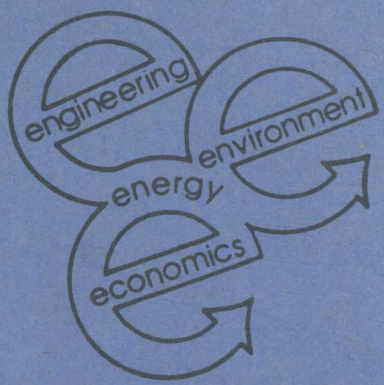
1984
17th Annual
Frontiers of Power Conference



Co-Sponsored by:

Engineering Energy Laboratory
and
School of Electrical and Computer Engineering

October 22-23, 1984

A University Extension Program
Oklahoma State University
Stillwater, Oklahoma 74078

PROCEEDINGS

1984

17th Annual

FRONTIERS OF POWER CONFERENCE

October 22-23, 1984

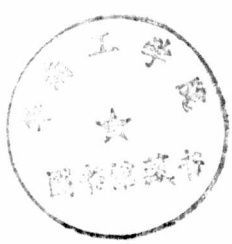
Co-Sponsored by:

THE ENGINEERING ENERGY LABORATORY

&

THE SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

OKLAHOMA STATE UNIVERSITY



A University Extension Program
Oklahoma State University
Stillwater, Oklahoma 74078

PERMISSION AND INQUIRIES

Inquiries regarding the individual papers should be directed to the authors.

Extra copies of the Proceedings may be purchased for $15.00 per copy if check accompanies order; $17.00 per copy if your organization is to be invoiced. Write or Call:

The Engineering Energy Laboratory
Oklahoma State University
216 Enginering South
Stillwater, OK 74078
PH: (405) 624-5157

PREFACE

1984 FRONTIERS OF POWER CONFERENCE

This Proceedings is a compilation of the papers presented at the Seventeenth Annual Frontiers of Power Conference sponsored by the Engineering Energy Laboratory and the School of Electrical and Computer Engineering, with the support of the electric utilities in this area.

This Conference is the outgrowth of the research on energy conversion and storage started in 1961, and actively sponsored starting in 1964, by six electric utilities in this area. These six utilities were:

Oklahoma Gas & Electric Company, Oklahoma City, Oklahoma
Public Service Company of Oklahoma, Tulsa, Oklahoma
Arkansas Power & Light Company, Little Rock, Arkansas
Kansas Gas & Electric Company, Wichita, Kansas
Empire District Electric Company, Joplin, Missouri
St. Joseph Light & Power Company, St. Joseph, Missouri

This original research resulted in the establishment of an Annual Conference starting in 1963, on Energy Conversion and Storage. This Conference was held annually through 1965, and essentially stressed direct energy conversion. About 1965, the number of national Conferences dealing with direct energy conversion increased rapidly, so the O. S. U. Conferences on Energy Conversion and Storage were not held in 1966 or 1967. The support by the utilities continued throughout this time.

The School of Electrical and Computer Engineering felt there was a continuing need for a forum whereby the electric utilities, electric power equipment manufacturers, the universities, and government agencies could discuss and examine the technology that was relevant to the needs of the electric power industry in solving the problems confronting them. Therefore, the Conference was reinstituted with a new name, a broadened scope and held in 1968, as the Frontiers of Power Technology Conference. With the continued support of the electric power industry, it was again possible to hold the Conference this year.

A special acknowledgement is made to the authors and moderators for their contribution, as the Conference would not be possible without them.

Dan Lingelbach, Professor
School of Electrical and
Computer Engineering &
Conference Director
Stillwater, Oklahoma 74078
October, 1984

MEMBERS OF THE PROGRAM COMMITTEE FOR THIS YEAR'S CONFERENCE:

Gill W. Fuller, Superintendent, Environmental Engineering, Empire District Electric Company, Joplin, Missouri

Tom R. Hoke, Manager of Engineering, Oklahoma Gas & Electric Company, Oklahoma City, Oklahoma

Dan Linglebach, Professor, School of Electrical and Computer Engineering, Oklahoma State University, Stillwater, Oklahoma

Harley Macklin, Manager-Fossil Production, Kansas Gas & Electric Company, Wichita, Kansas

Richard A. Schaefer, Electrical Supervisor, Power Generation, Public Service Company of Oklahoma, Tulsa, Oklahoma

Ray W. Toler, Director, System Engineering, Arkansas Power & Light Company, Little Rock, Arakansas

John Yost, Senior Electrical Engineer, Southwestern Public Service Company, Amarillo, Texas

MEMBERS OF THE EXECUTIVE COMMITTEE FOR THIS YEAR'S CONFERENCE:

R. O. Newman, Chairman of the Board, Public Service Company of Oklahoma, Tulsa, Oklahoma, Committee Chairman

George L. Gibbons, Vice President, Oklahoma Gas & Electric Company, Oklahoma City, Oklahoma

