pump technology. Customer growth and economic factors are expected to increase heating sales by 57 BkWh between 1990 and 2010. Electrification adds 33 BkWh to this growth due to an increase in heat pump shares from 5% in 1990 to 15% by 2010. This increase more than compensates for a slight decrease in electric resistance heating. Market efficiency changes, including the impacts of national heat pump efficiency standards and state residential building standards, reduce sales by 19 BkWh. Utility DSM further reduces sales by 14 BkWh, mostly through high-efficiency heat pump marketing and thermal shell retrofit programs. The net impact of these factors is an increase of 58 BkWh over the 20-year period, implying an average annual gain of 2.9 BkWh. This accounts for 22% of total residential growth.

Cooling. Substantial increases in central cooling system saturations will be partially offset by advances in equipment efficiency, leading to moderate growth in space cooling sales. Customer growth and economic factors generate a 24 BkWh increase in space cooling sales between 1990 and 2010. Electrification, driven by upgrades, conversions, and high new-home shares, pushes sales up an additional 48 BkWh. Central cooling system saturations expand from about 38% in 1990 to 59% in 2010. Equipment efficiency increases are mandated by federal standards and encouraged by utility DSM programs. As a result of these factors, average efficiency is expected to increase by over 20% between 1990 and 2010, implying a sales reduction of 41 BkWh. About one-fourth or 9 BkWh of the efficiency gain is due to DSM. The net result is an increase of 31 BkWh over the 20-year period, contributing almost 1.5 BkWh to the average annual sales gain.

Refrigerators and Freezers. National efficiency standards and reduced ownership of stand alone freezers and second refrigerators is expected to dramatically reduce refrigerator and freezer sales over the next 20 years. Assuming fixed efficiency and ownership shares, customer growth and economic factors would result in a sales increase of 96 BkWh. Negative saturation trends for stand-alone freezers and second refrigerators reduce sales growth by

32 BkWh. Market efficiency gains are driven by strong national standards. A doubling of refrigerator and freezer efficiency will reduce electricity use by 117 BkWh, pushing sales below 1990 levels. Utility DSM programs will be limited by efficiency standards and are expected to have little further effect on sales. The overall reduction of 55 BkWh implies a negative contribution to annual sales gains of almost -2.7 BkWh per year.

Commercial Sector–Summary and Key Conclusions

Historically, the commercial sector has been the most rapidly growing sector in terms of electricity sales and peak. Between 1970 and 1990, the sales gain for this sector has averaged about 24 BkWh per year, which is 36% of the total gain. Between 1990 and 2010, growth in this sector will slow significantly, reflecting the following key changes:

- The annual gain in commercial floor space is expected to decline from 1.3 billion square feet over the last 20 years to about 1.1 billion square feet per year over the next 20 years. This reflects a slowing in labor force growth and smaller increases in the commercial sector share of total employment.
- Commercial sector operating hours, which have broadened significantly over the last 20 years, are expected to level off.
- Significant efficiency improvements are expected as the result of better electric technologies, including more efficient lighting, more efficient air conditioning equipment, and more efficient office equipment.
- Utility DSM is strong in the commercial sector, focusing on lighting, HVAC, and commercial refrigeration. (See Figure 7.)

Decomposition of Commercial Projection

Commercial electricity sales increases are expected to be below historical levels. The annual growth is about 12 BkWh per year from 1990 to 2010, which is about one half of the rate of sales gain between 1970 and 1990. This gain is equivalent to an annual growth rate of 1.3% per year measured relative to 1990 sales. The ten-year projection is slightly higher, at 13 BkWh per year, giving a growth rate of 1.4% relative to 1990 sales.

