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TWENTY YEARS OF ENERGY POLICY:

LOOKING TOWARD THE TWENTY-FIRST CENTURY

PROCEEDINGS OF THE
TWENTIETH ANNUAL
ILLINOIS ENERGY CONFERENCE

CONGRESS HOTEL
CHICAGO, ILLINOIS

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Sponsored by:

Energy Resources Center
University of Illinois at Chicago

In cooperation with:

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FOREWORD

FOREWORD

In 1973, immediately following the Arab Oil Embargo, the Energy Resources Center, University of Illinois at Chicago initiated an innovative annual public service program called the Illinois Energy Conference. The objective was to provide a public forum each year to address an energy or environmental issue critical to the state, region and nation. Twenty years have passed since that inaugural program, and during that period we have covered a broad spectrum of issues including energy conservation, nuclear power, Illinois coal, energy policy options, natural gas, alternative fuels, new energy technologies, utility deregulation and the National Energy Strategy. To our knowledge, no other state has achieved this record of twenty consecutive annual energy-environmental policy forums.

In view of the two decade anniversary and recognizing the major political and policy shifts which have occurred since the 1970s, both at the national and international level, the Conference Planning Committee decided to devote the Twentieth Annual Illinois Energy Conference to a retrospective agenda. They felt that this was an ideal time to review some of the major energy and environmental policies of the 1970s and 1980s with the objective of determining what lessons have been learned from these programs and how they might serve as models directing energy policy for the 21st Century.

In particular the Planning Committee was interested in bringing back some of the original keynote speakers of over a decade ago. These individuals were asked to revisit their presentations from earlier years and comment on their projections. With the advantage of twenty years of hindsight as the backdrop, the speakers were asked to comment on what positive elements we can take with us from the experience of the 70s and 80s that will help us shape future energy and environmental policy.

The resulting conference was entitled, "Twenty Years of Energy Policy: Looking Toward the 21st Century" and was held in Chicago on November 23-24, 1992.

Against this background, I extend a special appreciation to the outstanding speakers whose papers appear in this publication including Arcot Ramachandran, Peter Saba, Richard M. Morrow, Kurt Yeager, Peter D. Blair, Valdas Adamkus, and Philip R. O'Connor. The longevity of this conference program is best explained by the consistent high quality speakers who have graciously agreed to participate over these many years.

It also is important to recognize the long-term financial sponsors of this program. It is fair to say the majority of our sponsors have been with us for the entire twenty year period. Again, our program's success may be judged by the unwavering support of our State and federal agencies and utilities. With deep appreciation I thank the following sponsors: U.S. Department of Energy, U.S. Environmental Protection Agency, Illinois Department of Energy and Natural Resources, Illinois Environmental Protection Agency, Illinois Department of Commerce and Community Affairs, Citizens Council on Energy Resources, Chicago Association of Commerce and Industry and Commonwealth Edison Company.

Finally, a word of thanks is given to the University of Illinois at Chicago Energy Resources Center staff especially Amanda Heredia, David Balderas and Douglas Sitzes who handled the detail work of the conference. I also thank James Wiet, who managed the conference activities from beginning to end.

I hope you find these conference proceedings useful in providing a historical perspective which may help in planning our nation's energy and environmental future.

J P Hartnett

James P. Hartnett
Planning Committee Chairman

WELCOME REMARKS

WELCOME REMARKS

Mitch Beaver
Deputy Director
Illinois Department of
Energy and Natural Resources

The Department of Energy and Natural Resources has been a sponsor and partner of this energy conference effort for 20 years. I would like to give my congratulations to Dr. James Hartnett and the University for Illinois Energy Resources Center for sustaining this effort and for continuously bringing cogent and current energy discussions to us each year.

As you will undoubtedly hear during this conference, all manner of energy issues have been discussed over the past years, and this particular conference has not shied away from controversy. They have discussed coal and air quality, the future of nuclear power, alternative and renewable energy sources, including solar and ethanol. They have discussed energy conservation and regulatory reform. We have had our share of protests, arguments, and heated discussions at this conference over the years, but I have always found them enjoyable and enlightening.

You will also undoubtedly hear what an excellent job those of us in the energy field have done over the past 20 years. We have met and conquered two energy crises. We resolved the synfuels problem. We have increased our energy efficiency, and we have safely benefitted from nuclear power for 20 years.

Now maybe we haven't really done all that and maybe we shouldn't be too proud of our methodology. But most people in this room have worked very hard to improve this nation's energy system, and I believe we have made progress on many of these issues. But what you are also likely to hear today is many individual perspectives on energy issues still facing the nation. You will hear from the gas industry, the coal industry, the utility perspective, the perspective of those advocating conservation and alternative pathways, and the big oil perspective. And with all due respect, these individual perspectives over the past 20 years have resulted in the National Energy

Strategy. I do believe that the passage of the Clean Air Act this year coupled with world concerns over global climate change will force us into taking seriously those who advocate a more comprehensive, integrated approach to energy planning.

Choosing one example out of the debate, I have heard many speakers over the years propose to propel natural gas onto center stage as our primary energy source. While most agree that natural gas is a quality fuel capable of solving some of our energy and environmental problems, few believe it can fulfill all expectations as a clean utility, transportation, industrial and home heating fuel without significant cost increases. As plentiful as natural gas is, can it be expected to be the solution to all of our energy problems at reasonable cost? I hope that we will seriously consider a planning process which will fairly evaluate and identify the highest and best uses for our various energy sources.

As you listen to the individual perspectives of the speakers today, I urge you to think about the next 20 years. Can we undertake a planning process which will examine the various fuels, environmental externalities, safety and reliability and still provide our citizens with the energy services they demand at a reasonable cost? I hope you will listen critically today and tomorrow to the discussion about the last 20 years of energy policy and determine for yourself, is there a better way?

KEYNOTE ADDRESSES

ENERGY AND ENVIRONMENT: A GLOBAL CHALLENGE

Arcot Ramachandran
United Nations Under-Secretary-General
and Executive Director
U.N. Centre for Human Settlements (Habitat)

This conference is an event of significance not just for the engineering and scientific professions, but for the entire industrial and business community, as it provides a window on the energy policies and energy technologies which will be required in the 21st century.

First of all, let me say that although I am addressing a predominantly U.S. audience, the observations I will make here on future environmental challenges have relevance to political leaders, engineers and industrialists everywhere. This is especially true when we speak of energy and the environment: rising energy demand in the developing countries affects world supply and thus the energy future of the industrialized countries; and as we all know, environmental degradation and atmospheric pollution respect no frontiers. We live, for the first time in history, in a world system and are part of a world economy. The world system has also given us world problems. They are made global by a world system which, shaped by the forces of science, technology, and communication, has effectively integrated its component parts, eroding the traditional insulators of time, space, and political boundaries.

Environmental issues are no longer marginal in the policy arena. We have arrived in the 1990s at a stage where the way we address the environmental challenges of this and coming decades will, to a large degree, determine continual *global* economic growth and prosperity. For if humankind has already known three economic revolutions — agricultural, industrial, and informatics — I should like to suggest that we are now on the threshold of a fourth: one which will make environmental performance and sustainability basic prerequisites in industrial growth and competitiveness. Much of the current technology, which has its roots in the late 19th and early 20th centuries, will soon become outdated. We have reached a watershed when it comes to technology, a market between past and future. From now on the key words will be "conserve, reduce, recycle" and more and more of the primary focus of work in the energy field will shift to such things as clean production processes, energy efficiency, co-generation, pollution prevention measures, zero-emission vehicles, material recycling, alternative fuels and materials, to name just a few of the many new priorities which could be mentioned here. These will also be at the core of the energy agenda of the 21st century.

Breakthroughs will be required similar to the one which led to fiber optics, in which fibers from one kilogram of sand now transmit as much electronic information as 300 tons of copper wiring did just a decade ago. Superconductivity, battery technology, and photovoltaics seem likely areas, among others, where such breakthroughs must also take place — and soon.

All of this is not just the message emerging out of the Rio Earth Summit held in 1992, nor just the point of view of the United Nations, environmentalists and the environmental movement; it is also the growing consensus of the entire international scientific and technical community, and more and more, of industry as well. Evidence of this is that the interpenetration of environmental and energy issues will be discussed at length at this conference.

As a mechanical engineer and former civil servant responsible for the formulation of national science and technology policy, including the field of energy, in my home country of India, I should like to say that I fully share this view. This point of view has also been confirmed by my experience over the past decade plus as the executive head of the United Nations agency responsible for providing technical and policy assistance to national and local authorities in the management and development of their towns and cities.

For nowhere is the need to reconcile the imperatives of environmental integrity and economic growth by means of a sustainable development path more urgent than in the world's urban areas, where in the next century, the majority of the world's population will be living and working, where already most of the world's goods and services are produced, where most resources are transformed into products, and where most energy is consumed, but where also most vehicular and industrial emissions originate and where most wastes are generated. The challenge of environmentally sustainable development is therefore largely an urban challenge. How we will live and work in the world's cities and towns in the next century, how we manage economic growth there, will determine the ecological future of this planet to a large degree.

