Climate Change: Update on International Negotiations

Linda Silverman
U.S. Department of Energy

5th Annual Clean-Coal Technology Conference

January 9, 1997

U.N. Framework Convention on Climate Change

- signed at Earth Summit in Rio (June 1992)
- entered into force in March 1994
- contains non-binding "aim" to stabilize greenhouse gas emissions in developed countries (Annex I) to 1990 levels by 2000

U.S. Plan -- *Climate Change Action Plan (October 1993)*

- *44 mitigation actions*
- *reduction of 106 MMT not realized due to faster than expected economic growth, lower than expected oil prices, and reduced funding for CCAP actions*
- *Germany and UK the only OECD countries that will meet 2000 aim*

COP I in Berlin (March 1995)

Resulted in Berlin Mandate focused on post-2000 period

- QELROs (quantified emissions limitations and reductions objectives)
- Policies and Measures
- no new commitments for developing countries
- JI pilot: "Activities Implemented Jointly"

COP II in Geneva (July 1996)

- *Geneva Declaration: calls for Annex I Parties to adopt **legally binding** commitments by COP 3 (Dec 97)*
- *Based on science contained in IPCC Second Assessment Report (Dec 96)*
- *U.S. Position: verifiable, medium-term targets that are realistic & achievable, with maximum flexibility (with emissions trading and joint implementation)*

Current issues to be resolved:

- *QELROs or Targets/Timetables*
- *Policies and Measures*
- *Advancing Commitments of all Parties*
- *Compliance*

QELROs
Defining the Form of the Target

- Flat Target vs. Multi-year Target
- Differentiation among Annex I Parties
- Comprehensive (or all gas) approach
- Flexibility: Emissions Trading & Joint Implementation with credit

Policies and Measures

- European Union supports harmonized policies and measures
- U.S. opposes harmonized policies and measures

Continuing to Advance Commitments of all Parties

- Article 4.1: inventory, mitigation, adaptation, national communications, technology transfer, financial resources
- Developing countries believe Annex I has not lived up to commitments
- What happens with developing countries in the Kyoto agreement?

Implications for Clean-Coal Technology

- *binding target would increase need for clean coal technology*
- *joint implementation with credit could expand technology export opportunities*
- *could spur R&D funding*
- *implementation flexibility increased with emissions trading and JI + credit*

**Domestic Environmental Requirements,
New and Projected**

5th ANNUAL CLEAN COAL TECHNOLOGY CONFERENCE

Remarks of
Brian J. McLean,
U.S. EPA

January 9, 1996
Tampa, Florida

ENVIRONMENTAL CONCERNS

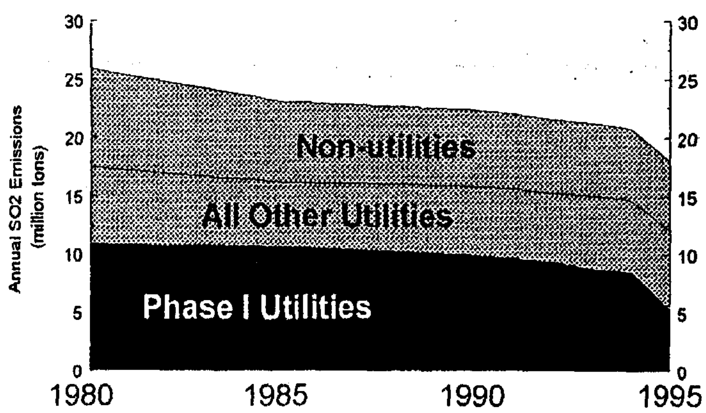
Public Health	Environment
Ozone	Acidification
Fine Particles	Eutrophication
Toxics	Materials Damage
	Crop/Forest Damage
	Visibility/Regional Haze

Climate Change

GOAL OF TITLE IV

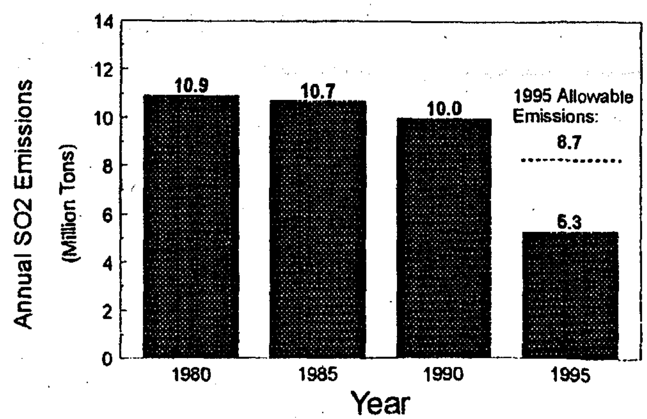
To reduce SO2 and NOx from power generation as cost-effectively as possible in order to protect public health and the environment

NATIONAL SO2 EMISSIONS All Sources

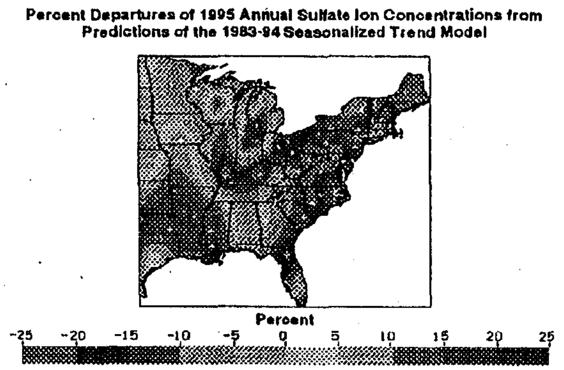


SO2 Emissions

445 Phase I Affected Utility Units



REDUCTIONS IN WET SULFATE DEPOSITION



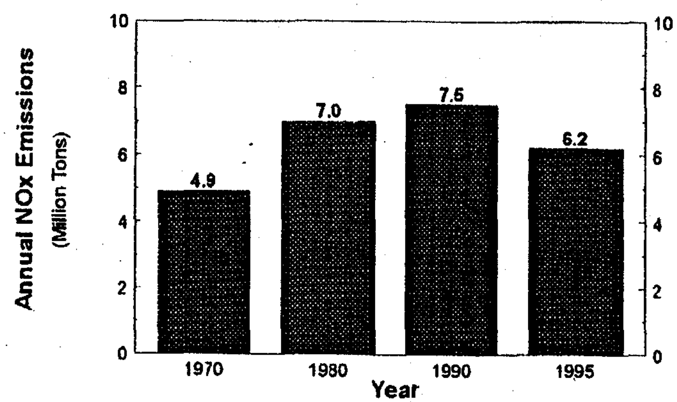
SO2 ALLOWANCE PROGRAM: BENEFITS

- Health: $12 - 40 billion per year by 2010
- Visibility: $3.5 billion per year by 2010
- Fewer acidic lakes & streams
- Reduced damage to buildings & monuments

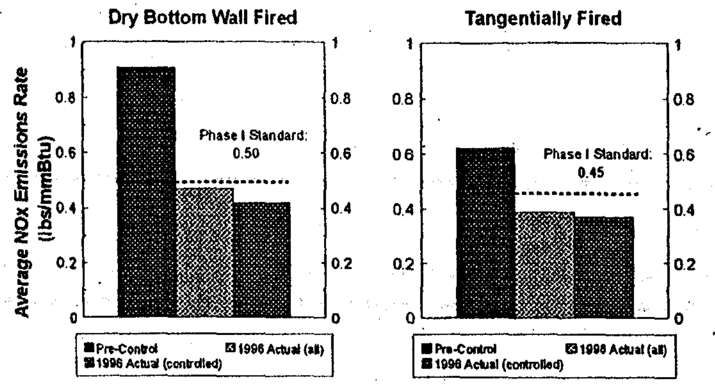
SO2 ALLOWANCE PROGRAM: COSTS

- In 1990, estimated to cost $4 billion per year by 2010
- By 1994, estimated cost dropped to $2 billion per year by 2010
- Less than half the cost of command and control: $5 billion per year
- 1 percent of government air pollution control personnel for 40 percent of emissions reductions under 1990 Clean Air Act