William L. Hughes, Director, Engineering Energy Laboratory, Oklahoma State University, Stillwater, Oklahoma

R. L. Lamb, President, Empire District Electric Company, Joplin, Missouri

Merle J. Lindburg, Vice President, Power Generation, Public Service Company of Oklahoma, Tulsa, Oklahoma

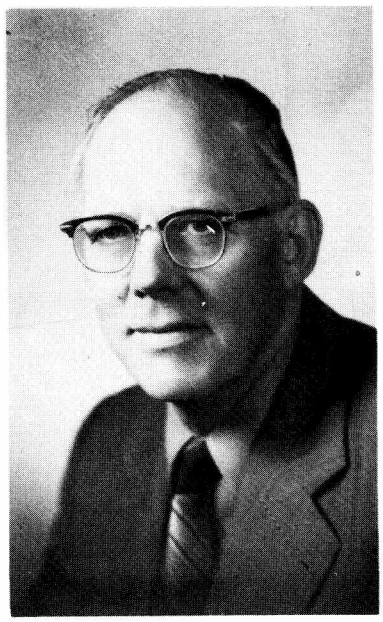
J. B. Matthews, Vice President, Generation Plant Design and Construction, Southwestern Public Service Company, Amarillo, Texas

Bernard N. Ruddick, Vice President--Engineering, Kansas Gas & Electric Company, Wichita, Kansas

Ray W. Toler, Director, System Engineering, Arkansas Power & Light Company, Little Rock, Arkansas

Moderator

MERLE J. LINDBURG



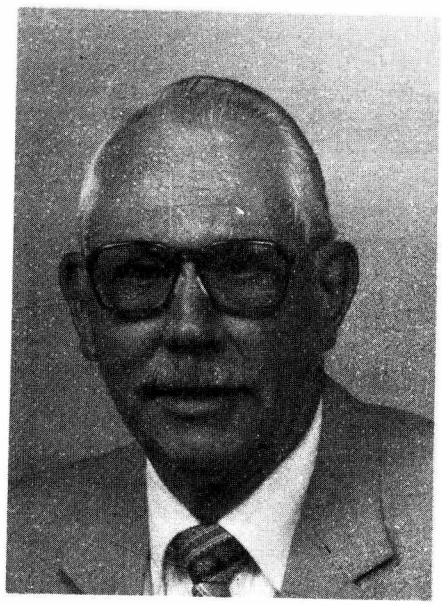
Merl J. Lindburg is Vice President of Power Generation for Public Service Company of Oklahoma.

Since graduation from the University of Kansas in 1950, with a degree in Mechanical Engineering, he has held various positions in Public Service Company of Oklahoma relating to the operation, maintenance and construction of electric generating stations.

He is a Registered Professional Engineer in Oklahoma.

Moderator

BERNARD N. RUDDICK



Bernard N. Ruddick is Vice President - Engineering for the Kansas Gas & Electric Company, Wichita, Kansas.

He received his B.S. degree in Electrical Engineering from Kansas State University, Manhattan, Kansas, in 1949, but began his utility career in 1947. Prior to serving in the Army Air Corp WW II, 1943-46, he attended Emporia State Teachers' College, Emporia, Kansas, majoring in physics and attended the Army Cadet Program for meterology from June 1943-February 1944. In 1962, he attended the Public Utility Executive Program at the University of Michigan Graduate School of Business Administration.

Mr. Ruddick is a member of the Institute of Electrical & Electronics Engineers, Wichita Professional Engineers Society, National Society of Professional Engineers, EEI Systems & Equipment Committee and a Registered Professional Engineer in the state of Kansas. He is also a member of the Wichita Chamber of Commerce, Kiwanis, Masonic Lodge, Wichita Consistry, Shrine, Kansas One-Call System, & Kansas Electric Utility Research Program.

He has authored articles published in Electrical World, Transmission & Distribution, and Wood Preserving magazines.

Moderator

DON VICE

Don Vice is a Kansas State University graduate in electrical engineering. He joined The Empire District Electric Company in 1965, as a Substation Design Engineer. He has since been Standards Engineer, Assistant Distribution Engineer, Assistant System Supervisor, and Superintendent of Transmission and Distribution, Operation, Maintenance and Construction.

On July 26, 1984, he was elected to his current position of Vice President, Transmission and Distribution.

Keynote Speaker

RICHARD O. NEWMAN

R. O. (Dick) Newman, Chairman of the Board of Public Service Company of Oklahoma, was born and reared at Enid, Oklahoma. Mr. Newman was graduated from Oklahoma State University with a degree in mechanical engineering and emerged from World War II a Captain. He is married to the former Betty Lou Bennett of Stillwater, Oklahoma, and they have two sons and one daughter, Richard, Jr., Mark B. Newman and Linda Weathers. They also have eight grandchildren.