As we look towards the 21st century, two prospects appear almost certain: continued growth of the world economy and continued growth of the global population. By mid 21st century, the world population will probably double to ten billion, and the output of the global economy, now about $16 trillion U.S., could be five times larger. If we maintain our past practices, such growth cannot occur without the consumption of tremendous quantities of natural resources and consequent environmental degradation.

The only way out of this dilemma appears to be technological progress. As has been pointed out by many in the scientific community, environmental degradation is related to population growth, income levels, and the pollution intensity of production, as well as vehicular emissions. In theory, therefore, environmental degradation could be controlled by lowering any one or all of these factors. In fact, the truth is that it will take close to a miracle to stabilize global population at double the level of today some time in the next century. Furthermore, increases of income levels and living standards are a basic aspiration of most of humankind; it is, after all, the reason we all get up and go to work every morning. Such rapid economic development is certainly a basic goal of the people of the developing countries, where 80 percent of the world's population lives. All of this gives continued economic growth such powerful momentum. For sound political reasons, it cannot be opposed nor can it be opposed out of sound moral and ethical reasons since it is required to lift much of the world out of poverty and human misery.

In the light of all this, it becomes clear that the factor in the equation which would be most susceptible to manipulation is the pollution intensity of production, as well as the consumption level within that production process of natural resources and the environmental quality of the products produced by that process. All of this puts the burden of the challenge largely on technology. In fact, technological change is essential just to avoid further deterioration: even today's unacceptable levels of atmospheric and aquatic pollution will rise unless the percentage of annual growth in global economic output is matched by an annual decline in pollution intensity.

That technology should have such a key role to play should really not come as a surprise to any of us in the engineering profession. After all, from humankind's earliest beginnings, technology has been the main agent of change, in the struggle upwards from subsistence towards a decent, healthier and longer life. What is different today is that global environmental decline has given a new dimension to technology and technical innovation. Today technology must not only guarantee economic growth and provide relief from poverty and hunger, but also ensure the ecological integrity of the planet. What will be required are technologies which are not, like many technologies today, economic successes but ecological failures.

Already, dramatic progress in advanced materials and biotechnology, as well as in information technologies and miniaturization, have the potential to provide new products and processes which fulfill both economic goals and environmental needs. Furthermore, investment in "green" technologies represents an opportunity to enhance competitiveness. Business opportunities in industrial anti-pollution measures and energy efficiency can be highly profitable. What is required to capitalize on this potential, however, is a more conducive regulatory framework — one which favors new technologies and focuses on pollution prevention measures rather than on "end-of-pipe" pollution controls. The emphasis should be, for example, on *clean* processes producing *cleaner* products. This emphasis on clean production processes and cleaner products, and on greater efficiency in natural resource use in general, is what makes the "environmental" revolution in industry such a tremendous challenge. But it is a challenge which must be met, and met successfully.

Sweeping changes will be required across a wide range and in particular in the field of energy and transportation, linked as they are to atmospheric pollution, global warming and climate change — prime environmental issues of our day. Even though opinions may vary over the extent and speed of global climate change if current practices persist, there is nevertheless clear consensus that it is better to reduce greenhouse gas emissions now than to risk paying for costly remedial action later. Moreover, in many of the world's major urban areas, the risks inherent in air pollution are already self-evident. Smog emergencies have closed schools and factories. Air pollution there has become a threat to both health and productivity. Certainly all countries have a shared interest in greater energy efficiency: it reduces the costs of economic growth and development, and at the same time, less consumption produces less pollution.

For energy is life. The improvement of living standards necessarily entails the consumption of energy. The disparity in living standards between industrialized and developing countries is reflected in the regional distribution of energy consumption. Industrialized countries make up 24 percent of the total population and account for more than three quarters of world energy consumption. At around seven tonnes of coal equivalent, or TCEs, industrialized countries' per capita energy consumption is almost ten times higher than in developing countries. However, energy-saving technologies are being increasingly used in industrialized countries, allowing energy consumption to be reduced while the economy continues to grow. In the Federal Republic of Germany, for example, energy consumption over the last decade from 1980 to 1990 has remained *constant*, while the national product has grown on average by 2.2 percent in real terms over the same period.

But with the developing world's share of world energy consumption set to double over the next 30 years as a logical requirement of their economic growth and development, energy efficiency in industrialized countries will not be enough if fossil fuels alone are relied on for power and transport — there may be a reduced rate of build-up of greenhouse gases, but it would still increase already high global levels, whereas a decline is what is required. Particularly significant is the prospect of increased power generation in the developing countries using fossil fuels, given that, power generation from fossil fuels already produces 27 percent of global carbon emissions. Increased fossil fuel consumption in the developing countries, without a corresponding *decline* (which it is not easy to foresee) in consumption in the developed countries, could thus offset whatever advances may be made worldwide to reduce emissions.

The current environmental debate is dominated by the ecological effects of fossil fuels. These fuels account for 90 percent of the annual world energy consumption of 12 billion TCE. The use of fossil fuels can give rise to "acid rain" as they release sulphur dioxide and nitric oxide into the air upon combustion. Acid rain can damage lakes, woodlands, plants and buildings. In addition to acidic emissions, fossil fuels also release carbon dioxide into the atmosphere where it gradually builds up. Many scientists believe that the carbon dioxide emitted by burning fossil fuels, along with other greenhouse gases, could raise the temperature of the earth by several degrees by the middle of the next century.

Over the past four decades, fossil fuel use has accelerated rapidly, with carbon dioxide emissions over the period totaling 130 billion metric tons. Improving energy efficiency in transportation, industry and in the home, in lighting, space heating and cooling and appliances certainly is one way to reduce carbon emissions. But such reductions have to be weighed against steadily increasing consumption in developing countries. As a result of higher energy consumption levels, carbon dioxide emissions will rise from their current level of 23 billion tonnes per year to 33 billion per year by the year 2020, despite major energy savings in industrialized countries. Such figures make it increasingly clear that atmospheric pollution, today still considered to be primarily due to high energy consumption levels in industrialized countries, will be produced more and more in developing countries and become a major political issue. Here at the same time, it is also clear that many developing countries, including China to site one example, have staked their future development on the burning of fossil fuel, particularly coal. It is certainly in the interest of the entire world economy that China develops rapidly. However, one certain consequence of its increased fossil fuel use in the pursuit of development will be increased levels of atmospheric pollution. And not just in China, but because of prevailing winds, in neighboring Japan as well. This just goes to show that when it comes to atmospheric pollution, there is no North or South, East or West, just one interdependent planet.

It stands to reason, therefore, that the threat of global warming can only be overcome by a joint strategy to restrict and restructure energy consumption by both industrialized and developing countries. In more concrete terms, this means that energy must be used more efficiently and economically all over the world. In all forms of energy consumption there are still considerable energy savings to be made. In the industrialized world, the mass consumption of fuels for transport and domestic heating has the greatest potential for energy conservation.

Certainly, in the long-term, development of advanced energy technologies, such as fusion reactors, solar energy systems and technologies based on hydrogen — are sound and necessary options. They may be more expensive to install; they may still need to be perfected; but this, of course, is part of the challenge of which I have been speaking. But over their life cycle, I believe they can be cost-effective alternatives which are essential for a sustainable energy future. But such technologies must be shared by all countries, developing and industrialized, if the end result is to be a halt in global environmental decline.

Finding such mechanisms for global cooperation in energy and pollution -- control technologies — is going to be one of the principal challenges of the coming decades, particularly as those who are and will be developing these new technologies will not share them free of cost. This is only natural, and of course, perfectly comprehensible. Those who require access to new technology must understand this, and here I am not just referring to developing countries. Despite the United States head start in environmental protection, Germany, Japan, and other OECD countries have acquired an edge in many environmental technologies — air pollution equipment, for example. In these countries, industry and government often cooperate in developing advanced technologies, including those with potentially momentous environmental and economic advantages. Such cooperation should not be frowned upon. It should be imitated.

Finally, let us not forget that large sections of the population in many developing countries almost exclusively use traditional fuels for their energy needs, such as wood, charcoal and vegetable and animal waste products. The widespread use of wood as a fuel has had a very damaging effect on the environment. Drastic reductions in the biomass in some areas have exacerbated the problems of water shortage and soil erosion, thus reducing the productivity of the agricultural economy. At the same time, the cutting of forests has a negative effect on the atmosphere, as it seriously depletes carbon dioxide uptake, a principal function of tree cover. Finding a solution in the form of alternative fuel use is limited by the poverty of the users, a situation which, over time, may be remedied by accelerated economic development, which, in its turn, will require, unless new technologies are introduced, greater fossil fuel consumption on the part of other sectors of the society and economy. This in turn will hasten environmental decline. Breaking such seemingly vicious circles will stretch all of our talents in the 21st century. Solutions, particularly when we take into account such factors as pervasive absolute poverty in the developing countries, will require a multi-sectoral and multi-disciplinary approach.