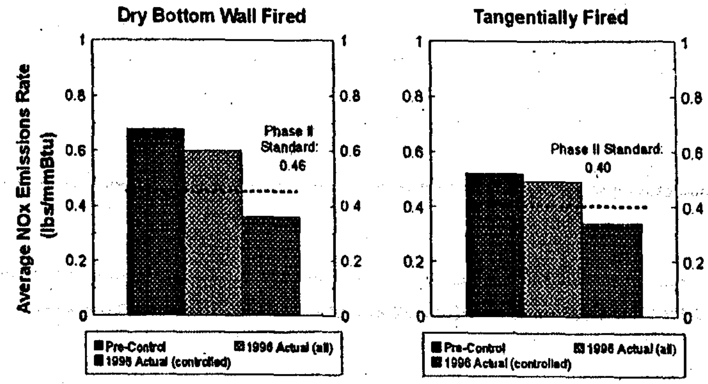
UTILITY NOX EMISSIONS (1/3 of total U.S. NOx emissions)



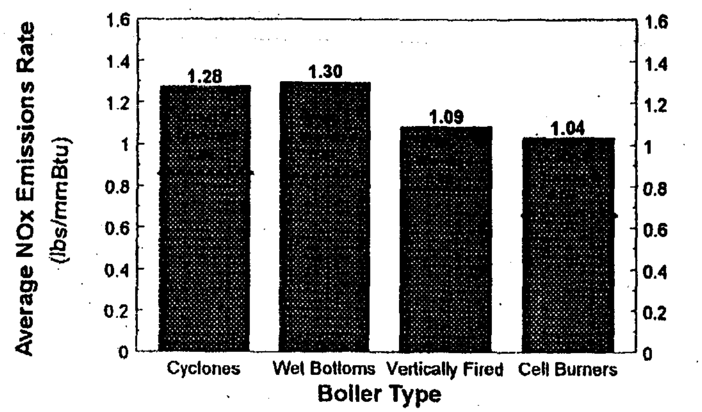
Group 1, Phase I NOx Emission Rates



Group 1, Phase II NOx Emission Rates



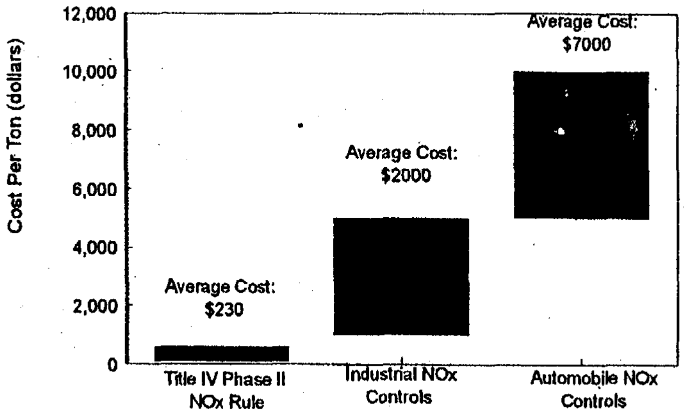
GROUP 2 BOILERS NOx EMISSION RATES



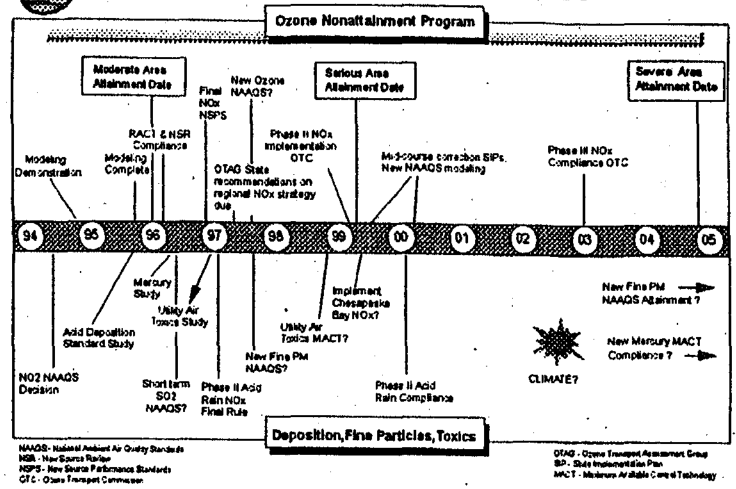
NOx COMPLIANCE OPTIONS

- Boiler-by- boiler compliance with annual emission limitation
- Emissions averaging across holding or operating company
- Alternative Emission Limitations (AEL) for boilers unable to meet limits with Low NOx Burners (LNB's) or Group 2 Technology
- Early Election option for Phase II, Group 1 boilers
- Cap & Trade option for Phase II boilers

COST EFFECTIVENESS OF NOx CONTROL (by Source Category)



Electric Power Regulations Timeline - Clean Air Act



CLEAN AIR POWER INITIATIVE

Goal: To develop an integrated strategy for achieving the goals of the Clean Air Act with respect to the power generating industry

WHAT WOULD A NEW APPROACH LOOK LIKE?

- Translate health & environmental goals into emission targets
- Employ cap & trade with banking
- Provide more certainty, flexibility, & cost savings
- Reduce continuous and disjointed regulatory hits

SCENARIOS ANALYZED

- Traditional Regulatory Approach
- Nationwide caps on NOx, SOx, (and possibly mercury), with trading & banking

SO2 CAP & TRADE SCENARIOS ANALYZED

- Lowered Title IV allowance allocations by 50 percent in 2010
- Lowered Title IV allowance allocations by 60 percent in 2010
- Lowered Title IV allowance allocations by 50 percent in 2005

NOx CAP & TRADE SCENARIOS ANALYZED

Year 2000

Set allowance caps based on Title IV NOx rule

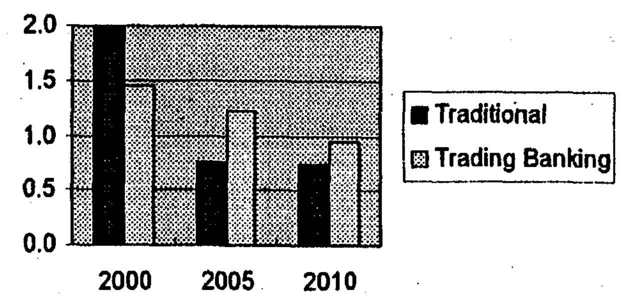
Summer = 2.2 million tons

Winter = 2.9 million tons

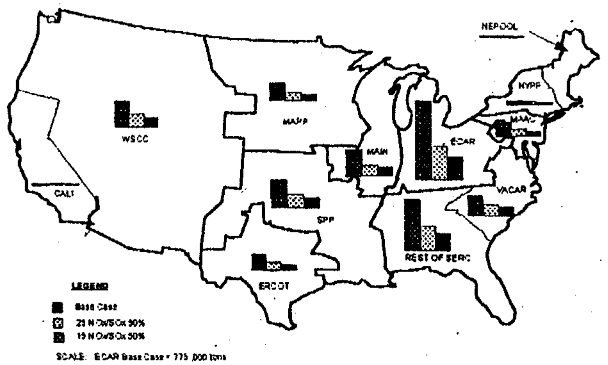
Year 2005 (3 Scenarios)

Lowered summer allowance cap to 1.3 million tons, 1.0 million tons, and 0.8 million tons (based on 0.25, 0.20, & 0.15 lbs/mmBtu rates)

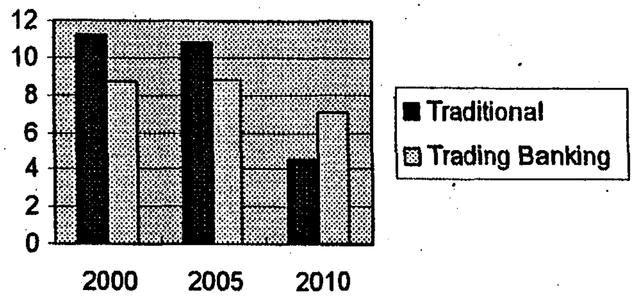
Summer NOx Emissions of the Traditional and 0.15 NOx/SOx 50% Trading/Banking Options (million tons)