Mr. Newman joined Public Service Company of Oklahoma in 1946, serving in various positions in the company's generation and operations departments. He was elected President and Chief Executive Officer in 1972, and Chairman of the Board in 1982.

A Registered Professional Engineer, Mr. Newman has been active in many facets of the electric utility industry and is associated with professional and engineering societies.

He is a Board Trustee of Phillips University and the University of Tulsa. He served as President of the Metropolitan Tulsa Chamber of Commerce in 1976 and 1977, and was 1983 President of The Oklahoma State Chamber of Commerce.

TABLE OF CONTENTS

THE ELECTRIC UTILITY INDUSTRY -- A CAREER PERSPECTIVE

R. O. Newman, Chairman
Public Service Company of Oklahoma
Tulsa, Oklahoma 74100

Introduction

The 1970's were turbulent years for the electric utility industry. Fuel costs doubled, doubled again, and then again -- in some cases an increase of over 1200 percent!

Capital requirements escalated with the surge of inflation. Skyrocketing interest rates and low stock prices gave nightmares to corporate treasures. And, for utilities in the Southwest, the Federally-mandated switch from natural gas to coal and nuclear generating capacity and the associated costs of complying with the Clean Air Act and a host of other environmental statues, exacerbated these financial problems.

During the last decade the relationship between utility managements and state regulatory commissions deteriorated as they struggled to balance the interests of stockholders and customers -- usually with all parties both unhappy and frustrated.

Compounding these state regulatory problems, was the changing role of the Federal Government in its oversight of nuclear power. Heretofore, the old Atomic Energy Commission had played an active part in advocating the growth of the nuclear power. When the AEC became the Nuclear Regulatory Commission in the late 1970's, the new entity immediately assumed a passive, almost indifferent attitude towards its change. After Three Mile Island, this passive role gave way to an openly adversarial relationship between the NRC and the electric utility industry.

To be fair, the delay in nuclear plant construction was often caused as much by the financial problems of utilities as by the inappropriate regulation of the NRC. Nuclear power station costs literally went through the roof, which have driven some utilities to the verge of bankruptcy. Dividends have been reduced or cancelled by some companies and new plants, coal and nuclear, have been shelved from coast to coast. As a result, the stock prices of all utilities have suffered, with many utility stocks selling at only a fraction of their book values.

The damage has not been limited to investor-owned utilities. Electric cooperatives, federal, state and municipal utilities have been affected as well -- most notably in the WPPS abandonment and bond default, and the Tennessee Valley Authority's recent cancellation of four nuclear units. The total cost of these write-offs is not yet known, but it most certainly will be many billions of dollars.

As one who survived this period of turmoil in the electric utility industry -- from the filing of my company's first- ever rate increase, to seeing our fuel costs increase ten-fold, to the ultitmate "melt down" of our investment, application, court fight and eventual cancellation of a nuclear plant -- I am an authority on the trials of a utility manager in the 1970's. I have been there -- and I know.

Losing the confidence of our customers was the most traumatic experience of all. Except for military service, I had spent my entire adult life -- sometimes working for days without sleep under the worst possible conditions -- in the electric utility industry. My first priority had always been to serve our customers. Serve them faithfully, honestly, dependably, fairly, efficiently and -- most of all -- at the lowest possible cost!

Ironically, those whom I most desired to please were the people who were the angriest. Many customers thought they had been betrayed by their electric utility and its management. This fact -- the knowledge that many customers felt deceived -- was my greatest burden.

But, let there be no doubt: my tenure as the Chief Executive Officer of PSO was not only challenging but exciting and rewarding. They were years I will always treasure. I know in my heart that I left a good legacy for those who follow me and that they feel this way too.

The purpose of this long introduction is to prepare you for my conclusion. Before that, though, I think it would be useful to review some recent trends in the energy industry. Since the electric utility industry is only a part of the overall puzzle, we will have to at least superficially touch on what is happening with oil, natural gas, coal, nuclear and others in order to fit all the pieces together. Then, the conclusion, of which I will give you this hint: most of you will see the day when utility managers -- even utility presidents -- are again viewed as "Guys in the White Hats."

Supply and Demand

The energy market, like other economic markets, is best understood as a function of supply and demand. To facilitate understanding, I want to consider supply issues and demand issues separately, and then take the special case of electricity. I'll begin with supply.

Total U. S. Energy Supply By Fuel Type

Taken together, all sources of energy can meet a gradually increasing demand through 1995. (See Figure 1).