Customer Growth. The key driver of commercial sales is employment growth, which translates into growth of commercial floor space. Related factors are labor force growth

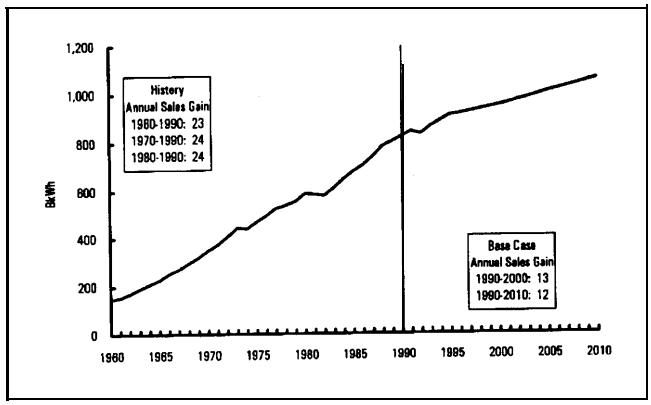

Figure 7. Commercial Electricity Sales (Billion kWh)

and the shift in employment away from manufacturing and into the service sectors. In the Customer Growth step, annual floor space gains are about 1.1 billion square feet per year. With saturations, appliance size, efficiency and usage held fixed, this implies annual sales growth of about 14 BkWh per year.

Economic Factors. The primary factor here is increasing operating hours, which leads to increased equipment usage. Real electricity prices are also a factor, through impacts on equipment usage. When saturations and efficiency are held fixed, the impact of these factors on annual sales growth is about 3 BkWh per year.

Electrification. Electrification is a strong positive driver in the commercial sector. Continued saturation increases for office equipment and cooling combine with competitive gains in the space-heating and water-heating markets. The impact of these drivers on annual sales growth is about 6 BkWh per year.

Market Efficiency. Strong efficiency gains are expected for some commercial equipment, especially lighting, heat-pump heating, and cooling. These gains result from naturally occurring efficiency improvements, as well as efficiency gains mandated by state and federal standards. The impact of these drivers on annual sales growth is about -6 BkWh per year.

Utility DSM. Commercial DSM programs impact equipment efficiency, thermal efficiency, and the saturation of equipment controls. Significant impacts are expected for lighting, space heating and cooling. The net effect averages to a reduction in annual sales growth of about 6 BkWh per year between 1990 and 2000. This impact is about half of the combined "conservation" savings from efficiency gains and DSM. Between 1990 and 2010, the extended DSM impact averages about -5 BkWh per year, reflecting the assumption of smaller impacts in the retrofit and replacement markets beyond 2000. (See Figures 8 and 9.)

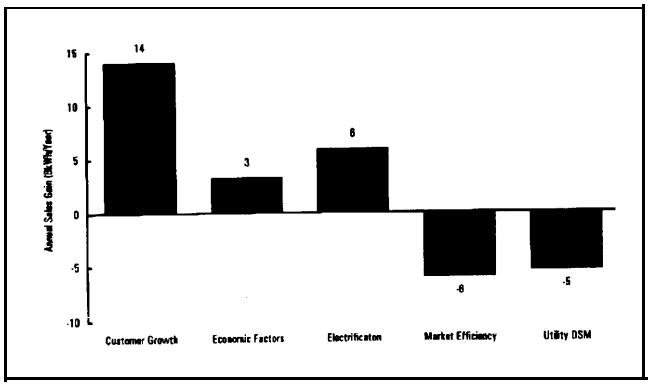

Figure 8. Impacts on Annual Sales Growth (1990-2010)

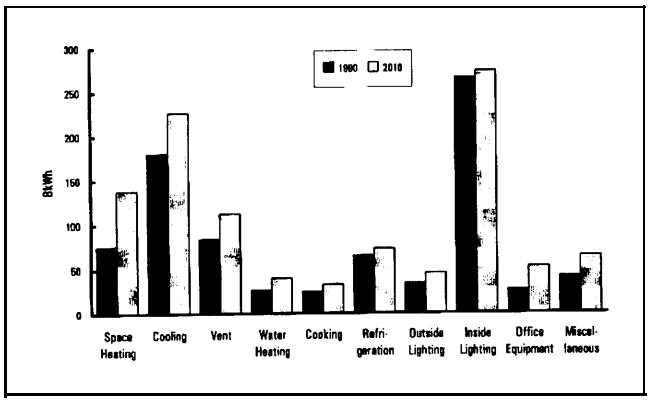

Figure 9. Commercial Sales by End Use: 1990 and 2010 (BkWh)

Commercial End-Use Results

The discussion above focused on the factors that drive the electricity forecast. Customer growth and economic factors affect all end uses similarly. However, electrification, market efficiency, and utility DSM have significantly different effects on each end use. The following discussion summarizes the results for some of the main commercial end uses.