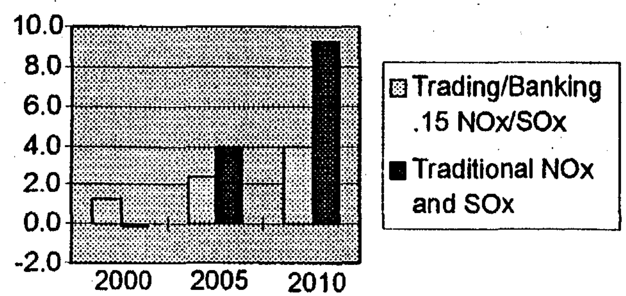
Comparison of Summer NOx Levels in 2010 for the 0.15 and 0.25 Options



SOx Emissions of the Traditional and 0.15 NOx/SOx 50% Options (million tons)



Costs of Traditional vs Trading/Banking Approach to NOx and SOx ($Billions)



For More Information on The Acid Rain Program or CAPI

Visit our Acid Rain Home Page:
http://www.epa.gov/acidrain/ardhome.html

Visit our CAPI Home Page:
http://www.epa.gov/capi

Coal

Cornerstone of America's Competitive Advantage in World Markets

For
Center for Energy & Economic Development
National Mining Association
Western Fuels Association

By Mark P. Mills
Mills•McCarthy & Associates Inc.
6900 Wisconsin Avenue, Suite 700
Chevy Chase, MD 20815

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Contents

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Key Findings

Key Finding #1

Coal-fired electric generation is a major contributor to the U.S. dominance in the world's economy.

Study Support

- U.S. industrial and small business electric rates are among the lowest in the world.
- U.S. has world's largest fleet of coal-fired power plants. Majority (56%) of U.S. electricity is coal-fired.
- The central advantage for U.S. electricity consumers is that electricity producers pay less for fuel.
- U.S. manufacturers are 50% more productive than just two decades ago. Electric technologies fueled by low-cost electricity are a primary factor in this progress.
- Over the past two decades non-electric non-transportation energy use fell 10% while electric energy use rose 70%. This tracks productivity increases.

Key Finding #2

Coal-fired generation will supply a majority of the nation's growth in electric needs for the next 10-15 years.

Study Support

- A competitive electricity market will seek the lowest cost supply.
- Industry-wide forecasts show coal taking a 44 to 77% share of electric growth to 2010.
- GRI predicts 60% of future electricity through 2015 will come from coal use in existing plants.
- Over 85,000 MW of coal-fired capability exists without additional "green field" construction through the greater use of existing coal-fired capacity.

Key Finding #3

Low-cost electricity is crucial to the future productivity, competitiveness, and economic health of our nation.

Study Support

- Productivity is driven by technology. New non-transportation technology is dominantly electric in nature. Low-cost electricity accelerates these technologies.
- Productivity growth over the past two decades is projected to continue in critical industries and is highest in electric dominant industries.
- U.S. electric demand and GDP have grown together, over 60%, since 1975.
- U.S. spends more on electric energy ($200 billion annually) than any other commodity.

Key Finding #4

Emissions associated with coal-fired electricity will continue to decrease despite increased use of coal.

Study Support

- U.S. EPA projects a 24% increase in coal use, along with a 15% and 37% decline, respectively, in nitrogen oxide(NO_x) and sulfur dioxide(SO_2) emissions by 2010 from all coal-fired generation due to improvements in emissions controls.
- Taking into account total fuel cycle impact of electric technologies -- end-use emissions reductions from electric technologies -- there will be an even greater decline in critical smog precursors than projected by EPA.
- If 50% of new electric supply is coal-fired, the emissions reduction arising from the new uses of electrotechnologies will yield a net annual decline of about four million tons NOx and one billion tons CO_2 per year.

Executive Summary

The United States' competitive position in world markets will be determined by many forces. Two of the fundamental factors are the increased use of new technologies, and the availability of low-cost electricity to operate those technologies. The U.S. currently has and will likely continue to have market dominance in both these critical areas. Both of these factors are intimately related since the primary source of new technologies is electric in nature. And, because low-cost coal now dominates and will continue to dominate the electric supply system, and because the U.S. has both an abundance of coal and the world's largest fleet of coal-fired power plants, the U.S. will have an expanding base of low-cost electricity that will secure its current competitive advantage for years to come.

Electric technologies and, increasingly, computer-based technologies integrated with electric technologies are the primary sources of innovative advancement and economic growth. As a consequence, the growth in electricity, which has historically tracked GNP growth, is expected to continue. And, with the restructuring of the electric utility industry and the emergence of vigorous competition, prices are expected to decline as competition increases. The net effect of these forces will be to dramatically increase the use of electric technologies—and those sources of electricity that can provide low-cost electricity. The data show that coal, the primary source of new low-cost electricity, will supply between one-half and three-fourths of all new electric supply through 2010, at prices of about 3¢/kWh, and can do so without new power plant construction. Since the use of coal is expected to rise by at least 200 to 250 million tons/year over the current consumption of 850 million tons, and could increase as much as 400 million tons/yr, some have raised concerns about the emissions impact from the power plants. *This report also shows that the net effect of increased electric use, assuming coal dominance, will be a decrease in emissions.* This decrease will occur for two reasons: a) power plants are becoming increasingly clean, and b) the electric technologies that consume the electricity displace more emissions than are created at the power plants.

The bottom line for America:

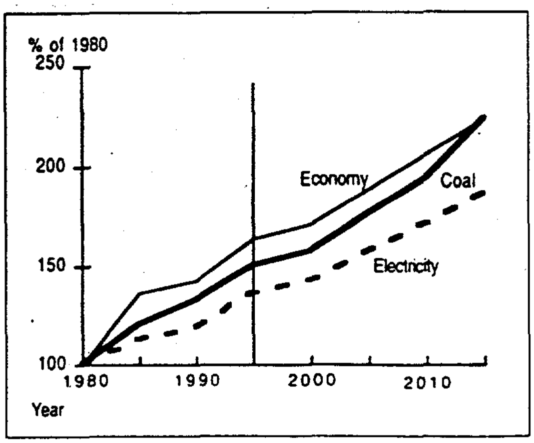
- **Improved economy**
  Lower cost electricity stimulates greater demand for electricity. Electric demand is a direct measure of the use of electric technologies, which will, through their productivity benefits, boost the U.S. economy.

- **Increased U.S. competitiveness**
  Electric technologies dominate the productivity growth of an economy. Low prices stimulate greater use of electric technologies. U.S. global economic power will be powerfully reinforced and protected by an economy with low-cost electricity.

- **Moderate inflation**
  When any commodity is projected to have stable and declining prices, economists predict low inflation. Since *electricity is the biggest commodity* bought and sold in our nation— three times the size of the second largest commodity—low and declining electric rates will moderate inflationary pressure for years to come, thereby protecting the integrity of savings and investments.

- **Reduce environmental impact**
  With the growing use of advanced electric technologies, the overall use of materials will decline. This will lead to declining use of hazordous chemicals, reduced land use, and reduced air emissions.

Growth in the Economy, Electricity and Coal Consumption



Data from DOE/EIA & EPA

Introduction

Competition. This word dominates discussions in and around the electric utility industry today. Understandably. Without regard to the effect on individual utilities, the pending changes to the regulations surrounding electric utilities have a potential impact at least comparable, over time, to those associated with or predicted to arise from the *Telecommunications Act of 1996*. This is true, if for no other reason than, because the electricity business alone has revenues equal to all of the major telecommunications activities combined; local exchange, long distance, cable, and cellular.

The focus of much of the discussion on the impact of legislative or regulatory changes leading to greater electric-sector competition has been on issues such as identifying the corporate winners and losers: tracking mergers and acquisitions; and—the most widely covered issue in the popular press—gauging the price consumers will pay for a kilowatt-hour. The popular and trade press, as well as state regulators and the U.S. EPA, have also focused on potential changes in power plant emissions.