A great part of the energy/pollution equation is, naturally, the motor vehicle. At the present time, motor vehicles account for 14 percent of world carbon dioxide emissions and this share is increasing. They are also responsible for most of urban smog. Transportation emissions constituted 32 percent of U.S. carbon dioxide in

1987, of which three quarters arose from road transport; and in 1990 transportation was the source of 38 percent of nitrogen oxides, 31 percent of lead, 23 percent of particulates, and one-third of volatile organic compounds. In 1986, there were about 500 million cars on the world's roads. If transportation trends in developing countries follow historical patterns, there will be around 650 million automobiles worldwide by the year 2000 and one billion by the year 2030. Certainly the rates of motorization are extremely impressive in rapidly industrializing developing countries. For example, the Republic of Korea (South Korea) went from 30,000 buses, cars and trucks in 1961 to more than 2.6 million motor vehicles in 1989, of which more than 1.5 million were automobiles. Given such projected massive increases in motor vehicles over the coming decades, nothing less than transcendental change will be required to protect the Earth's atmosphere and the globe's urban areas from dangerous levels of smog and other forms of pollution.

Three basic technological strategies could lessen or eliminate these environmental costs: cleaner vehicles, more efficient vehicle use, and decreased travel demand. Leaving aside travel demand, which may be difficult to modify due to economic, social and cultural factors, it is clear that in the short term at least, fuel efficiency and other measures to reduce motor vehicle pollution may help. These measures may include advanced engine designs, ceramic engines, improved electronic controls, and continuously variable transmissions, among others, and would be relatively easy to integrate into the current vehicular fleet. Technology could contribute much to the improvement in surface travel efficiency through, for example, "smart highway" systems.

But in the medium and long-term, the solution is for transport, whether individual or collective, to be based on non-polluting fuels. This, of course, leads us, inevitably, to the discussions of the so-called "zero-emission vehicles," passenger cars which would be powered by greatly improved batteries or by hydrogen. Such cars are about to move off the drawing boards and into the streets. In both Europe and Japan, electric cars will be on the market next year, primarily for use as short-distance carriers in urban areas. Energy storage in these vehicles may still have to be perfected, but the first step has been taken; a hydrogen-powered vehicle may not be far behind. There is no doubt that these new types of vehicles represent a revolution in themselves, affecting entire sectors of industry.

Similar changes are also required in mass transportation from polluting to less or non-polluting forms of transport. Certainly buses using liquified natural gas as fuel, as in Japan or Italy, is one first step in that direction. In the future, however, the solutions will also have to include a greater reliance on electric light rail and trolleys, especially to reduce congestion and pollution in urban areas. Given urbanization patterns in developing countries, these countries would be well advised to move into such modes of mass transport in order to reduce dependence on fossil fuel burning motorized vehicles. There is no reason why the developing part of the world should always follow yesterday's trends. Moreover, dependence on such motor vehicles means increased oil consumption. For many countries of the Third World, the problem in the future may be less one of availability than one of the ability to finance increasing oil consumption.

These, then, are some of the principal challenges in the field of energy and transportation which we will have to face and resolve in the coming decades when it comes to sustainable development, to promoting both economic growth and ecological viability. And these challenges are global — they cannot neatly be separated, as I have pointed out repeatedly — into those facing developing and those facing industrialized countries. As I mentioned earlier, we stand on the threshold of a new economic revolution based on new, cleaner, and *more sophisticated* production processes and on new and cleaner recyclable products. Such a revolution will demand many things. It will certainly require a much better trained, better educated, more technically competent and sophisticated work force. It is not just a matter of better university education, it is also a matter of better mass education produced by business necessity. All other factors being equal, the countries whose *educational and social policies* produce such a work force, no matter where they may be on the globe, will take the lead in the 21st century.

Already the European market, soon to become the largest single trading area, is insisting on strict environmental standards for products and processes which anyone wishing to do business there cannot afford to ignore, and this approach is spreading to other parts of the world. We cannot continue to look backward and resist change. The 21st century will require a new class of business executive and manager, aware of environmental issues and limitations, and able to incorporate them into *long-term* planning. The latter is a concept which is already well institutionalized in the corporate cultures of other countries, including some of the more advanced developing ones, but which has been neglected here in the United States in recent years.

All of this leads me to one final point: human society will be far from sustainable as long as the full value of the environment resources is not reflected in the prices according to which business and consumers make their choices in the marketplace, and this raises such issues as life-cycle costing and end of life cycle consequences of products and processes, all of which will have greater prominence in the business and industrial culture of the 21st century. The question is therefore not who is going to pay for sustainable development — that is a question reflecting the old defensive mentality of environment protection — but how can business and industry fully integrate the value of the environment into their operations, thereby not only conserving energy and other natural resources for future generations, but also using the environment as a renewable resource for sustainable economic growth.

TWENTY YEARS OF ENERGY POLICY: LOOKING TO THE NEXT CENTURY

Peter Saba
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INTRODUCTION

The theme for this 20th anniversary conference — "Twenty Years of Energy Policy: Looking Toward the 21st Century" — is both historical and forward-looking. This dual perspective is valuable not only because there is much truth in the adage that "those who cannot remember the past are condemned to repeat it," but also because there are important positive lessons that can be learned from past energy policies that can help guide us into the next century.

Following a brief review of the energy policies of the past two decades, I will focus on the lessons learned and how those lessons have been applied to forge an energy strategy for the 1990s and beyond.

ENERGY POLICIES OF THE 1970s AND 1980s

The energy policies of the 1970s can be characterized largely as greatly increased government intervention in the energy sector, motivated by the "energy crises" of that decade. This government intervention had several effects that proved detrimental to the U.S. economy and often only exacerbated the crisis they were intended to resolve. For example, oil price controls encouraged consumption and increased oil imports, natural gas controls created artificial shortages, and elaborate oil allocation systems created major domestic disruptions and gasoline lines. As a result, the energy policies of the 1980s were aimed in large part at undoing the energy policies of the 1970s.

The policies that emerged in the 1970s included President Nixon's Project Independence in response to the 1973 oil embargo and President Carter's Synthetic Fuels Corporation in response to the 1979 oil disruptions caused by the Iranian revolution. These policies were announced in major Presidential television addresses, complete with much rhetoric. President Nixon asked the country to undertake Project Independence "in the spirit of Apollo, with the determination of the Manhattan Project." President Carter had made a campaign promise to unveil a national energy policy within 90 days of inauguration, and in April 1977 he donned a cardigan for a fireside address in which he described his energy program as the "moral equivalent of war."

These policies also were tied to grand goals. The goal of Project Independence was to develop the potential to meet our own energy needs by 1980. President Carter's 1979 plan, announced in the famous "malaise" speech, was to make 2.5 million barrels per day of synthetic fuels by 1990. Obviously, the nation did not come anywhere close to meeting either of those goals.

Contrary to the basic premise of Project Independence, it has become clear that energy independence is neither a realistic nor necessarily a suitable goal. Energy independence is not necessarily a suitable goal because in a highly interdependent world energy market our nation's vulnerability to price shocks is determined less by how much oil we import than by other factors such as how dependent our economy is on oil, our fuel switching capability, and the amount of spare oil production capability and strategic reserves around the world. The contrasting experiences of Great Britain and Japan in 1980, after the Iranian revolution, offer a classic example of how oil imports alone are an inadequate gauge of "oil vulnerability." Great Britain was almost totally self-sufficient in oil, but it suffered economically more than most countries, including Japan, which did (and still does) import all the oil it uses.

Just as Project Independence was based on a questionable premise, the Synthetic Fuels Corporation was based on the premise of rapidly increasing oil prices, decreasing domestic production, and increasing consumption. In fact, oil prices dropped after 1981, domestic production increased through 1985, and domestic petroleum consumption has remained below 1979 levels. The experience of the Synthetic Fuels Corporation demonstrated that the government should not try to dictate a solution for a complex and rapidly changing energy system. In other words, it demonstrated the government's inability to pick winners and its penchant to back losers.

Other examples of government intervention in the 1970s included oil price and allocation controls, thermostat controls, and natural gas price and supply controls.

Some of these policies pre-dated the 1970s, but few of them have survived the test of time. Unfortunately, that test came at a substantial cost to the economy. For example, the direct cost to government and industry just to administer and comply with the oil price and allocation regulatory regime was estimated to be over a billion dollars a year in the mid-1970s. Consumers not only wasted countless hours in gas lines, but also, by one estimate, may have wasted more than six million gallons of gasoline a day waiting to fill their tanks. In addition, the costs of the natural gas regulatory scheme have been estimated at between $2.5 to $5 billion annually in increased energy costs and significant losses in industrial production as a result of curtailments.

While a large number of these policies were dismantled, some policies begun in the 1970s survive today. These include the Strategic Petroleum Reserve, automobile fuel efficiency standards, and the Trans-Alaskan Pipeline.

The close of the decade also showed the first signs of the deregulation movement that was to become a major force in the 1980s. In 1978, Congress passed the Natural Gas Policy Act which created a complex pricing scheme for natural gas that resulted in new economic distortions, but also provided some price decontrol. In addition, Congress passed the Public Utility Regulatory Policies Act of 1978 which created limited competition in the electricity generation sector. Finally, in 1979, President Carter announced a plan to phase out crude oil price controls.