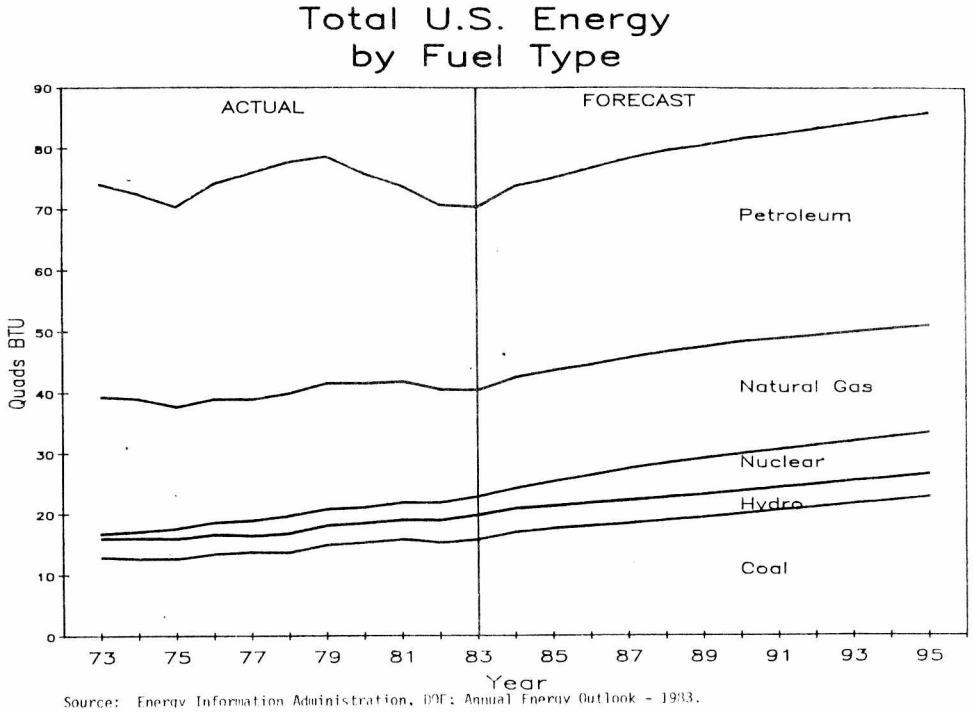


Figure 1

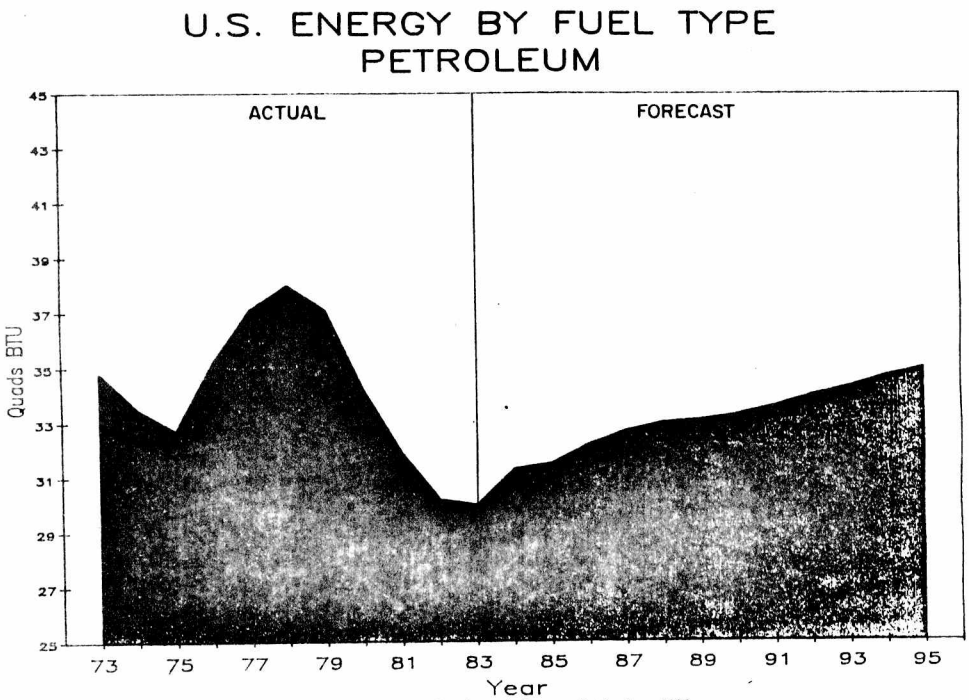
Oil

Perhaps the central fact of the energy crisis that developed in the 1970's was our country's continued reliance on oil -- especially imported oil -- as a fuel. Oil is still the single largest fuel source in the United States. After the Arab Oil Embargo of 1973, demand for liquid petroleum dropped in response to dramatically higher prices. However, soon thereafter, demand rebounded, peaking at nearly 38 quadrillion btu's in 1978. Unfortunately, this was the same year the Ayatollah Khomeini assumed leadership in Iran and promptly cut back his country's production to a little over half the previous rate. This caused prices to more than double.

Because of cutbacks in consumption and increased worldwide exploration for oil since then, most forecasters agree that we will have adequate supplies of oil through the next decade, although oil demand should increase modestly (See Figure 2). I find this increase interesting, given our well -- defined and articulated national priority of energy independence -- which essentially means independence from foreign oil.