Heating. Electric space heating is one of the fastest growing end uses. Customer growth and economic factors would increase space heating sales by about 42 BkWh between 1990 and 2010. Electrification, through a 10% increase in market share, would add an additional 46 BkWh. These gains are partially offset by improved efficiency of heating equipment and buildings. Market efficiency reduces electric sales by about 7%, or 12 BkWh in 2010. Utility DSM results in a further reduction of about 13 BkWh. The overall impact of these factors is that electric space heating sales almost double over the 20-year period.

Cooling. Substantial growth is expected in electric space cooling. Customer growth and economic factors are expected to increase cooling sales by about 77 BkWh between 1990 to 2010. Electrification, through a 7% increase in cooling penetration, causes sales to increase by an additional 32 BkWh. Market efficiency, including naturally occurring efficiency trends and federal and state standards, reduces sales by about 34 BkWh. Utility DSM also reduces sales by about 29 BkWh. The net impact of these factors is an increase of 46 BkWh over the 20-year period, implying a contribution to annual sales gains of 2.3 BkWh per year.

Inside Lighting. Inside lighting sales are not expected to grow significantly over the 20-year period. Customer growth and economic factors increase sales by 110 BkWh between 1990 and 2010. This increase is almost completely offset by market efficiency and utility DSM. Efficiency standards, which include national ballast and lamp standards, along with efficiency trends, are expected to reduce lighting sales by 56 BkWh. Utility DSM reduces lighting sales by another 47 BkWh. The net impact is a modest increase from 265 BkWh in 1990 to 272 BkWh in 2010. The total gain of 7 BkWh translates into an annual gain of .4 BkWh per year.

Office Equipment. Office equipment is the fastest growing commercial end use. Customer growth and economic factors contribute 11 BkWh between 1990 to 2010. In addition, the saturation of office equipment is expected to increase by 50%, which causes sales to increase by 23 BkWh. This gain is partially offset by the trend toward smaller and more-efficient equipment, which reduces sales by 9 BkWh. With little utility DSM activity anticipated in this area, the overall result is a doubling of office equipment sales from 26 BkWh in 1990 to 52 BkWh in 2010. This 26 BkWh increase translates into an annual gain of 1.3 BkWh per year.

Industrial Sector–Summary and Key Conclusions

The industrial sector consists of the following industry groups: Manufacturing (SIC 20-39), Agriculture (SIC 01-02), Mining (SIC 10-14), Construction (SIC 15-17), Municipal Water and Waste Water Treatment (SIC 49), and other portions of nonresidential energy use not covered in the commercial buildings sector. This sector has been the slowest growing sector in terms of electricity sales and peak. Between 1970 and 1990, the sales gain for this sector has averaged about 20 BkWh per year, which is 30% of the total gain. Between 1990 and 2010, electricity growth in this sector will strengthen relative to the residential and commercial sectors, reflecting the following key changes:

- The annual gain in value of shipments, which averaged $73 billion (1990 dollars) per year between

1970 and 1990, is expected to increase to $89 billion per year over the following two decades.

- Since the mid-1970s, the share of total industrial production accounted for by the most energy intensive industries declined. This downward trend is expected to flatten over the projection period.

- Significant electrification of industrial processes is expected as a result of rising fossil fuel prices, environmental restrictions, and the productivity and product-quality benefits available through the use of advanced electrotechnologies. (See Figure 10.)