President Reagan left no doubt that deregulation would be the crux of his energy policy. His plan to dismantle the Department of Energy and the signing of an Executive Order completely deregulating the price of crude oil as one of his first acts in office were unmistakable signals. Other important deregulatory actions in the 1980s included Congressional repeal of the Fuel Use Act in 1987 and actions by the Federal Energy Regulatory Commission that brought regulatory reform to natural gas transportation and effectively deregulated the wellhead price for pre-1976 gas. In 1989, Congress passed the Natural Gas Wellhead Decontrol Act, which will eliminate all price controls on natural gas at the wellhead by January 1993.

Some have argued that the policies pursued by the Reagan Administration swung the pendulum too far and that a *laissez-faire* approach is not appropriate because energy markets are not free markets and energy prices do not properly reflect societal costs. For these proponents of an increased government role, the policies of the 1980s were the equivalent of "trickle down energy."

The point of this historical review is not to argue old issues or to assign blame for efforts that failed, no matter how well intentioned. Instead, the point is to extract the lessons from this policy evolution to help guide current and future policies.

LESSONS LEARNED

History has clearly shown that a badly designed energy policy can inflict large costs on the economy without commensurate benefits. At home, a bad energy policy can force economic losses on numerous industries and regions of the country and impose heavy burdens on consumers. It also can significantly reduce U.S. competitiveness abroad.

The lessons learned from the past are that energy policy should:

- Be balanced;
- Rely on market forces and technology innovation wherever possible;
- Be built on consensus; and
- Look to the future

Balance is an important concept in making any public policy decisions. For energy policy, balance is vital in a number of respects. First, an effective policy must balance the nation's energy, environmental and economic goals. Too often these goals are viewed as competing, but in reality these goals are best achieved together — in a balanced and comprehensive approach. Second, balance is also necessary among fuels and technologies. We cannot rely on just one fuel or technology to meet our country's diverse energy needs, and we cannot afford to exclude a fuel or technology from consideration. It is clear that we need all of our energy resources — conservation, fossil fuels, nuclear, renewables and alternative fuels — to achieve our energy, environmental and economic goals.

The second lesson of past policies is the need to rely on market forces and technological innovation wherever possible. Command and control regulations or taxes cannot deal adequately with all the various factors in the nation's complex energy system and the interdependent world energy markets. Further, government intervention reduces flexibility and creates rigidities that prevent or inhibit market forces from adjusting to changing circumstances and leave no room for technological or economic breakthroughs.

Wherever possible, markets should be allowed to determine prices, quantities, and technology choices. Energy markets, however, do not always resemble the economist's concept of an efficient market because of factors such as monopoly power, existing government regulation, or imperfect information. In specific instances where markets cannot or do not work efficiently, government action should be aimed at removing or overcoming barriers to efficient market operation.

The long-term history of energy is one of various fuels and technologies replacing others in response to changes in energy demand, supply, and prices. Such transitions accompanied the nation's changing technology base, ongoing economic development, and improvements in the quality of life. Technological innovation played a key role in these transitions. While the market is best suited to make these decisions, this does not mean the government has no role to play in this area. For example, the federal government can encourage the development of energy technologies through cost-shared research and development with industry, academia, and state and local governments. The government also has an important role to play in creating a financial, trade, and regulatory environment in which innovative technology and firms can compete. However, the government should not try to pick one technology or product over another. These choices should be driven by the market.

The third lesson learned is the need to build consensus. Energy policy has frequently been characterized not by consensus, but by opposing interests — one fuel interest pitted against another, consumers pitted against producers, or one region of the country pitted against another region. The result has often been gridlock. If the stalemate was broken, the polices that emerged frequently better served a particular special interest than the national interest. A balanced and comprehensive energy policy should rise above the special interests taking account of the interests of all segments of the energy community to achieve the consensus needed to turn policy into results.

The final lesson learned is that energy policy should be forward-looking and not simply a reaction to the latest energy crisis. Crisis policy making often leads to overreaction, short term solutions and negative or unforseen consequences. Energy policy should set a course for the mid and long term, looking to the future, not reacting to the past.

These lessons are the ones that guided the development of the National Energy Strategy, released in February 1991, and the recently enacted Energy Policy Act of 1992 which implements key elements of the Strategy. Together, the Strategy and the Act lay the foundation for a more secure, efficient and cleaner energy future for the 1990s and beyond. I would like to take a few minutes to discuss the development and impact of the National Energy Strategy (or NES, for short) and the Energy Policy Act, then look towards the future of our nation's energy policy.

NATIONAL ENERGY STRATEGY

In July of 1989, more than a year before Saddam Hussein invaded Kuwait, President Bush directed the Department of Energy to develop a National Energy Strategy that would balance the need to promote economic prosperity, energy security and environmental common sense.

In 1990, events in the Persian Gulf added urgency to the Administration's National Energy Strategy development effort. The President responded with a series of initiatives, including the first drawdown of the Strategic Petroleum Reserve, that enabled the nation to manage one of this century's most severe oil supply interruptions without the gas lines and costs to the economy that resulted from government intervention in the past.

While the Bush Administration drew on the NES development effort to fashion its response to the Persian Gulf crisis, the goal of NES development was longer-term -- to set forth a blueprint for the nation's energy future into the next century. In addition, development of the NES did not take place in a vacuum or in some dark, deserted basement office at Department of Energy headquarters. It was the result of an 18 month public and interagency process that included 18 public hearings and over 1,000 written submissions (totaling over 22,000 pages) from all interested persons from across the country.

Involving interested and affected parties reflected a consensus-building process that was instrumental in obtaining support for both the NES and the bill that followed. For possibly the first time, energy interests were working together for common advantage rather than simply pressing their own individual interests which in the past had resulted in the gridlock that was a major topic in the recent election. With the NES and the bill, we were able to break that gridlock in energy. The support of energy producers and consumers, both big and small, all across this country was an important element in breaking that gridlock.

In February 1991, the President released the National Energy Strategy. The NES is a comprehensive and balanced approach which promotes energy production and efficiency and which will improve our nation's energy security, enhance environmental quality, and spur economic growth. The Strategy does not contain a single silver bullet or set forth one specific path for America's energy future. The basic component of the Strategy is a package of over 100 specific initiatives. The key to the NES is a balanced approach that continues the successful policy of market reliance by removing regulatory barriers and investing in research and development. While some of the NES initiatives required new legislation, more than 90 of these initiatives could be accomplished through our existing authority. The Administration moved quickly after the NES was released to implement those action items. Examples of our progress include:

- Measures to encourage energy conservation and efficiency such as a Presidential Executive Order to reduce energy consumption in federal buildings and reduce fuel consumption in federal vehicles;

- Natural gas and hydropower regulatory reforms;
- The purchase of thousands of alternative fuel vehicles for the federal fleet; and
- Increased technology transfer, including the launching by the President of the National Technology Initiative to explore ways for the private sector to commercialize federally funded R&D in order to spur U.S. competitiveness and create jobs.

The remaining NES actions required new legislation. DOE addressed them by sending a comprehensive legislative proposal to the Hill in March 1991. After more than a year and a half of bi-partisan effort, the legislative process has borne fruit in the Energy Policy Act of 1992, which was passed by Congress and signed by the President in October.

ENERGY POLICY ACT OF 1992

The Energy Policy Act of 1992 and its companion, the NES, will affect almost every aspect of the way this nation produces and uses energy, including reshaping federal and state regulation of the nation's energy sector to spur competition and investment in new technologies. In overview, the energy legislation:

- **Removes obstacles to increased competition in electricity generation** by amending the Public Utilities Holding Company Act of 1935 and **increasing transmission access**, which will benefit consumers through lower electricity costs.
- **Promotes the development and use of clean burning alternative motor fuels** by:
  - providing tax incentives for alternative fuel vehicles and refueling facilities;
  - establishing an alternative fuel fleet program;
  - setting up electric and electric-hybrid vehicle demonstration programs; and
  - providing financial support for demonstrations of alternative fuel use by urban mass transit systems.
- **Removes an artificial barrier to greater use of ethanol** by authorizing tax exemptions for more ethanol blends.

- **Promotes use of mass transit and vanpools** by increasing the tax free limit on employer-provided benefits to $60 per month.

- **Provides permanent, much-needed Alternative Minimum Tax relief** for independent oil and gas producers worth over $1 billion over five years.

- **Promotes energy efficiency in federal, state and industrial, commercial, and residential uses** through:

  - tax exemptions for utility payments to customers for energy conservation investments;

  - energy-efficient construction for new federal buildings and homes financed with federal mortgages;

  - energy efficiency improvements in federal facilities;

  - development of technologies that will improve efficiency in energy-intensive industries; and

  - energy efficiency standards and labeling for industrial, commercial, and residential equipment and appliances.

- **Promotes greater use of clean-burning natural gas** by: providing the natural gas industry with expanded market opportunities, in areas such as electricity generation, natural gas vehicles, and gas research and development.