All of these are important issues, but they all miss the central impact. Regardless of the form that regulations and legislation ultimately take, utilities are in a more competitive environment. The effect of this competition will be cheaper electricity for most customers, fewer new power plants being built (likely none for a while) and more coal being used to make electricity. Because of how, why and where electricity is used, profound economic implications from these changes are in store for the American economy that go far beyond receiving a lower electric bill. The changes underway in the electric sector will ultimately be seen as one of the single most important structural changes in our economy undertaken in decades. These changes presage a new age of enhanced and robust competitiveness on the part of the U.S. economy in world markets because of the central role that electricity and electric technologies play.

This paper summarizes the results of analyses and research undertaken over the past several years, including frequent presentations as expert testimony before many state regulators. In addition, this paper brings together the results of a new analysis regarding the potential future value of the nation's investment in coal-fired electric power plants.

Background

Coal: the cornerstone of America's competitive economic advantage? The 21st century is next door and the Information Age is dawning. How can coal be a cornerstone of anything but a monument to the historic achievements of the 20th Century? The answer can be summarized by a single word: connections. There are tight, demonstrable and critical connections between primary energy sources, electricity, new technologies, and the nation's economy. **This report is about those connections and the relevance of those connections to one of the largest industries in the nation, the electric utility industry.** This industry is undergoing changes now that are as dramatic and tumultuous as any time in this century. This report is about the relevance of those connections to businesses, jobs and **the American worker. And, critically, this report is about the relevance of those connections to coal, the primary source of fuel for the American economy.**

The seemingly tenuous connection between coal and our high-tech dominated economy is in fact fundamental. Basic inputs are connected to our day-to-day life, no matter how high-tech that life becomes. For example, soil and water—two of the oldest ingredients supporting life and civilization—are essential and hardly high-tech or 'modern'. They are nonetheless self-evident starting points for the food chain that leads to our dinner table, regardless of how exotic the meal. Basic energy sources are similar starting points in the "chain" that supports essentially everything in society. Like soil and water, coal and oil are the two primary starting points.

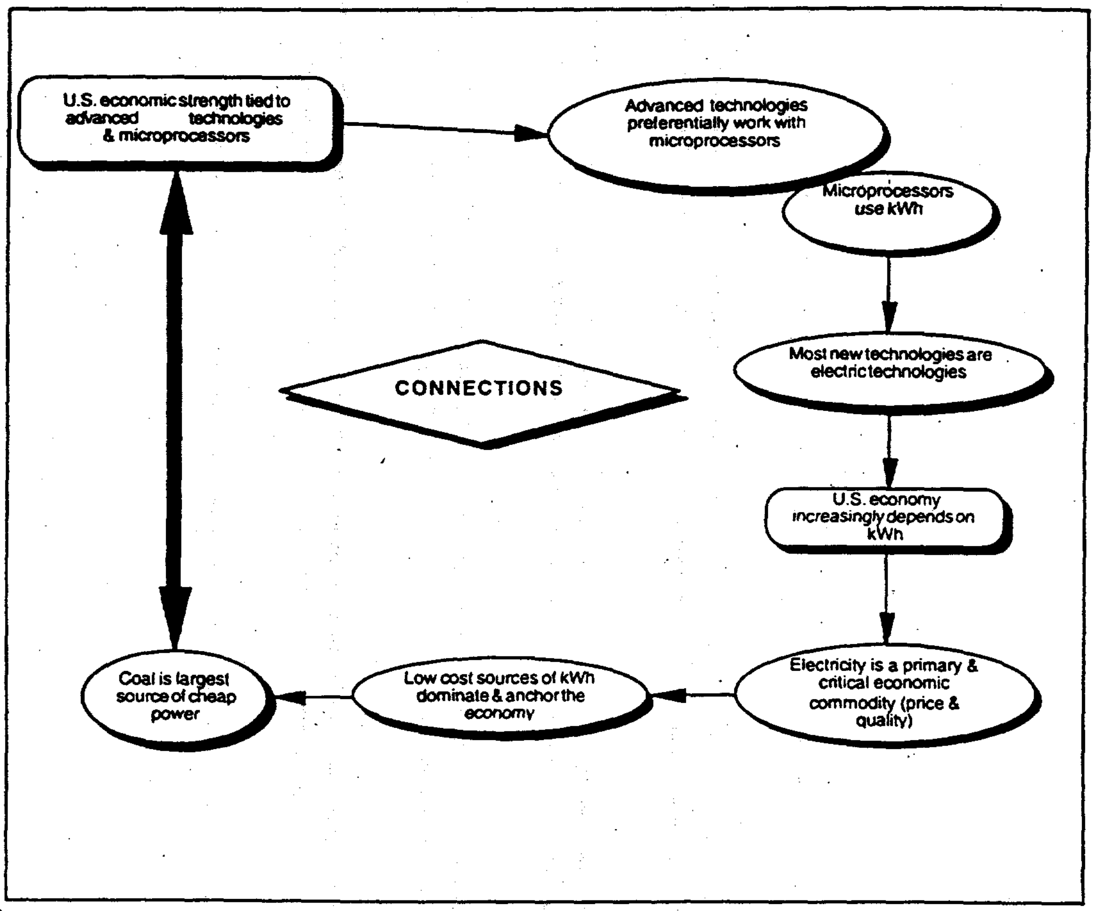
Changes in one part of a technology "food chain" can be felt rapidly throughout the economy. Economists talk about ripples through the economy from basic commodity price changes. The price of wheat, metals and other commodities do ripple through the economic system. The ripple of changes in energy commodities tends to move rapidly. Recently, the basic price and availability of crude oil changed and consumers quickly saw gasoline prices rise—and shortly start to fall again. When it comes to electricity—the biggest commodity in the economy—changes (when they occur) won't work like ripples, but will move at lightning speed through the economy and will have a larger effect.

This reality is the driving force behind the changes that are currently shaking the entire electric utility industry. As this report shows, neither gasoline nor oil, while important, are the underlying energy driving forces of the economy. Electricity, and specifically the technologies that use it, is the single largest factor supporting the economy. (Over three times as much money is spent each year on electricity as is spent on gasoline.)

If the direct linkage between coal and our high-tech economic well-being does lead to greater use of coal, as this report shows, will this linkage be bad for the environment—as some claim? This concern is also addressed in this analysis. The reason that this environmental concern is misplaced? Again, connections. ***The electricity from power plants, and thus the emissions from those plants, is directly connected to the emissions eliminated by electrotechnologies that use the electricity. The true net environmental impact can only be determined by comparing the two sources of emissions: emissions from power plants must be compared to, and are offset by, decreases in emissions from end-uses of electric technologies. This connection is real—and typically results in net reductions in emissions to the atmosphere.***

This report is structured in a conventional "building block" fashion, outlining key points and facts and then establishing the link to the next step in building the connections in the chain that anchors the nation's future as a high-tech economy with coal as the primary fuel support.

Connections in the U.S. Economy



There is a strong demonstrable chain of events and technologies that link coal to the health and strength of the U.S. economy.

Technology & Economic Growth

Economist Paul Romer is making waves in the theoretical field of economics with his model that establishes a clear linkage between knowledge, technology and economic growth. Romer's contribution is not the notion that technology growth drives the economy—this is common wisdom—but in providing a rigorous mechanism for observing and predicting the relationship, something economists have never been able to do. If Romer's modeling techniques hold up to scrutiny, some of his colleagues predict a Nobel Prize.

The link between technology and productivity, and its importance is evident in various basic indicators. This evidence is the first step in connecting the economy, through technology to electric technologies and to low-cost coal-fired electricity.

A common issue for policy planners seeking to spur the economy is to find ways to encourage companies to invest in new technologies. Spurring investment requires an understanding of how businesses can finance capital acquisitions and issues pertaining to integration of new equipment and processes into existing operations, training, maintenance, and reliability. Investment in new technology brings financial rewards for companies which become more competitive, and for employees—through the retention both of existing jobs as well as creation of new jobs—and, ultimately, growing income for both employer and employee.

Studies consistently show that machinery and equipment investment have a strong predictive value and relationship to economic growth. No other investment factor is as strongly correlated with economic growth. And, as *Table 1* shows, not only has capital investment in equipment (i.e., new technology) rebounded in recent years, but at the same time investment in computer-related equipment is soaring. As *Table 1* shows, the growth rate in spending on equipment is at a higher level than during any business expansion cycle of the past thirty years. Similarly, business investment in computer-related equipment is growing even more rapidly.