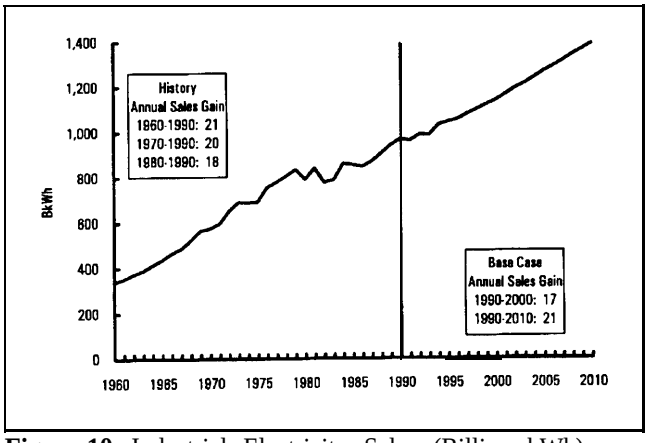

Figure 10. Industrial Electricity Sales (Billion kWh)

Decomposition of Industrial Projection

Industrial electricity sales gains are expected to increase relative to recent historical levels, largely reflecting stronger output growth. The annual growth of 21.0 BkWh per year is slightly higher than the average gain over the 1970 to 1990 period, which was 19.6 BkWh per year. This gain is equivalent to an annual growth rate of about 1.8% per year, measured relative to 1990 sales. The ten-year projection is slightly lower, with an annual gain of about 17 BkWh, giving a growth rate of 1.6%.

Customer Growth. The key driver for industrial electricity sales is the level of industrial output. Impacting factors are defense spending cutbacks, foreign competition, the strength of the dollar, labor-force growth, labor productivity, and capital investment. Base-Case growth is 2.2% per year, which reflects an annual output gain of $89 billion (1990 dollars). With industry mix and energy intensities (Btu/$ of output) held fixed, this would imply annual sales gains of about 25.1 BkWh per year.

Economic Factors. Since the mid-1970s, the top energy-intensive industries have accounted for a steadily decreasing share of total industrial production. Foreign competition and rising energy prices are key factors contributing to this decline. The pace of this downward trend is expected to ease over the projection period. With energy intensities held fixed at 1990 values, the net impact of a shift of production away from energy-intensive industries is a reduction in annual sales gains of 2.6 BkWh per year.

Electrification. The key forces expected to drive electrification of industrial processes are rising fossil fuel prices, environmental regulation, and the increased productivity and product quality gained through the use of electrotechnologies. The impact of these drivers on annual sales gains is about 7.0 BkWh per year.

Market Efficiency. Strong efficiency gains are expected from more efficient motors, increased use of electronic adjustable speed drives, improved lighting efficiency, and more efficient process configurations. These changes result from continuation of efficiency improvements that have already occurred in an attempt to reduce operating costs as well as further improvements mandated by federal and state standards. The impact of these drivers on annual sales gains is about -5.9 BkWh per year.

Utility DSM. DSM programs impact equipment efficiency, process configurations, and operating behavior. Significant impacts are expected from installation of electronic adjustable speed drives and improved process configurations. The net effect averages to a reduction in annual sales growth of 3.2 BkWh per year between 1990 and 2000. This impact is about one third of the combined "conservation" savings from efficiency gains and DSM. Between 1990 and 2010, the extended DSM impact averages -2.6 BkWh, reflecting the assumption of smaller impacts in the retrofit and replacement markets beyond 2000. (See Figures 11 and 12.)

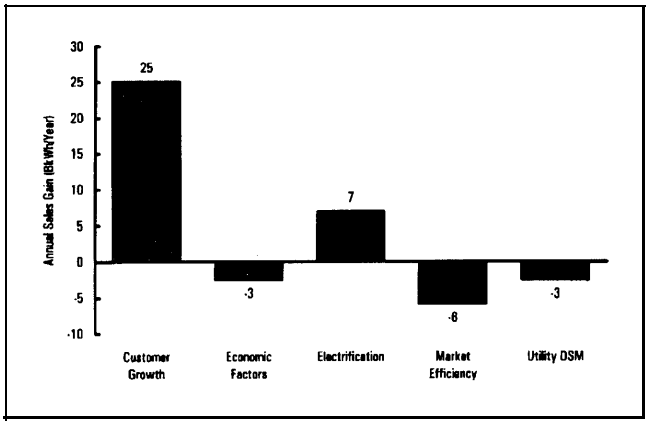

Figure 11. Impacts on Annual Sales Growth (1990-2010)