- **Supports the future use of nuclear energy** by:

  - reforming the nuclear power plant licensing process;

  - encouraging the development of advanced, even safer nuclear power plant designs;

  - restructuring the uranium enrichment enterprise; and

  - providing guidance on the development of regulations to govern the permanent disposal of high-level waste.

- **Supports the environmentally sound use of our nation's abundant coal resources** through: research and development of advanced coal technologies and programs to promote the export of U.S. coal and clean coal technologies.

- **Promotes the development and use of renewable energy resources** through:
    - tax incentives for certain renewable energy production and investments;
    - research, development, demonstration and commercialization programs for renewable energy technologies; and
    - expansion of programs to promote export of renewable energy technologies.
- **Encourages increased research and development** on a wide range of energy technologies, including natural gas end-use technologies, high efficiency heat engines, advance oil recovery, and many others.
- **Supports post-secondary math and science education programs** for low-income and first generation college students.
- **Streamlines regulation of oil pipelines.**

IMPACT OF THE BILL

The Department of Energy's estimates of the impact of the energy bill on the nation's energy sector are that:

- U.S. oil imports will be reduced by about 1.4 million barrels per day by the year 2000 and by 4.7 million barrels per day by the year 2010. This reduction in oil imports will result in a significant positive contribution to the nation's balance of trade (over $575 billion during this period);
- Alternative transportation fuel use is projected to increase by more than 50 percent over projected 2010 levels;
- Burner tip natural gas prices to industrial users are projected to be 13 percent lower by 2010 than they would be without the bill;
- Demand for primary energy is projected to decline by six percent by 2010 as a result of a significant investment in efficient conservation (projected to reduce the nation's cumulative energy demand by the equivalent of about eight billion barrels of oil between now and 2010);
- Renewable energy consumption is expected to increase by over 20 percent in 2000;

- Overall, the new law is anticipated to save over $600 billion in the nation's total energy bill through the year 2010. A large part of that savings (over $350 billion) will come from a reduction in the nation's electricity bill.

The bill is likely to have its biggest impact in the electricity sector. Indeed, the impact for both producers *and* consumers of electricity are far-reaching. The bill has the potential to revolutionize the industry and give us more efficient, lower cost electricity supplies in the future.

There are two key components of the electricity portion of the Energy Policy Act of 1992.

- First, the bill amends the Public Utility Holding Company Act (PUHCA) to remove unnecessary regulations on who can enter the electric generation business, both domestically and aboard.

- Second, the bill amends the Federal Power Act to expand the Federal Energy Regulatory Commission's (FERC's) authority to order owners of electric power transmission facilities to furnish transmission services to wholesale electric generators.

PUHCA reform has been a key objective of the President's NES and will spur competition in this segment of the electric industry. Increased competition should lead to innovation and introduction of new technologies that are cleaner and more efficient and to reduced costs. These reforms will allow a wider range of U.S. companies to enter into the electric generation business without subjecting themselves to PUHCA restrictions. PUHCA amendments will also allow U.S. companies — utility and non-utility — to own or operate electricity generation, transmission or distribution facilities and gas distribution facilities abroad without subjecting themselves to PUHCA restrictions.

One of the biggest barriers to getting full competition for electric generation has been transmission access. The bill lowers this barrier by giving FERC greater authority to order transmission-owning utilities to provide transmission services to a wholesale buyer or seller of electricity. Virtually any entity that generates electric energy for resale, including qualifying facilities, municipalities, and co-ops, may apply to the commission for an order requiring a transmission owner to provide access.

There are limits on this new authority. FERC, for instance, cannot order transmission services to be furnished directly to an ultimate consumer — or to an entity that would sell the power directly *to* an ultimate consumer, unless it is TVA or another particular entity with a given public service obligation. More open transmission access, as called for in the President's National Energy Strategy, can lead to increased competition in the electric industry. Wholesale buyers will have access to a larger numbers of sellers. Enhanced competition will drive down the cost of generation and lower rates for all customers. The result will be a better balance between supply and demand, the lowest reasonable prices, more choices for consumers and a cleaner environment.

FUTURE OF ENERGY POLICY

In conclusion, the impacts and benefits of the NES and the Energy Policy Act will be far-reaching not only in providing for a secure energy future, but in enhancing our environmental quality and providing for a strong economy as well. The guidelines we followed in developing the NES and the legislation — balance, reliance on markets and technology, consensus, and long-term perspective — are the keys to its future success.

As a result of a more than three-year process, we were able to forge a strong bi-partisan consensus where none existed in the past. The substantive balance, the bi-partisan consensus, and the considerable investment of time and resources required over three years to achieve that balance and consensus, are the main reasons that I believe the National Energy Strategy and the Energy Policy Act will continue to serve as the foundation for energy policy in the future.

In the near term, the legislative foundation for energy policy has been set. Although the change in Administrations and the new faces in Congress will surely have some impact, it will not be a rewriting of this act. Rather, the change will be changes in emphasis as the bill is implemented, and clearly there is much that needs to be done to implement this legislation. In addition, energy policy will be impacted by the continuing implementation of the Clean Air Act Amendments of 1990 and by environmental legislation that is likely to be considered in the next Congress.

For the longer term, the National Energy Strategy was always envisioned as an evolving and dynamic policy, responsive to new knowledge and changing circumstances. As future energy policies evolve, hopefully the past will be remembered so that we are not condemned to repeat it, but rather can let the lessons we have learned continue to guide us on a balanced path.

THE PATH TO A NATIONAL ENERGY STRATEGY

Cherri J. Langenfeld
Manager
Department of Energy
Chicago Field Office

We meet today in the wake of the President's signing of the Energy Policy Act of 1992, which Secretary of Energy James D. Watkins called, "the most comprehensive and balanced energy legislation ever enacted."

Earlier in the year when this conference was being planned, very few energy policy analysts would have wagered that national energy legislation would be enacted in time for our discussions. What better time to be looking forward as well as back? We have a program made up of perceptive and expert speakers on the national energy policy scene and substantial energy policy initiatives to discuss. We also have the prospect of a new administration and a substantially altered Congress in Washington.

DOE CHICAGO OFFICE

A short time ago, it was my privilege to be appointed Manager of the Department of Energy's (DOE) Chicago Field Office. As manager, I now head an organization that has played a role implementing national energy policies since the earliest days of the Manhattan Project and the development of nuclear technology. My office traces its ancestry back to a pioneering partnership forged between the U.S. government and the academic research community which made possible exploitation of a revolutionary, new energy source.

Those with a sense of history probably know that 50 years ago in December of 1992 the first controlled nuclear chain reaction was achieved by Dr. Enrico Fermi and his team at the University of Chicago.

Prior to my appointment in Chicago, I served as DOE's Director of Technology Utilization, the Department's lead technology transfer official. In that role I helped to develop the technology transfer component of the National Energy Strategy.

NO "MAGIC BULLETS"

We have all heard the view expressed that what this nation needs to solve its energy problems is a new "Manhattan Project." This viewpoint reflects the bold assumption that there is a perfect technology waiting out there, somewhere, that will answer our every need. We need only to organize and develop it.

Implementing this ideal technology would be no problem. It would reflect the old adage: "Build a better mousetrap and the world will beat a path to your door." Since the first Illinois Energy Conference in 1972, we have learned that this bright hope is, in part, false.

Indeed, our experience with the Manhattan Project and the nuclear energy program has shown us that the introduction of new technology, even that with tremendous revolutionary promise, is never easy or uncomplicated. Even here in Illinois, the nuclear option is not without drawbacks.

In our efforts over the last several years to develop a rational National Energy Strategy, we have frequently been reminded that there is no "magic bullet," no perfect energy form. Based on our track record, we are inclined to make oil our energy of choice, if we only had more of it! As it is, our domestic production has declined while we increase dependence on imports. Over the long term, this cannot continue.

Illinois and the Midwest have vast coal reserves, but environmental concerns have sharply limited our reliance on this option, while cost and technical issues remain about many promising clean coal technologies.

Natural gas is clean, efficient and, for now, in good supply. However, transmission, storage and price stability concerns limit this option. Ultimately, all fossil fuel options may be constrained by concerns over carbon dioxide emissions and potential global change.

Renewable energy technologies offer great environmental benefits, but most will require additional development to compete economically with conventional energy sources.

Controlled thermonuclear fusion, although unlimited in promise, is likely to remain technically out of reach until well into the next century.

Conservation has great potential. We can do much more to reduce our demand for new energy. Ultimately, however, we must develop new energy resources and technologies. We cannot meet the needs of the 21st century with conservation alone.

Lastly, environmental concerns *must* rank high on our list of issues as we strive to select our best mix of energy forms. All energy forms have environmental impacts to varying degrees. None is totally benign.

In many respects, electricity is the perfect energy form — clean, efficient, and adaptable to almost every task. Our only problem is generating the increasing amounts we will need in the 21st century in environmentally acceptable ways.