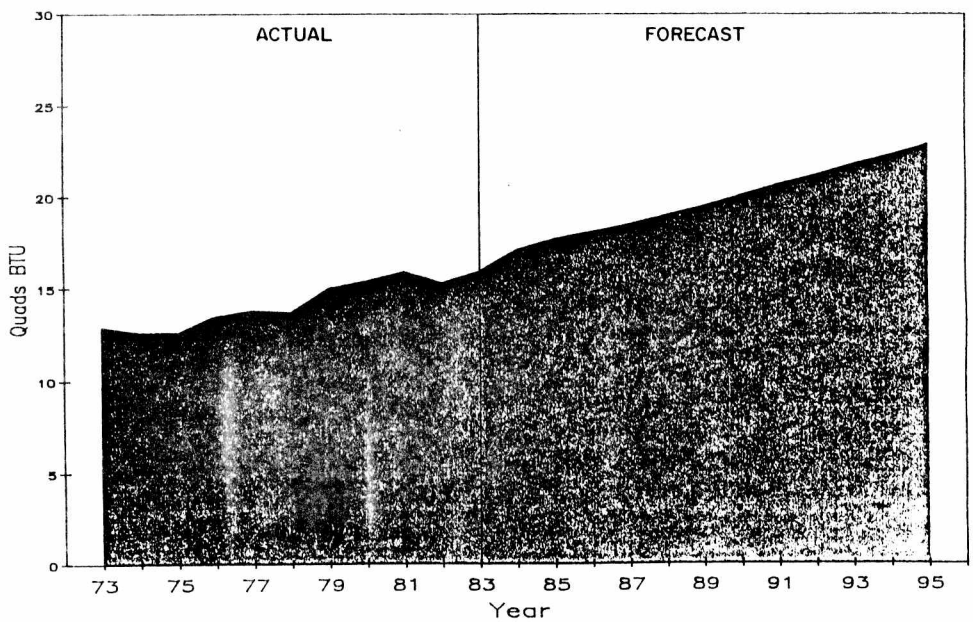
Coal

Coal is the second largest fuel supply in the U. S. Couple this with the reality that coal now represents the largest percentage share of our total national energy inventory, and the forecasts of continually increasing coal usage are quite understandable. In fact, I believe that most forecasts, which estimate annual coal consumption at between 20-25 quadrillion btu's, are on the low side (See Figure 3). The, as yet unresolved, acid rain problem is the only possible impediment to our increased reliance on coal.



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

Figure 2



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

Figure 3

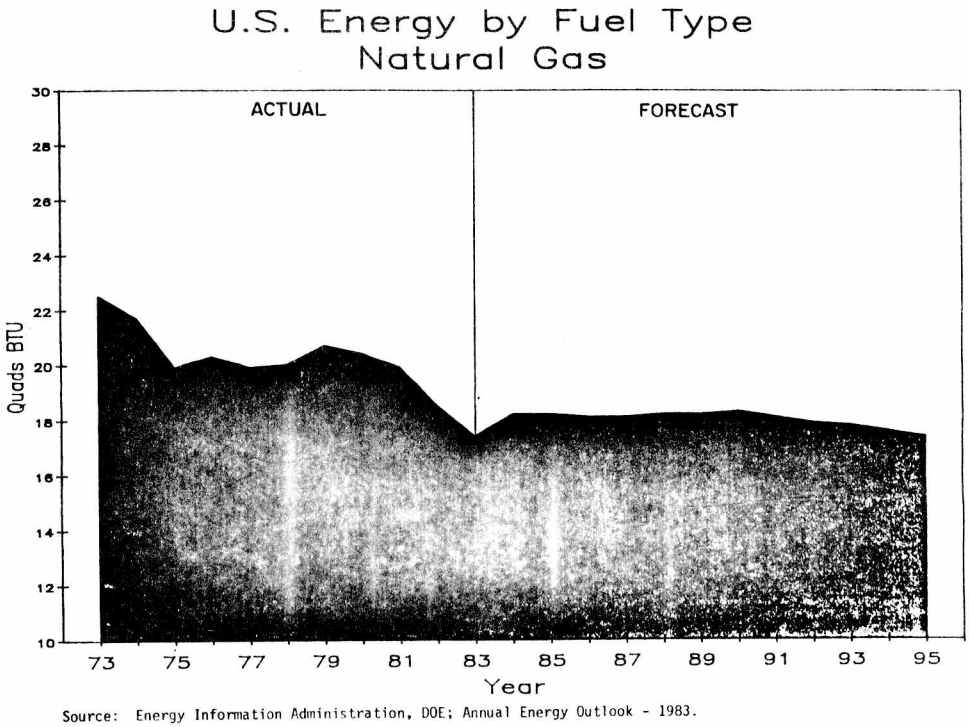
Natural Gas

U. S. dependence on natural gas as a fuel source came under pressure in the early 1970's when several gas suppliers found themselves unable to supply their commitments.