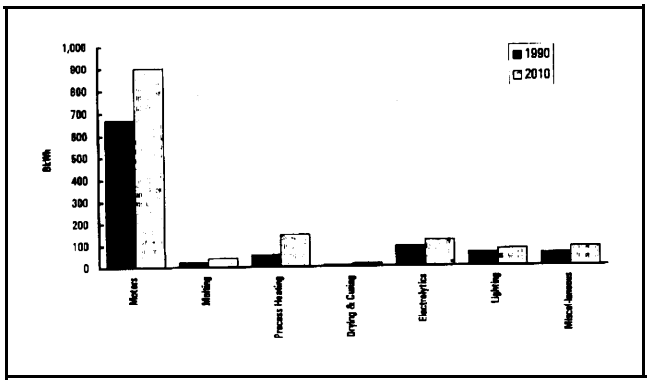

Figure 12. Industrial Sales by End Use: 1990 and 2010 (BkWh)

Industrial End-Use Results

The discussion above focused on the factors that drive the electricity forecast. Industrial growth and economic factors affect all end uses similarly. However, electrification, market efficiency, and utility DSM have different effects on each end use. The following discussion summarizes the changes for some of the main industrial end-use categories.

Motors. Electric motors are the dominant industrial end use, accounting for 69% of 1990 industrial electricity sales. Between 1990 and 2010, industrial growth and economic factors are expected to increase annual motor energy use by about 306 BkWh. Automation, through a 6% increase in motor stock, causes sales to increase by an additional 62 BkWh.

These gains are partially offset by trends towards more efficient sizing and use of motors, increased saturation of adjustable speed drives, and increased shares for high-efficiency motors. The trend to high-efficiency motors is certain as a result of the Energy Policy Act, which makes premium efficiency options mandatory for the main motor categories beyond 1998. Market efficiency impacts combine to reduce motor electricity use by about 93 BkWh by 2010, a decrease of 9%. Utility DSM is expected to reduce motor-related electricity use further by about 44 BkWh. The overall impact of these factors is that motor energy use is expected to increase by 35% over the 20-year period, from a level of 670 BkWh in 1990 to 901 BkWh in 2010. This increase of 231 BkWh implies a contribution to annual sales gains of 11.6 BkWh per year.

Process Heating. Process heating is found primarily in Transportation Equipment, Fabricated Metal Products, and Industrial Machinery and Equipment. The net impact of growth and economic factors on process heating energy use is a gain of 41 BkWh between 1990 and 2010. Electrification, in part through increased use of technologies like induction, microwave, and radio-frequency heating, is expected to increase sales by an additional 60 BkWh. Market efficiency, including naturally occurring efficiency trends and the development of less energy-intensive products, reduces sales by 8 BkWh, followed by utility DSM reductions of about 1 BkWh. The overall result of these factors is that process heating energy use is expected to increase by over 160%, from a starting value of 55 BkWh in 1990 to 147 BkWh in 2010. This increase of 92 BkWh implies a contribution to annual sales gains of 4.6 BkWh per year.

Electrolytic. Electricity use for electrolytic processes is concentrated in Primary Metals Production and Chemical and Allied Products. Between 1990 and 2010, the net impact of growth and economic factors on electricity use for electrolytic processes is a gain of 40 BkWh. Market efficiency and utility DSM combine to reduce usage by about 11 BkWh. The net impact of these factors is an increase of 29 BkWh, from a starting value of 91 BkWh in 1990 to a final value of 120 BkWh in 2010. This increase implies a contribution to annual sales gains of almost 1.5 BkWh per year.

Reference

Regional Economic Research, Inc. and Barakat & Chamberlin. August 1993. *Drivers of Electricity Growth and the Role of Utility Demand-Side Management.* Report TR-102639, Electric Power Research Institute, Palo Alto, California.