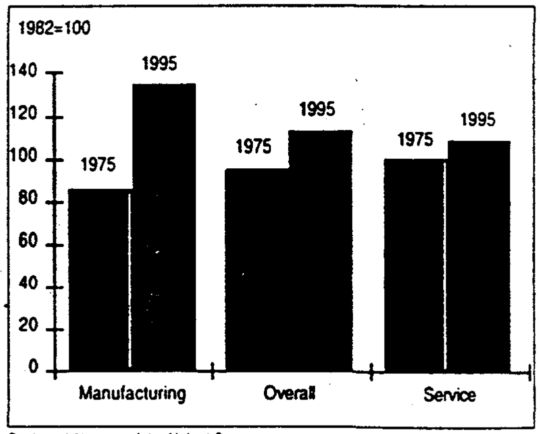
Table 1
Increase in Spending on Equipment
(During business expansion cycles)
(constant inflation-adjusted $)

Period	On Computer	All Equipment (excl. computer)
1962-66	34%	76%
1972-73	57%	34%
1976-79	170%	41%
1983-85	153%	21%

Fortune, April 3, 1995

The investments are often synergistic—that is, the computer-related equipment is used for or is an integral part of the "other" equipment. For example, more than half of all machine tool orders now incorporate a computer-driven control system, often one that can work on a computer/communications network. (*Fortune*, Dec. 13, 1994, "Welcome to the Revolution.") Both of these factors have direct relevance to the form of energy that businesses require, which is typically electrical, as we explore in the next section.

Figure 1
U.S. Productivity

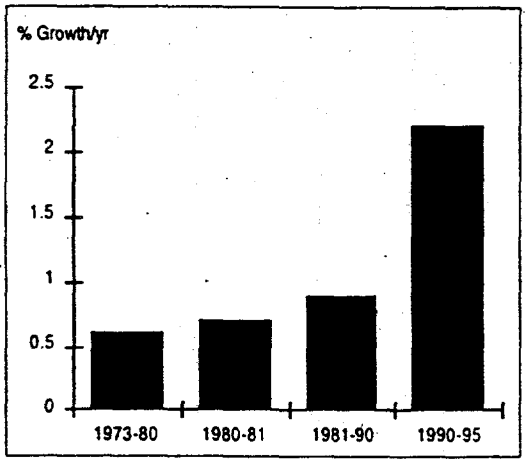


Statistical Abstract of the United States

The primary impact of new technologies on businesses is an increase in productivity. Productivity growth is what permits businesses to extract more value from the same inputs, and to increase wages while remaining competitive. In what amounts to a stealth revolution, U.S. manufacturing productivity growth has taken off over the past decade as businesses have adapted to new technologies. *Figure 1* illustrates the trends for manufacturing, the service sector, and the two blended as an overall U.S. trend. Manufacturing exports continue to be a critical part of U.S. competitiveness. U.S. manufacturing productivity is over 50% higher today than only two decades ago. This type of growth arises primarly from the use of new technologies.

The productivity growth trend is likely to both continue and to accelerate because U.S. firms in recent years have been spending more on capital equipment — new technologies — than at any time since the 1960s. (*Fortune*, April 3, 1995, p. 33). The U.S. already has the world's most productive economy. And recent events suggest even greater economic opportunity for the nation, as *Figure 2* shows.

Figure 2
Business Productivity Growth Between Business Cycle Peaks



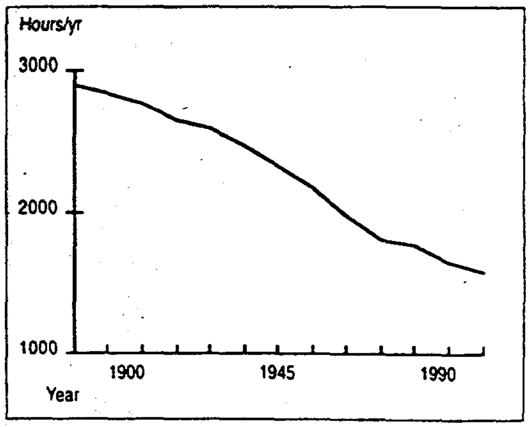
Business Week Oct. 9, 1995

Figure 2 illustrates the productivity growth rate measured during each of the productivity growth cycles of the past two decades. The most recent cycle, 1990-1995, has experienced unprecedented productivity growth at just over 2% per year, more than twice the growth rate of any previous business cycle of the past two decades.

The overall effect of new technologies and rising productivity is to increase the size of the economy and to increase personal wealth. **For example, if over the past decade the annual growth rate in productivity in the U.S. had been one-half of one percentage point higher per year, it would have yielded $1.5 trillion more in the economy, or $10,000 per household** (*Business Week*, October 9,1995 "Riding High").

Over time, new technologies and productivity growth also have the effect of reducing the amount of time the average person has to work to make a living. While everyone seems to instinctively understand this factor, the data are dramatic. *Figure 3* shows the trend of the past century during which average hours worked per year have been declining continuously. This means that people are on average earning more and working less, a trend that is made possible almost exclusively by increased productivity.

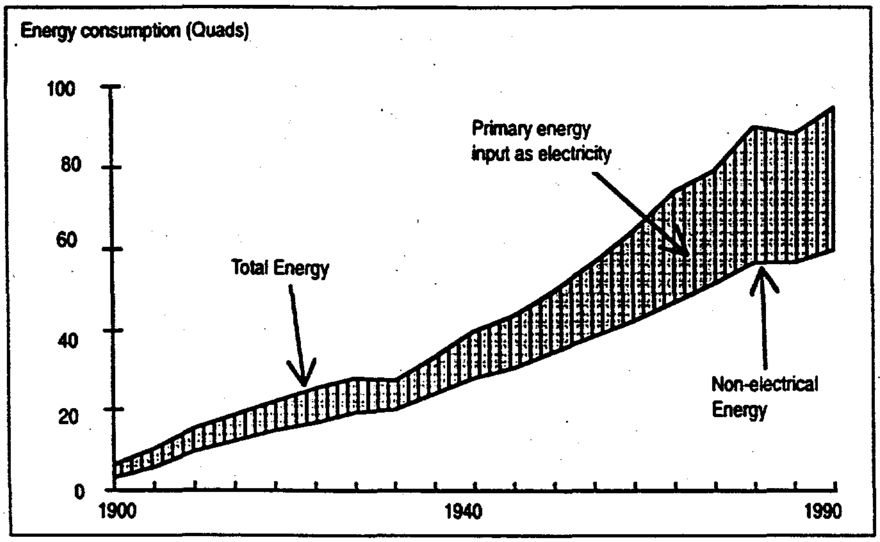
Figure 3
Average Annual Hours Worked in the U.S.



Ausubel & Gruebel, Technology Forecasting and Social Change, 1995

The relationship between growth in technologies and the economy is almost intuitively obvious. Perhaps less obvious is the role that electrotechnologies and, specifically, electricity have played in fueling this important economic and social trend. Considerable research has been devoted to demonstrating the important effect of electrification—increased use of electrotechnologies—on the American workplace. *Figure 4* suggests strongly that there is a linkage, one that is explored in greater detail in the next section. *Figure 4* illustrates that over the past two decades the nation's dependence on non-electric energy—i.e., on equipment that is combustion-based—dropped dramatically, while electricity use continued to rise.[1]

Figure 4
Historic Use of Electricity & Energy in the U.S.



DOE/EIA Annual Energy Review

1 To be sure, some of this effect is attributable to increased efficiency with which combustion fuels are used in equipment (conservation); but as the Technical Appendix outlines, improved efficiency of combustion equipment (notably cars) took place at the same time as improved efficiency of electric equipment (notably lights, refrigerators and motors), and furthermore, the combustion-conservation effect cannot account for the growing appetite for electric energy.

Electric Technologies: What Role in the Economy?