Gas deregulation allowed market prices for newly-discovered gas and the resulting dramatic increase in prices caused many customers to reduce their use. 1983 was a graphic illustration of the price-sensitive nature of our energy supply: some gas pipelines saw their sales drop to about half their 1973 levels.

Most forecasts are estimating increased gas use this year, not only because of adequate supplies, but also as a result of the significantly lower average price of flowing gas. Without these lower prices, gas use this year would have been lower than in 1983.

However, even with this current deliverability glut and subsequent lower prices, I believe the forecasted supplies of some 18-20 quadrillion btu's in 1995 are optimistic, given the industry's declining reserve base. (See Figure 4).



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

Figure 4

Nuclear

Nuclear power provided only three quads of our total national energy supply in 1983. It is forecast to increase substantially over the next four years as many nuclear plants are scheduled to come on-line. However, in 1984 -- since this forecast was made -- even more nuclear plants have been cancelled. Therefore, I would not expect any significant increase in nuclear energy beyond 1988. (See Figure 5)

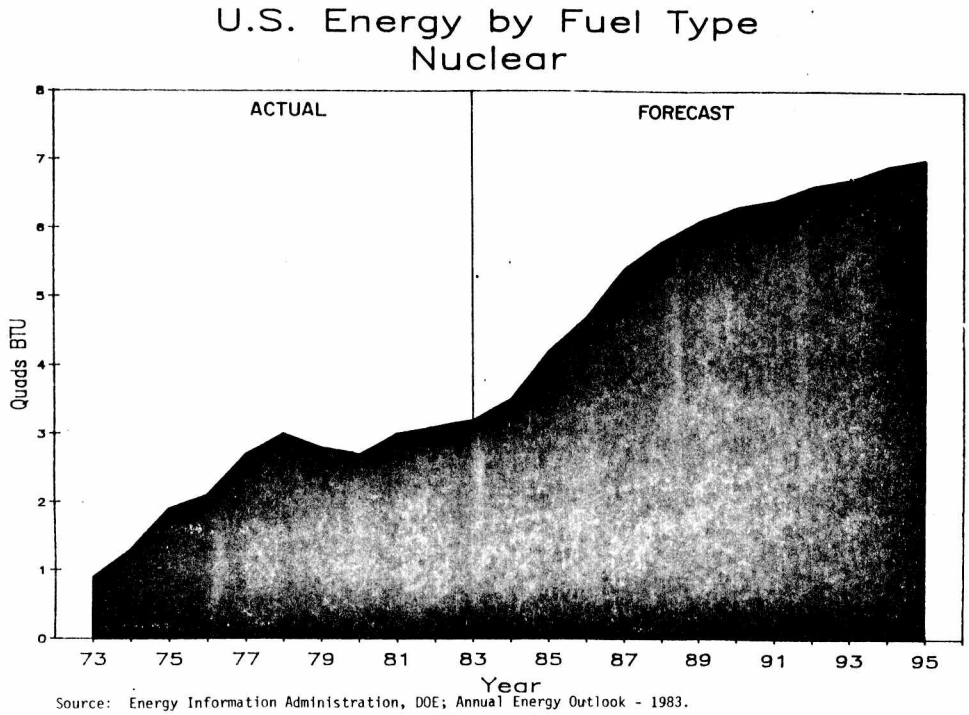
Hydroelectricity and Others

The contribution from hydroelectric power and other, less conventional sources of energy, is expected to be essentially flat through 1995, at about 3.5 quadrillion btu's. (See Figure 6)