As I said, there is no "magic bullet." If there is to be a "Manhattan Project" in energy, its aim will be to reduce the problems limiting those energy forms we already know.

DEVELOPING A NATIONAL ENERGY STRATEGY

Our energy problems and their solutions are just as complex as our society. Legislation, regulation, social change and, yes, technology, all need to be applied with wisdom and balance to achieve results.

Every issue has a bottom line. Energy is a key driver of the economy and critical to national prosperity. Efforts to increase our national competitiveness and to improve the economic health of the country cannot succeed if our energy policies do not make sense.

Over the last 20 years this Illinois Energy Conference has contributed to the national debate about these issues. A review of the proceedings of this conference provides a broad-ranging and comprehensive perspective on almost every aspect of the energy problem. Through these regional discussions, I believe you have all contributed in a very real way to national progress in energy policy.

ENERGY POLICY ACT OF 1992

After 20 years of false starts and frustration, we are fortunate to have finally made substantial progress toward a workable set of energy policies — the Energy Policy Act of 1992.

The Department of Energy estimates that the provisions of the new act, plus the more than 90 initiatives from the National Energy Strategy implemented by the President, will create hundreds of thousands of new jobs and increase our Gross National Product by $500 billion.

Many of these benefits will have positive impacts here in Illinois and the Midwest, the result of initiatives involving clean burning ethanol and alternative fuels, automotive technology, electric utility and tax reforms, enhanced coal exports and clean coal initiatives.

This hard-won national success, the result of hard work and real bipartisan initiatives, should not, however, lead us to a false sense of security. Much more work remains to be done. Not every problem and issue has been resolved.

Our new legislation provides the foundation upon which this conference will look ahead and begin to tackle those remaining problems and issues. As we begin to confront the remaining energy policy challenges before us, I am confident that this conference will continue to play a constructive and vital role.

I. THE FUEL USE SECTORS: A TWENTY YEAR HISTORY

THE WORLD OIL OUTLOOK: AN INDUSTRY PERSPECTIVE

Richard M. Morrow
Retired Chairman of the Board
Amoco Corporation

I last spoke to this group at the 14th conference in 1986. In many ways — and most of them were negative — that was an important year for the petroleum industry. Oil prices had collapsed; domestic production was falling; and imports of crude oil were increasing. Regulations left over from the 1970s still hampered domestic development, especially in the area of natural gas. And government continued to place prospective land off limits to resource development, both on and offshore.

Overseas, the war between Iran and Iraq had dragged into its seventh year, with serious implications for our nation's energy security, no matter what the outcome.

As I commented in 1986:

> "It is troubling enough to be dependent on a single, small area of the world for a strategic and economic necessity like oil. The Middle East is a hotbed of political and religious tensions, divided by suspicions and age-old rivalries. The mixture of political and religious enmity is so great that it threatens to explode at any time. Should the explosion occur at a time of increased U.S. dependence on Middle East oil, the consequences for this country will be severe."

Four years later, with the Iraqi invasion of Kuwait, that explosion very nearly did occur. Thanks to an extraordinary effort led jointly by the United States and the United Nations, the damage and fallout were minimal and the immediate threat was defused. But over the longer term, the treat remains, and it should have served as a distant and dramatic warning of what could happen if our dependence on any one region of the globe for crude oil continues to grow.

In the weeks following Sadaam Hussein's surrender, another monumental event occurred. Communism started to crumble throughout the world. The regimes fell like dominoes, running straight back to Moscow. And finally, the Soviet Union itself collapsed and became extinct overnight.

We are meeting at a time when the world as we have known it is changing in ways yet to be determined. What the world will look like is anyone's guess. But this much is certain. For business in general, and for the oil industry in particular, there is currently a more open playing field worldwide for new strategic initiatives.

As enterprises of all sorts rush to establish positions in the emerging post Cold War world, the search for resources and capital is intense. That is true for all business today and especially true for the oil industry, which currently faces sluggish product demand, unsatisfactory prices, and fierce worldwide competition. For the oil industry, the problem is intensified by being singled out for what often seems like discriminatory treatment. In part for political reasons, and in part because it is still a major and somewhat profitable industry, the oil business has been almost uniquely targeted by both revenuers and regulators.

Thus, just as was the case in 1986, the domestic oil industry continues to be buffeted by misguided and counterproductive regulations, especially in the environmental area, and severe restrictions on domestic exploration and drilling. These are contributing factors in the massive downsizing and redirection of the oil industry that we continue to see today.

Daniel Yergin, the Pulitzer Award winning author of *The Prize*, has put it this way:

> "We are seeing a fundamental contraction on the domestic side along with one of the greatest migrations in the history of the oil industry."

Exploration and production spending has been shifted from the U.S. to overseas locations where economics are more favorable.

Worldwide exploration and production capital expenditures rose rapidly during the 1970s as oil prices increased, peaking in 1981 at almost $130 billion, expressed in 1990 dollars. Expenditures in the U.S. also peaked in 1981, reaching nearly $80 billion in 1990 dollars. As oil prices declined during the 1980s, worldwide expenditures did likewise, falling to about $50 billion in 1991. U.S. spending fell to $17 billion in that same year, reflecting the industry's contraction and migration that started in the 1980s.

In the 1950s, about 80 percent of worldwide exploration and production expenditures were made in this country. By 1980, the U.S. share had dropped to 55 percent and continued to fall throughout the 1980s, declining to 40 percent in 1987 and to only 33 percent in 1991.

To the degree that the U.S. can diversify its petroleum supplies, the *strategic* importance of Middle Eastern oil reserves will be diminished. And as I will discuss later, the establishment of a coherent energy alliance within our own hemisphere would help to reduce that reliance further.

Nor should we abandon our ongoing efforts to develop domestic resources. There are still numerous oil and natural gas prospects in this country, and if the political climate should become more favorable, highly prospective areas may one day be freed up.

As I observed earlier, events in the world today are nothing short of momentous. We have witnessed the total economic failure of state socialism and communism — and of central planning in general. The political changes that are taking place offer significant opportunities for the oil industry to develop new business alliances with Eastern European nations and the C.I.S. United States industry is aggressively seeking new opportunities in some of these countries and expects to be involved in others.

There are also areas to be further developed in this hemisphere — especially in Venezuela, Mexico, and much of Latin America. With the initialing of the North American free trade agreement, an important step in that direction has been taken. When completed, a free-trade area involving the U.S., Canada, and Mexico will bind about 370 million people together into a $7 trillion economy, about 30 percent larger than the European community.

Although the agreement will not escape without some reconsideration, NAFTA will likely be voted on next year, when the political fires may be burning lower. On the issue of energy, NAFTA falls short in many respects. Political and constitutional considerations will require resolution. But in fact, a viable energy trade relationship already exists in the Western hemisphere.

The United States buys most of the oil exported by Canada, and more than half of that exported by Mexico and Venezuela. Canada supplies natural gas and electricity to U.S. consumers, while Brazil and Venezuela sell gasoline to the United States and we sell gasoline, LPG, and natural gas to Mexico.

Earlier this year, Energy Secretary Watkins summed it up in this way:

> "Our feeling is that we need to build a new hemispheric strategy with Venezuela, Mexico, Canada, all combined. We have a lot of work to do. But I think here is part of the new world order emerging. And this is the time to take advantage of it."

The vision of hemispheric free trade is the vision of a win-win situation, based on reciprocal obligations and cooperative action to the benefit of all parties. And within this vision, there is ample room for the development of a new hemispheric energy alliance.

It is still too early to predict the outcome of the dramatic changes that are taking place in other areas of the world and especially in Eastern Europe and the old Soviet Union. But whatever the final result, the world that is forming will still require more energy and petrochemical products.

With this as a prologue, let us take a more detailed look at the energy situation, with emphasis on crude oil supply and demand both here in the U.S. and throughout the world.

Currently, the world's population is increasing by about 100 million people a year. Between 1990 and 2010, world population is projected to increase by 2.1 billion — 1.9 billion or 90 percent of this increase will be in the developing countries. An explosive population growth is expected to continue in Mexico, South America, Africa, and the Middle East.

Two decades ago, as we entered the 1970s, we expected moderate increases in oil prices, with world oil demand forecast to grow at about seven percent per year. It was projected that the world would increase its dependence on Middle East oil and that free world oil demand would double by the early 1980s. However, the Arab oil embargo in 1973 and the political events in Iran in late 1979 dramatically changed those forecasts.

Oil prices, relatively stable for many years at $1 to $3 per barrel, increased to $10 to $13 per barrel following the Arab oil embargo in 1973 and then jumped to almost $40 following the Iranian Revolution nine years later. Prior to 1973, our government had put restrictions on domestic oil imports, giving the U.S. higher prices for oil than the rest of the world. From 1973 to 1981, however, some U.S. oil prices were controlled to levels below the world price.

The price increase of the 1970s caused consumers, industries, and governments to make dramatic changes in their use of energy. World oil consumption, which had increased from about ten million barrels per day in 1950 to 56 million barrels per day in 1973, was still about that level in 1985. Then, in 1986, oil prices collapsed to $10 to $15 per barrel when Saudi Arabia decided it could no longer continue cutting its oil production to try to stop the decline of OPEC oil price realizations.