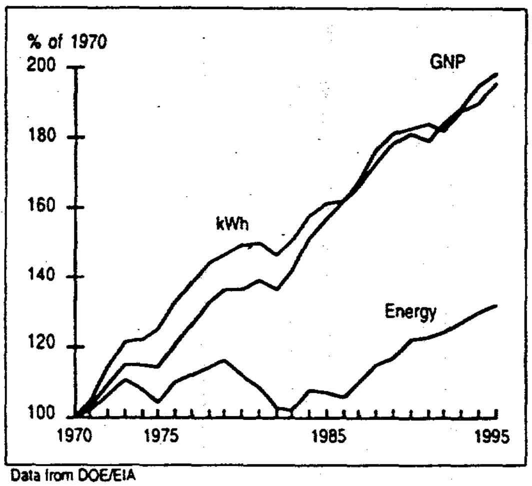
How significant are electric technologies in the context of all technology advancement? One obvious way to see the overall role of electric technologies as compared to fuel-based technologies is through the aggregate consumption of electricity. Clearly, significant increase in the use of electric technologies will appear as growth in consumption of electricity, and the extent to which electricity use tracks economic growth.

The kilowatt-hour and economic relationship, as a surrogate for electric technology growth, can be seen by looking at three data sets:

a) trends in the recent past,
b) current relationships, and
c) future projections.

Figure 5 illustrates trends of the **recent past** for the U.S., wherein it is clear that there is a close linkage between the growth in the economy and the increased use of electricity—which is fundamentally a direct measure of increased use of electric technologies.

Figure 5
U.S. Trends Excluding Transportation



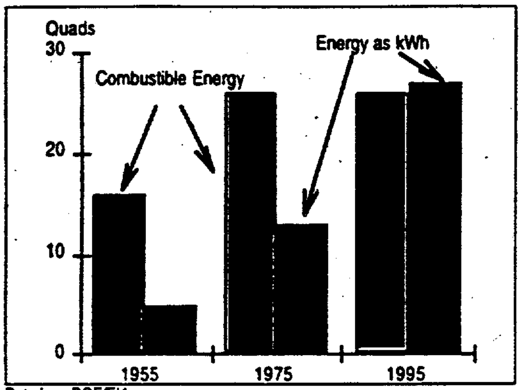
Data from DOE/EIA

Figure 5 excludes data relating to transportation energy use and the transportation sector's direct contribution to the Gross National Product. The reason for this is simple. Trends in transportation fuel use have virtually nothing to do with the electric sector. The transportation sector depends almost exclusively on oil—using over two-thirds of all oil, and less than 0.1 % of all electricity production. In addition, the transportation sectors direct contribution to the GNP totals under 10%. **Meanwhile, the other three major sectors of the economy—industrial, commercial and residential—account for 90% of the GNP, and consume 99.9% of all electricity.**

The continued growth in preference for electric-based technology, reflected in electric energy usage, can be seen by looking at the data in a slightly different way. In the past, the majority of equipment used in the economy has been in the form of combustible energy—primarily, oil, natural gas, and, earlier, the direct combustion of coal. As *Figure 6* shows, as recently as 20 years ago, nearly twice as much energy was purchased as combustible fuels than as in the form of electricity. This means that the majority of equipment being used in the marketplace (again excluding transportation) required combustible fuels—not electricity. Over the past two decades, a transformation has occurred. **Today, electricity provides for over one-half of all energy used by equipment in the industrial, commercial, and residential sectors.**

Not only have electric technologies been the primary source of new equipment purchases, but electric technologies must also have been replacing the use of existing fuel-based technologies over that two-decade period in order to lead to an energy transformation of this magnitude.

Figure 6
Uses of Energy by the Industrial, Commercial & Residential Sectors



Data from DOE/EIA

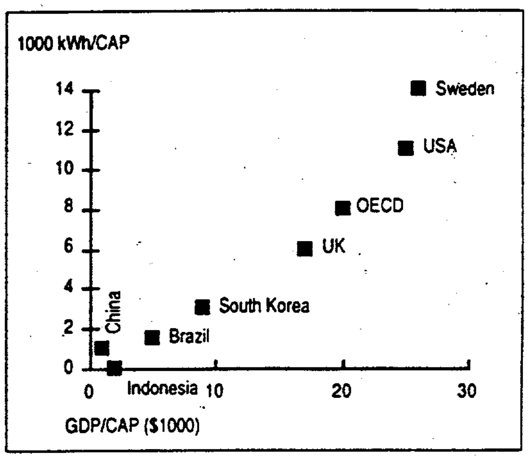
The linkage between electric technologies and economic growth was exhaustively documented in one of the most comprehensive explorations to date, undertaken a decade ago by the National Academy of Sciences (NAS). The NAS study, *Electricity in Economic Growth*, National Research Council, National Academy of Sciences, 1986, concluded:

"To foster increased productivity, policy should stimulate increased efficiency of electricity use, promote the implementation of electric technologies when they are economically justified, and seek to lower the real costs of electricity supply by removing any regulatory impediments and developing promising technologies to provide electricity."[emphasis added]

The close relationship between increased use of electric technologies (again, measured as rising kWh consumption) and the economy is not unique to the United States. As the graphs in *Figure 7* (next page) show, the relationship has been as strong, or stronger, in other industrial nations.

The present relationship
Just as the historic trends show a strong link between electricity and economic growth, so too do present data. This relationship is visible in current country-to-country comparisons. As *Figure 8* shows, a striking relationship exists between the per capita consumption of electricity among countries around the world today and the per capita income in those countries. The wealthier the citizens, the more electricity used per person. This, of course, is not a measure of electricity use per household, but total electricity use in the economy, measured per person. This is, in other words, a direct measurement of the effect of increased productivity providing greater individual wealth—productivity driven by technology, and technology that is dominantly electric in nature.