Total U. S. Energy Consumption by Sector

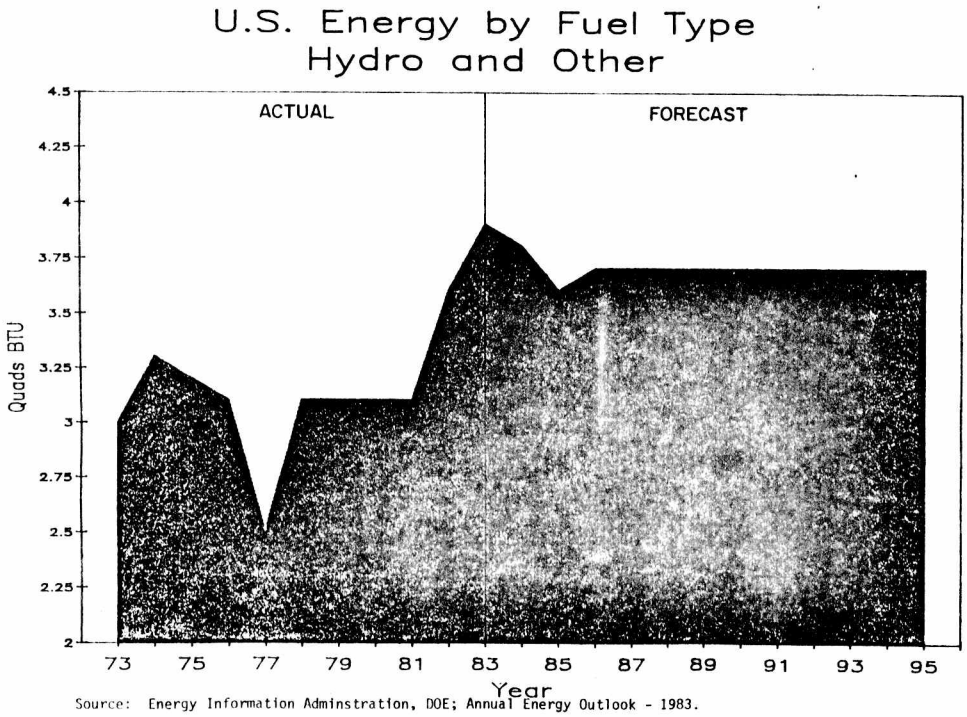
I have broken down the demand side of the equation, energy consumption, by the amount consumed in different sectors. When all these demand curves are added together, the resulting top line (See Figure 7) is exactly the same as the top line of my supply chart (See Figure 1) I've also included the same chart, broken down by energy source (See Figure 13).

Let's look at the largest energy user, the industrial sector, first.



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

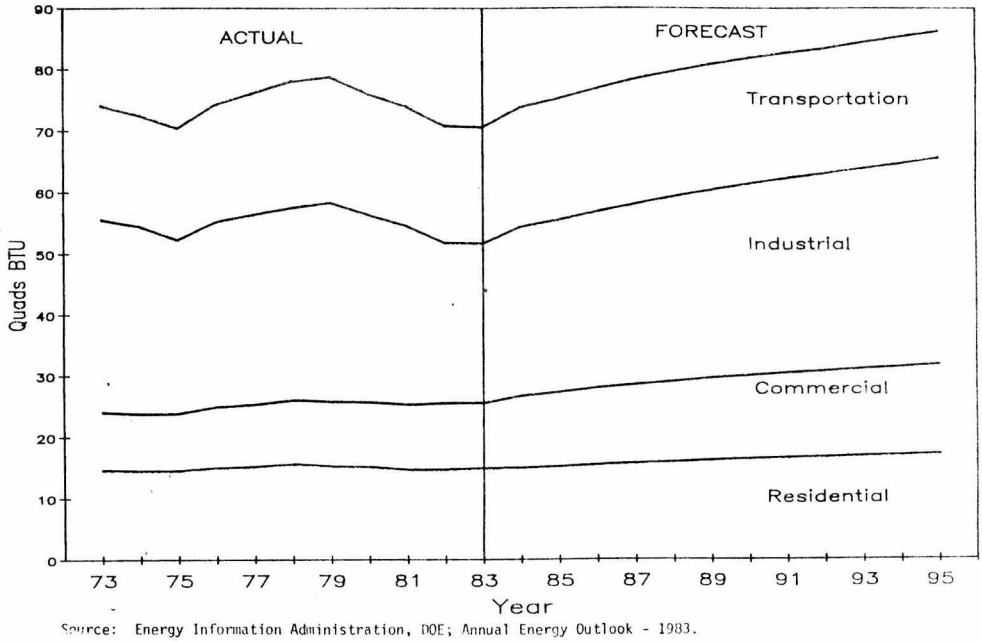
Figure 5



Source: Energy Information Adminstration, DOE; Annual Energy Outlook - 1983.

Figure 6

Total U.S. Energy Consumption by Sector



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

Figure 7

U. S. Energy Consumption - Industrial

Historically, industrial energy consumption has closely tracked the economy. This is borne out by a comparison between industrial energy consumption and the performance of the economy (See Figure 8).