As a result of lower prices since 1986, world oil demand has increased, and is likely to continue to grow throughout the 90s and into the next century. I will say more about this in a moment.

World oil demand is expected to increase ten million barrels per day by 2000 with another increase of about ten million barrels per day between 2000 and 2010.

The higher oil prices of the 70s and early 80s also increased the incentive to explore for oil and non-OPEC production increased dramatically. OPEC crude oil production fell from 31 million barrels per day during the late 70s to 16 million barrels per day in 1985.

In 1991, OPEC crude oil production averaged 23 million barrels per day and has increased to 24 to 25 million barrels per day during 1992. OPEC is expected to be producing about 32 million barrels per day of crude oil by 2000 and 40 million barrels per day by 2010.

One factor in the growth of oil demand is that gasoline-powered vehicles continue to increase throughout the world. The number of electric cars and alternative-fueled cars that will be in use by the year 2010 will be very small compared to the number of gasoline-powered vehicles. Thus, while we must plan for change, there will be restraints on the rate at which change occurs.

Clearly, the automobile has become the dominant means of transportation during the 20th century, especially in the industrialized world. The growth in the automobile population has been dramatic. Today, there are more than 450 million cars worldwide, with about one-third of them in the U.S. With respect to cars and trucks, developing countries appear to be following the trends set by the developed countries. This — along with greater use of oil fuels for electric generation and manufacturing in developing countries — will result in increased consumption of oil on a worldwide basis.

There is considerable uncertainty as to what will happen to oil supply and demand in the C.I.S., Eastern Europe, and China. Production output and consumption will largely depend on the degree of success in finding more oil and gas in these countries.

Nevertheless, despite an expected decline in U.S. oil production, the world should have adequate supplies of oil well into the next century. Proved oil reserves alone are adequate to supply world needs for about half a century at current consumption rates.

Large reserve additions have been announced in Saudi Arabia, Venezuela, Iraq, Mexico, and other countries in recent years and there is little doubt that further increases will be forthcoming.

It remains to be seen, however, at what rate oil will be made available from OPEC and other countries. And that, of course, presents us with a major challenge. About two-thirds of the proven crude oil reserves of the world are located in the Middle East while about three percent are in the U.S. Despite its small reserves, the U.S. consumes about a quarter of the oil used in the world each day.

At 1991 production rates, the Middle East has sufficient proved reserves for 100 years of production, while the U.S. has enough reserves for ten years. The Commonwealth of Independent States, formerly the Soviet Union, has about two-and-a-half times the proved reserves of the U.S. and a 22 year supply at current production rates.

From a strategic perspective, an important question is how U.S. industry should direct its efforts to obtain more oil supplies. How much of its focus should be exploring for oil in the U.S. and non-OPEC countries versus working out long-term oil supply arrangements with OPEC countries? How should the U.S. use its exploration and production, refining and marketing, and petrochemical technology, know-how, and assets to gain long-term oil supply security?

As we move toward the new century, our industry will probably be competing with the Europeans, the Japanese and others for a Middle East crude supply position. There is some uncertainty at what rate producing capacity will be expanded in Saudi Arabia, Iraq, and other Middle East countries. Also, it is not clear what actions the Russians will take should their oil production continue to decline.

Over the last few years, U.S. companies have had only limited success in finding significant new oil reserves throughout the world. In looking at the decade ahead, we should be careful to be neither overly optimistic nor pessimistic about future oil supplies. We must, however, keep in mind the increasing world dependence on the oil resources of a very small number of Middle Eastern countries, where about 70 percent of the world's known oil reserves are located.

We also need to recognize the rapidly evolving shape of the international oil industry and what this portends for our business and for our country.

The radical restructuring of the world oil industry, sparked by the nationalizations of the 1970s, had led to the emergence of huge national oil companies that dominate the international scene. Four of the ten largest producing companies in the world today are state-owned: the national oil companies of Saudi Arabia, Venezuela, Mexico, and Iran. Of the top 50 oil companies, 24 are wholly state-owned.

Several state-owned producers, both oil rich and oil dependent, are just beginning to explore for oil outside their own countries. Should this process intensify, there will be increased competition for new exploration ventures.

It is also not clear to what extent the OPEC countries will want to work with private companies in developing their own oil resources. And there is considerable uncertainty as to what pricing policies OPEC will follow in the future. Clearly, there is the potential for developing heavy oil deposits, tar sands, more natural gas, and oil from shale, along with the increased use of coal and nuclear energy should the price of oil increase to a level that would make these alternatives attractive.

It is obvious that many uncertainties exist with respect to the domestic as well as the global environment for the U.S. oil industry. Moreover, the challenges facing the industry today are not just economic or technological. It must also deal with public attitudes and perceptions. In the development of public policy, perception frequently is more powerful than reality. The formulation of that policy always reflects current public concerns. And one of the central concerns over the past decade has been the environment.

That concern has significantly affected the way in which the oil industry conducts its business. Environmental law departments and environmental staffs are rapidly becoming the corporate internal growth industries of the 90s. Environmental groups are engaged in well-publicized lobbying efforts for environmentalist directors on company boards. Pension fund managers, investment advisers and church groups are expressing concern for the adoption of corporate environmental behavior codes.

As one reputable research organization puts it, "It's hard to remember any other issue that spread into so many facets of corporate planning so quickly — save possibly consumerism when it appeared in the 1970s." The message, says this group, should be clear. "In many industries, corporations will pay a price for not building these (environmental) issues into their strategic planning." That is a message we should be taking very much to heart — especially at a time when oil production is falling and imports are rising. We are becoming increasingly reliant on OPEC oil and more tankers are coming to this country with the oil we must have.

As many of you know, the low level of drilling activity in the United States over the past few years has been inadequate to replace the oil reserves we are producing and its consequences are reflected in our oil production trends. This trend is in sharp contrast to that of the 1970s, when the domestic industry responded to threatened shortages and higher prices with spectacular growth. U.S. drilling rigs in operation increased from about 1,100 in 1972 to nearly 4,000 in 1981 before beginning to decline.

In spite of the recent seasonal increase, there are currently fewer than 1,000 rigs in operation in the United States. Seismic crews fell from 588 to 77 over the past ten years and industry jobs were nearly halved, from 708,000 to 390,000. Crude oil prices, gasoline prices, and until recently, natural gas prices, have similarly contracted. Only oil imports have increased.

U.S. crude oil production, which averaged nine million barrels a day in 1985, is expected to be seven million barrels a day this year. Alaska North Slope production, accounting for about 25 percent of the U.S. total, peaked in 1988 and is now declining. With domestic production *falling*, imports have been rising to fill the gap between demand and domestic supply. U.S. demand has been relatively stable at a little less than 18 million barrels per day for the past two years.

In 1992, our gross oil imports will average about eight million barrels per day, not too far below the all-time high of 8.8 million barrels per day in 1977, just before oil began to flow through the Alaskan pipeline. We are now roughly 48 percent dependent on foreign oil, and gross oil imports are expected to increase to roughly 67 percent of total U.S. oil consumption by the year 2010. The gross cost of oil imports was $51 billion in 1991. This could rise to $110 billion by the year 2000, and to $230 billion by 2010.

From all indications, the industry will continue to invest more exploration and development dollars abroad rather than on domestic projects. The economic attractiveness of new exploration investments is generally better overseas given the more abundant geological opportunities.

In relation to overseas exploration and production opportunities, the U.S. is a mature oil province. The most striking example to illustrate the difference is a comparison of the U.S. and Middle East petroleum industries.

The United States has over 600,000 producing oil wells compared to only 5,000 in the OPEC countries of the Middle East. Despite the much larger number of wells, the U.S. produces only about half as much oil. U.S. wells produce on average only 12 barrels of oil per day compared to 3,800 barrels per day for wells in the Middle East.

Although wells in the U.S. are not highly productive, there is obviously resource potential for additional oil recovery. For every barrel of oil that has been produced there are two barrels remaining in the ground that are not recoverable with current technology. Clearly, this is an area where advanced technology could play a significant role in increasing this country's supply of recoverable oil.

Sound public policy also is critical in this regard. What is needed to stimulate the U.S. oil industry are the right policies in place, including greater access to public lands, along with tax incentives to invest in the search for new reserves and in projects to recover more oil from existing fields.

One bright spot on the energy horizon is natural gas.

Although it is virtually impossible to stop the decline in U.S. oil production, there is good reason to be optimistic about natural gas. The Department of Energy estimates that the United States has approximately 1,000 trillion cubic feet of potential natural gas resources that can be produced using current technology. This would amount to a 60 year supply of gas at its current rate of production. However, the life of *proven* reserves is only about nine years. Thus, there will be a need for much greater development of our natural gas resources to add to our supply of proven reserves in the years ahead.

There are large quantities of deep gas, tight sands gas, and coal bed methane in the United States that will be economical to develop as natural gas prices increase. Natural gas found and developed within our national borders would represent a secure supply of clean energy for this country.