Figure 8
National Income & Electricity

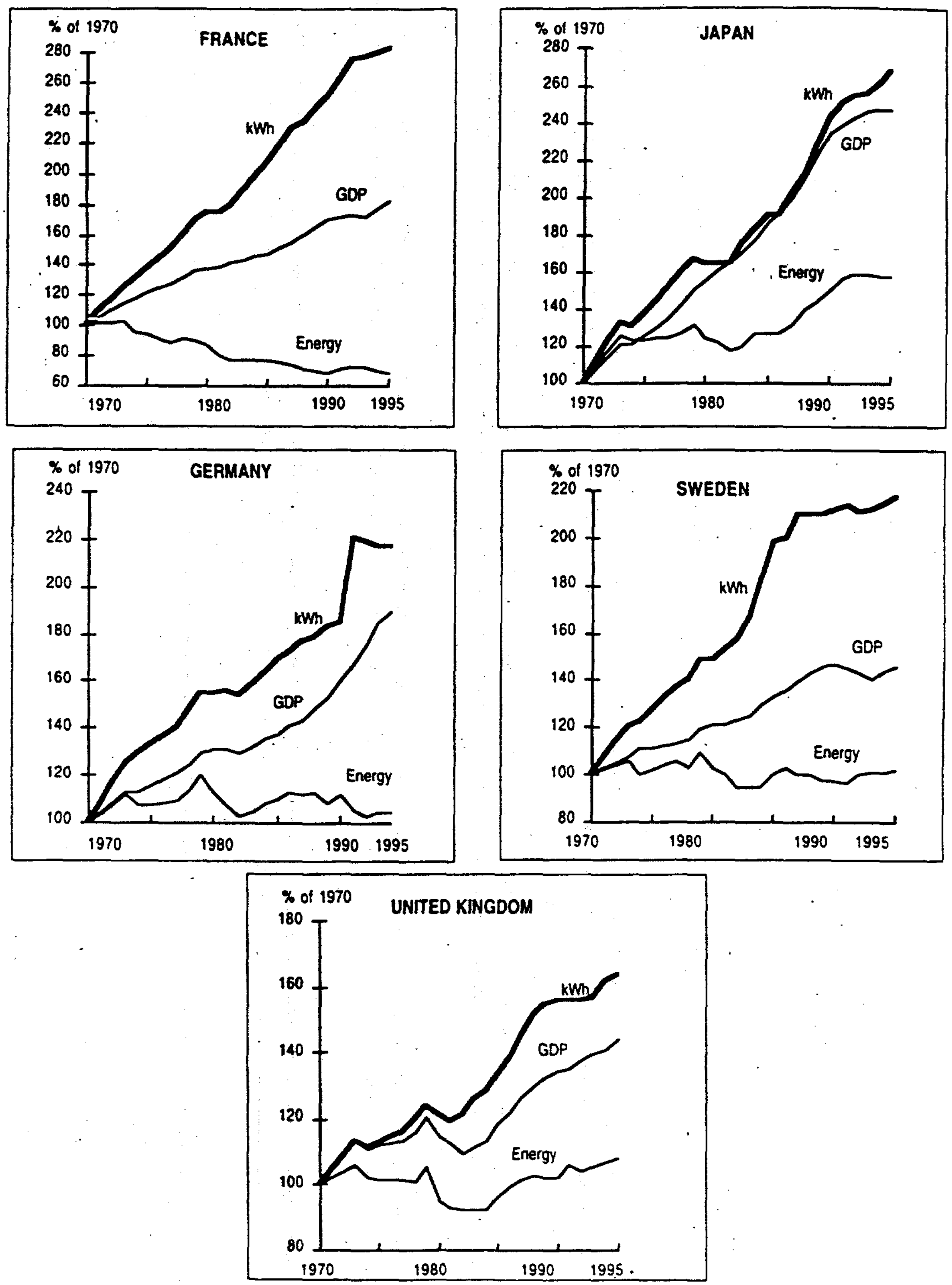


Data from OECD

Figure 9 is another way to look at the same overall effect—the role of electric technologies and their impact on the economy. *Figure 9* shows for various nations the growth in the size of the economies and associated growth in electricity consumption over the period 1960 to 1993. For that three-decade period, the United States experienced the largest increase in economic output, and the largest increase in the use of electric technologies—once again as measured by the use of kWh. During the same period, nations such as China, India, Brazil, and even the UK experienced far less total economic growth. Even Japan's economic juggernaut cannot compare to the U.S. performance—but the

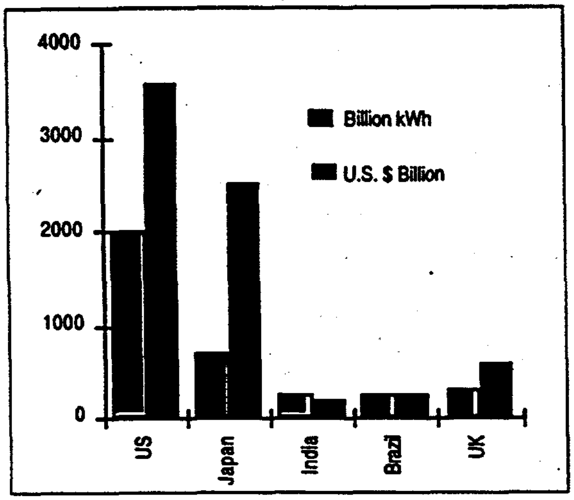
Figure 7
Trends in Other Industrial Nations

Data from OECD International Energy Agency



relationship between electricity and the economy is just as clear there.

Figure 9
Correlation between Economic & Electric Growth
[Total Increases between1960-1993]



Rainbow, The Electricity Journal, May 1996

The somewhat indirect measure of electric technology/economic trends illustrated in Figure 8 and 9 has been validated by a direct measurement. A recent U.S. Department of Commerce study of manufacturing technologies supports the conclusion that electric technologies are the dominant form of advanced/productive technologies being implemented. In a survey of advanced manufacturing technologies in over 6,000 manufacturing plants, the Commerce study concluded:

"Plants which utilize higher numbers of advanced technologies are less energy intensive and rely more heavily on electricity as a fuel source; use less energy per unit of output, but consume a higher proportion of electricity; plants over 30 years old are the most energy intensive and rely most heavily on non-electricity."

Energy Intensity, Electricity Consumption, and Advanced Manufacturing Technology Usage, M. Doms, T. Dunne, July 1993, Center for Economic Studies, U.S. Dept. of Commerce, Economics and Statistics Administration.

The Commerce Department study, in finding that more advanced manufacturing technologies lead to greater electricity use is a direct way of observing that those advanced technologies are primarily electro-technologies.

The Future Indicators

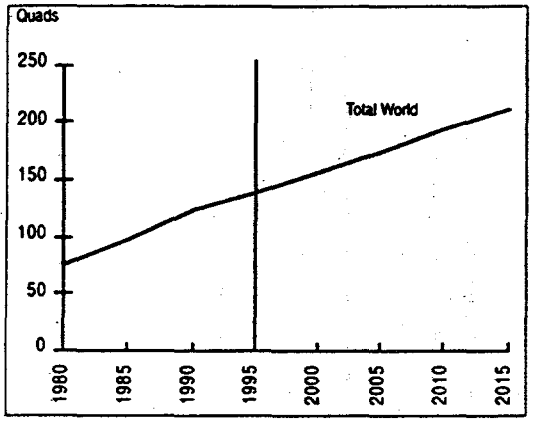
If, as is clearly the case, electric technologies have dominated the growth in new technologies, and currently dominate the market—what of the future? Do projections of future trends indicate an increase or decrease in their importance?

The clear answer from all available data is that electric technologies, measured as the consumption of electricity, will continue to dominate technological progress for at least the next two decades. Projections for both the industrial and developing nations show a clear pattern of increased use of electricity. As *Figure 10* shows, the use of electricity globally is projected to increase more than 50% over the next two decades.

Growth continues in all nations, and growth rates in developing nations are more rapid because they are starting from a much lower point of utilization of electric technologies. The point of departure for growth in some cases for developing nations involves many electric technologies (pumping of fresh water and sewage management for example, lighting, refrigeration, etc.) that are already commonplace and taken-for-granted in developed nations.

For the United States, in which many electric technologies have already reached maximum market penetration, a question arises with regard to the potential for additional growth in electric demand. Analysts agree that there is unlikely to be any growth in demand for electricity to meet future lighting and refrigeration and cooling needs. Even as the population grows, and housing and building stock grow faster than the population, driving significant demand for lights and chillers, the expected increased efficiency in these applications of electricity will more than offset increased use of the equipment. Indeed, most analysts expect

Figure 10
Projected Growth in Global Electricity Use



DOE/EIA International Energy Annual

demand for electricity in these applications to decline slightly.

Nonetheless, all projections still show a net overall increase in electricity demand. This outcome is a direct result of the increased use of electric technologies that are the anchor of economic growth, and especially growth tied to "high-tech" scenarios for the future of the nation.

The greatest uncertainty with regard to the future demand for electricity is associated with potentially larger, not smaller, growth. This arises from the fact that our understanding of technologies that reduce demand (so-called Demand-Side Management technologies) is more mature than our understanding of electric- and information-based technologies which accelerate growth in demand.

New electric technologies, of which there are hundreds, not only increase demand for electricity directly because of their specific use of kWh, but also because these new technologies contribute to productivity growth. The resulting economic growth generates a secondary—and sometimes larger—impact on electric needs because of the overall boost given to the specific industries and overall economy creating demand for electricity in other applications.

Electrotechnologies Dominate Growth

As the previous sections of this report have highlighted, advanced technologies tend to be primarily electric technologies, and these are the technologies that spur the economy. Some analysts have attempted to predict the effect. Table 3 below summarizes the outcome of one such attempt. Here the effect of a high-tech future (i.e, one strongly dominated by new technologies) is found to add nearly one-percentage point to the overall annual growth in the economy—a dramatic difference—and similarly increase growth in electric demand by over 0.5 percentage points a year. The difference represents about 500 billion kWh more demand by 2010—equivalent to the output of 250 power plants each generating 250 MW of electricity more per year than is currently projected.

Table 3
Differences Between Two Economic Futures
Average Annual Growth Rates 1995 to 2010

	Business as Usual	High-Tech Future
GDP	2.20%	3.00%
Per capita GDP	1.54%	2.66%
Electric demand	1.80%	2.40%

Electricity Futures: America's Economic Imperative, Edison Electric Institute.