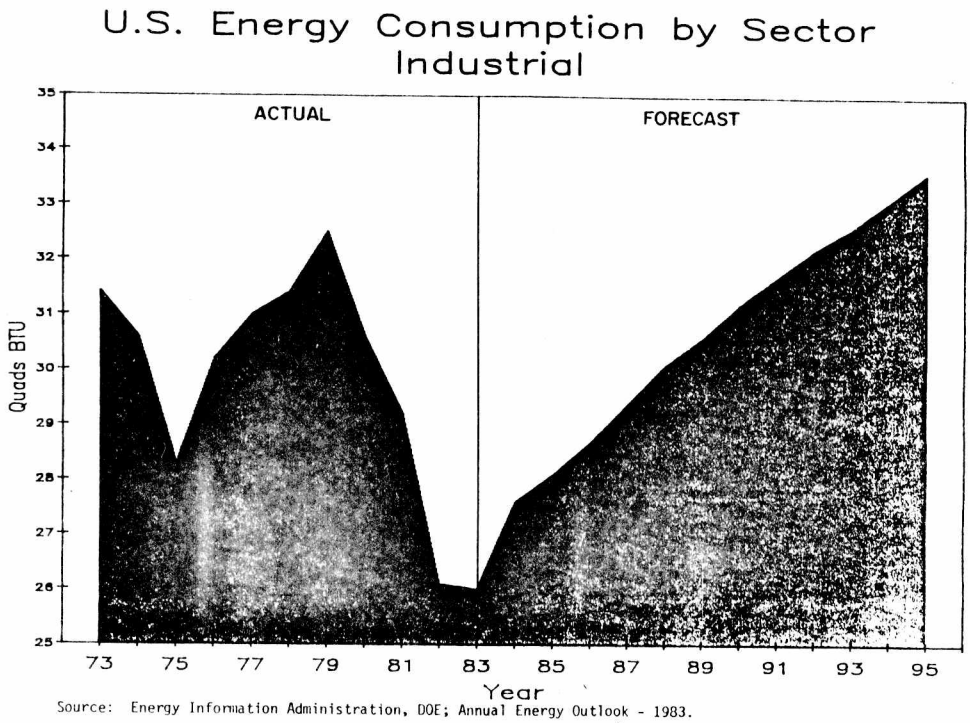
Industrial energy consumption is also affected by other considerations -- price being one -- and perhaps the shift that the nation's economy is undergoing as a part of the global economy. The U. S. has closed down many of its major steel mills, while modern new mills have been built in Italy, Japan and Brazil -- to name a few. In 1980, Japan became the world's number one automobile manufacturer when it produced 12 million units. As Third World nations continue to develop, energy intensive "smoke stack" industries may go to other nations. Forecasts that show a large increase in industrial energy consumption, as the one in Figure 8 does, may well be optimistic.

U. S. Energy Consumption - Transportation

Transportation is a major consumer of U. S. energy. Most estimtes show a substantial increase in 1984, with continuing increases through the rest of the century. Though I agree that the economy has been better in 1984 than in 1983, it takes a brave person to forecast a long-term increase after 5 years of decreased use. The high cost of fuel is going to be a deterrent to growth in the future, and it is a fact that the automobiles manufactured today are in many instances using half as much fuel as those cars they are replacing. (See Figure 9).

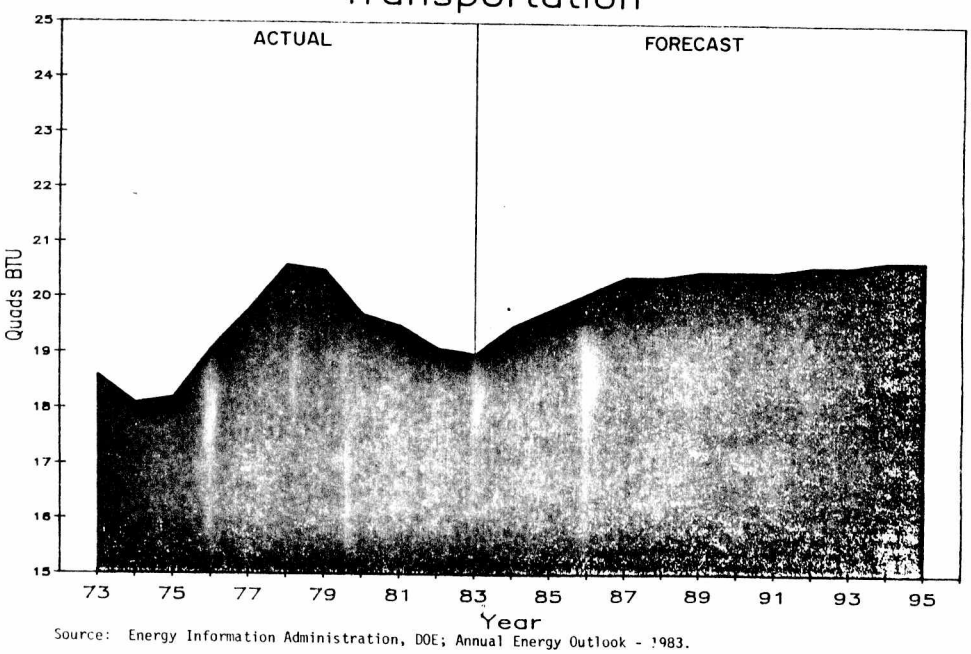
U. S. Energy Consumption - Commercial

Most forecasts of energy consumption in the commerical sector expect sizeable increases -- roughly 40% over present levels -- through 1995. At first blush, this again seems optimistic, though if we consider our long-term move towards a service and information -- based economy, these predicted high consumption levels may turn out to be accurate. (See Figure 10).



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

Figure 8



Source: Energy Information Administration, DOE; Annual Energy Outlook - 1983.

Figure 9