There is strong evidence of the synergy between new technologies and electric technologies from another perspective. Recent projections for changes in productivity by sector provide additional insight. As *Table 4* shows, the greatest projected growth in productivity is expected to occur in three sectors: manufacturing, communications, and the electric sector. The first depends heavily and the second exclusively on electricity. And the third is the sector in which the electricity is produced to fuel the first two.

Table 4
Overall Projected % Growth in U.S. Productivity

Sector	1993-2000	2000 - 2020
Farming	6.7	23.9
Fish, forestry, agr	8.0	1.4
Mining	4.5	-6.9
Construction	9.3	15.5
Manufacturing	18.4	64.3
Transport	2.6	10.4
Communications	19.7	81.1
Utilities	7.6	29.7
Wholesale trade	6.5	27.5
Retail trade	1.4	19.3
Finance	4.3	19.3
Services	4.4	12.6
Government	4.4	12.6

"Future growth in worker productivity will be greatest in the communications and manufacturing industries." NPA Data Services, Washington D.C., American Demographics, June 1995

This synergy, and expectation for electric technologies to dominate the market place's appetite for new technologies, is also reflected in the projections by the natural gas industry—which understandably also views direct gas-to-electric competition for equipment as an important market-share battleground. The growth in demand for gas projected by ENRON directly reveals the kinds of new equipment dominating the future end-use market. As *Table 5* illustrates, ENRON projects that over three-fourths of all new demand for natural gas through 2010 will arise from fueling electric power plants. ENRON anticipates a greater market for gas in powering electrotechnologies than it does in providing gas at the point-of-use to displace electric technologies.

The ENRON view of the world is reflected, although less strongly, by the Gas Research Institute. The GRI projections for future natural gas use also show electric sector dominance, as shown in *Table 6*. GRI projects that at least one-half of all growth in gas demand will be to support the market's increased use of electric technologies. GRI's projections imply a greater confidence on their part that natural gas end-use technologies in the industrial sector will compete against electric technologies more effectively than ENRON projects. GRI is also less bullish about the overall growth rate in natural gas consumption—primarily linked to a lower expectation for electric demand growth (and thus by extension, a lower expectation for economic growth).

Table 5
ENRON projections
Growth in U.S. gas demand to 2010

Gas Demand for	Quads	Share of Growth
Power generation	5.8	77%
Industrial	0.5	7%
Residential	0.3	4%
Commercial	0.6	8%
Other	0.3	4%
Total	7.5	

Oil & Gas Journal, Oct. 23, 1995, p. 33.

Table 6
GRI projections
Growth in U.S. gas demand to 2010

Gas Demand for	Quads	Share of Growth
Power generation	3.2	53%
Industrial	1.5	25%
Residential	0.5	8%
Commercial	0.3	5%
Other	0.5	8%
Total	6.0	

1996 GRI Baseline Projection of U.S. Energy Supply & Demand to 2015.

The reason for electrotechnology market dominance

The reason that the marketplace has in the past preferred electric technologies on average over fuel-based technologies (and will continue to do so in the foreseeable future) is anchored in inherent productivity advantages. Considerable research has been devoted to studying the productivity gains attributable to electrotechnologies, many of which are summarized in the Technical Appendix to this report. *Table 7* summarizes the principal advantages of electrotechnologies:

Table 7
Typical Advantages of Electrotechnologies

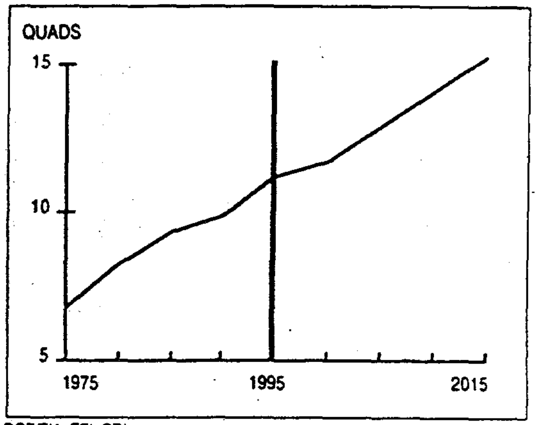
Faster PROCESS TIMES
Lower EQUIPMENT COST
Less SPACE
Greater FLEXIBILITY
Lower total ENERGY COST
Greater total CONSERVATION
Greater QUALITY CONTROL
Lower PRODUCT LOSS
Easier MAINTENANCE and higher RELIABILITY
Greater ADAPTABILITY
Lower ENVIRONMENTAL PROTECTION COST

Two examples illustrate the key differences between fuel-based and electric technologies (the Technical Appendix provides many examples).

Electric infrared (IR) paint drying directly displaces the use of natural gas heaters. The IR technology permits the use of smaller drying ovens, dries faster, and provides for greater uniformity, higher luster and fewer rejects (thereby reducing the time, expense, and environmental aspects of stripping paint and repainting). In addition, the IR technology dramatically reduces total energy consumption counting the combined efficiency of the IR lamps and the power plants used to make the electricity. IR drying is already in commercial application on automobile production lines, and is finding applications in painting and coating shops of all kinds.

Other examples can be found in the entire range of processes, new and emerging, based on microwave energy. Microwaves can be used to replace or enhance an almost limitless range of important manufacturing and processing operations. For example, microwave curing of rubber produces higher quality results in less time. Microwaves can be used to enhance chemical reactions, reducing energy use and waste. Microwaves have been successfully used to create synthetic diamond coatings on metal parts, thereby increasing their longevity and also reducing friction (with the related impact of improved energy efficiency). Microwave applications are showing up in an entire array of pollution control technologies. For example, it is feasible to use microwaves to clean up toxic spills in soils without excavation.

Figure 11
Projected Growth in U.S Electric Demand

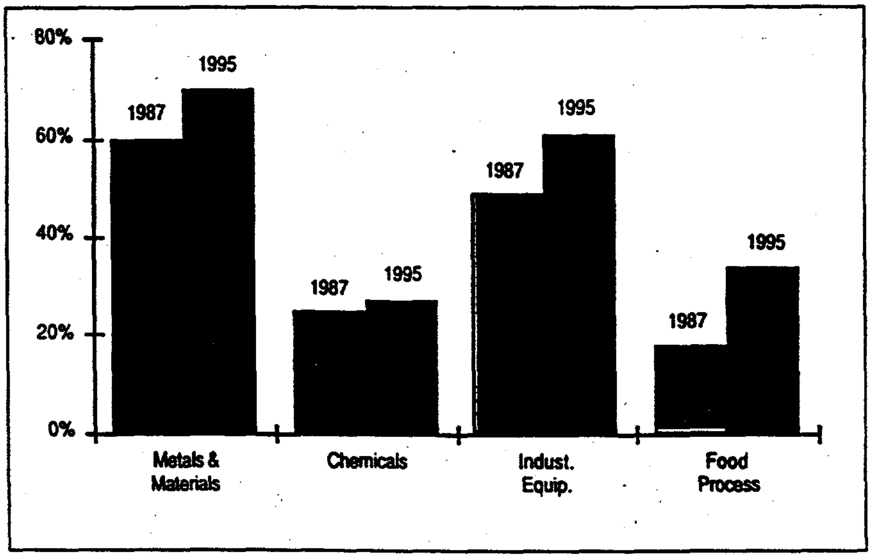


DOE/EIA, EEI, GRI

These examples are typical of the inherent advantages of many emerging electrotechnologies. The expectation that electrotechnologies will dominate new technology growth is reinforced by the outcome of a study of U.S. patents. The study focused on patents in aerospace, automobiles, chemicals, computers, electronics, food, fuels, health care, industrial products, machinery, metals and materials, and telecommunications. The study found that the share of all process (and manufacturing) patents has been rising, and that, overall, over 40% of all innovation in patent filings are electrotechnologies.

Since it is safe to assume that important new technologies will be patented, and since there is a lag time between patent applications and deployment of the resulting technologies, these results point to a strong and on-going growth in new and yet-to-be-realized applications for electricity. *Figure 12* summarizes the findings for the years 1987 and 1995.

Figure 12
Electrotechnologies as a Share of Total Process Technology Innovation Found in U.S. Patents



Data from The Role of Electric Technologies in U.S. Patents, CHI Research/MM&A, July 1996.