Moreover, when we add the natural gas resources of Canada and Mexico to our own, our supply of natural gas has even greater potential. New and expanded natural gas markets include the use of compressed natural gas as a transportation fuel and the increased use of gas for generating electricity.

Besides a greater measure of national and economic security, natural gas provides obvious environmental advantages. Its cleaner burning characteristics are especially important now, with concerns about air quality. In short, factors on both the supply and demand sides point to an enhanced role for natural gas in the U.S. energy mix.

Finally, as we look back over the past 20 years, what observations can be made about government policies and their impact on the energy business?

Perhaps the most significant and overriding conclusion is that short-term political reactions to complex longer term economic and energy supply issues were frequently counterproductive. Throughout the 1970s, beginning with wage and price controls, governmental actions created misallocations, shortages, and some damaging price distortions. Whether it took the form of controls, standards or regulations, governmental intervention too often exacerbated the problems it attempted to alleviate and created new ones in the process.

Many of these distortions remained in our economy for years before control advocates could be persuaded that decontrol or deregulation was the most efficient allocator of energy supplies and the most effective determinant of energy prices and consumer decisions.

In looking ahead, what can we expect from the new administration?

We know from President-Elect Clinton's statements the general nature of his energy program, with its emphasis on natural gas and alternative fuels along with conservation and protection of the environment. It appears, however, that his program will do little to arrest the decline of domestic oil production or slow the growth of foreign oil imports in the years ahead. But we also know that campaign positions can be modified once a candidate is in the seat of power.

So Yoggi Berra may have gotten it right when he said, "The future is still ahead of us." And we can only speculate on what that future will bring. There is no question, however, that a healthy energy industry is vital to the future growth and progress of this great nation.

That was very true 20 years ago. It is true today. And it will be true 20 years from now.

Table 1

1986 — A LOOK BACK

- Oil Prices Collapsed
- Domestic Production Falling
- Crude Oil Imports Increasing
- Regulations Hampered Domestic Development
- Prospective Land "Off Limits"

Table 2

CHALLENGE AND CHANGE

- Iraqi Invasion of Kuwait
- The Immediate Threat Defused
- Dependence on Any One Region for Crude Oil a Long-Term Threat
- Communism Crumbled Throughout the World

Table 3

AN EMERGING NEW WORLD

- Still in the Process of Defining Itself
- A More Open Playing Field Worldwide
- 1992 a Difficult Period for the Oil Industry
  - Search for Resources and Capital Intense
  - Sluggish Product Demand
  - Unsatisfactory Prices
  - Fierce Worldwide Competition
  - Targeted by Both Revenuers and Regulators

Table 4

THE OIL INDUSTRY TODAY

- Misguided and Counterproductive Regulations
- Severe Restrictions on Domestic Exploration and Drilling
- Massive Downsizing and Redirection of the Oil Industry

Table 5

THE OIL INDUSTRY IN TRANSITION

- Diversification of Petroleum Supplies
- Coherent Hemispheric Energy Alliance
- Numerous Oil and Gas Prospects in the U.S.
- Political Change
- New Opportunities in Russia and Eastern Europe

Table 6

NORTH AMERICAN FREE TRADE AGREEMENT

- Binds U.S., Canada, Mexico
- More than 370 Million People
- Initialed in 1992 — Approved in 1993?
- Existing Energy Trade — Canada, Mexico, Venezuela
- Basis of New Hemispheric Energy Alliance?

Table 7

CHANGES

- Eastern Europe and Former Soviet Union
- World will still Require More Energy and Petrochemical Products

Table 8

WORLD CRUDE OIL RESERVES AND PRODUCTION

	Proved Reserves, Billion Bbl.	1991 Production Million B/D	R/P Ratio, Years
Middle East	662	16	110
U.S.*	32	9	10
CIS	80	10	22
All Other	240	26	25
Total	1,014	61	45

*Including NGL

Table 9

THE COMING CENTURY

- Competition with Europeans, Japanese and Others for a Middle East Crude Supply Position
- Rate of Middle East Producing Capacity Expansion Uncertain
- Increasing World Dependence on Middle East Oil
- International Oil Industry Evolving Rapidly

Table 10

WORLD'S TEN LARGEST OIL COMPANIES

Saudi Aramco*	Saudi Arabia
Royal Dutch/Shell	Netherlands/United Kingdom
PDVSA*	Venezuela
Exxon	United States
Pemex*	Mexico
National Iranian Oil Company	Iran
Mobil	United States
British Petroleum	United Kingdom
Chevron	United States
Amoco	United States

*State Owned

Table 11

ECONOMIC CHANGE AND TECHNOLOGICAL CHANGE

- Challenges Today not just Economic or Technological
- Public Attitudes and Perceptions
- Environmental Concerns
  - Environmental Staffs the Growth Industry of the 1990s
  - Corporate Environmental Behavior Codes

Table 12

EXPANSION AND CONTRACTION OF U.S. OIL AND GAS EXPLORATION AND PRODUCTION INDUSTRY

	1972	1982	1992 (Est)	Contraction '92 vs. '82 Percent
Drilling Rig Count	1,107	3105	710	77
Seismic Crews	251	588	77	87
Industry Jobs, Thousands	268	708	390	45
Crude Oil, $/B	3.40	28.50	16.80	41
Natural Gas, $/MCF	0.19	2.46	1.74	29
Gasoline, $/Gal. (ex. tax)	0.24	1.12	0.83	26
Gross Oil Imports, %	29	32	48	50

Table 13

CRUDE OIL PRODUCTION — 1991

	Mid-East OPEC	U.S.
Producing Wells, Thousands	5	613
Production, Million Barrels/Day	15	7.4
Daily Barrels/Well	3,000	12

Table 14

NATURAL GAS

- Reserves Substantially Higher than Recoverable Oil
- 1,000 Trillion Cubic Feet of Natural Gas using Current Technology
- 60 Year Supply at Current Rate of Production
- Need for Greater Development of Natural Gas Resources

Table 15

CLEAN ENERGY FOR AMERICA

- Large Quantities of Deep Gas, Tight-Sands Gas and Coal Bed Methane
- Canadian and Mexican Natural Gas
- Transportation Fuel and Electrical Generation
- A Greater Measure of National and Economic Security
- An Enhanced Role for Natural Gas

Table 16

CONCLUSIONS

- Short-Term Political Reactions to Long-Term Economic Problems Inevitably Create Distortions
- Governmental Actions Created Misallocations, Shortages, and Damaging Price Distortions
- Intervention Exacerbated the Problems It Attempted to Alleviate

Figure 1

WORLDWIDE EXPLORATION AND PRODUCTION CAPITAL EXPENDITURES

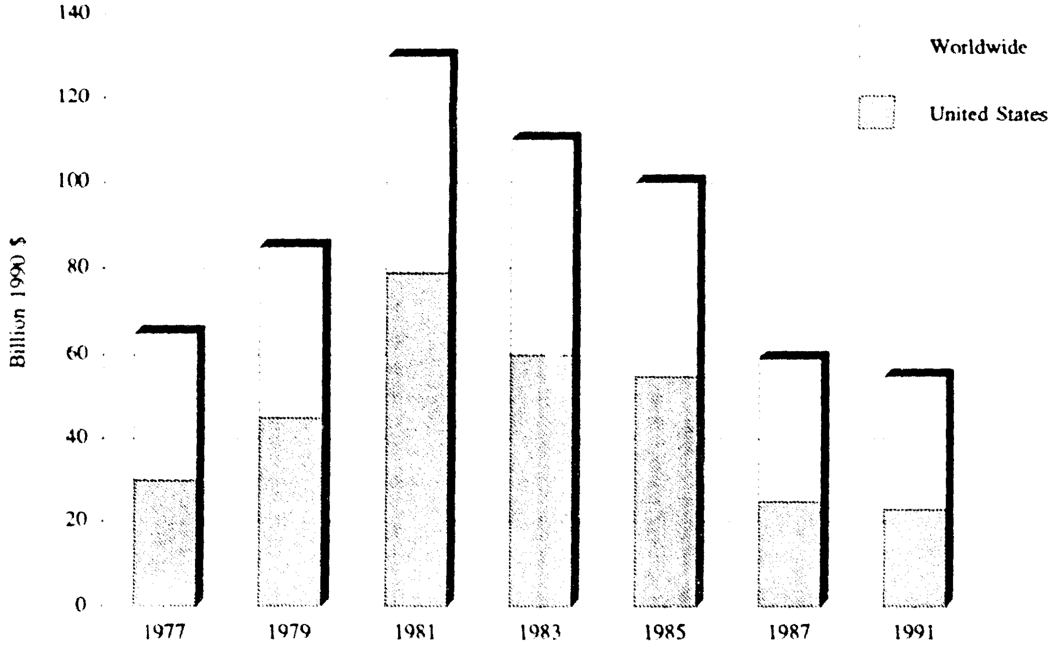


Figure 2

U.S. SHARE OF EXPLORATION AND PRODUCTION CAPITAL EXPENDITURES (EX. RUSSIA, CHINA)

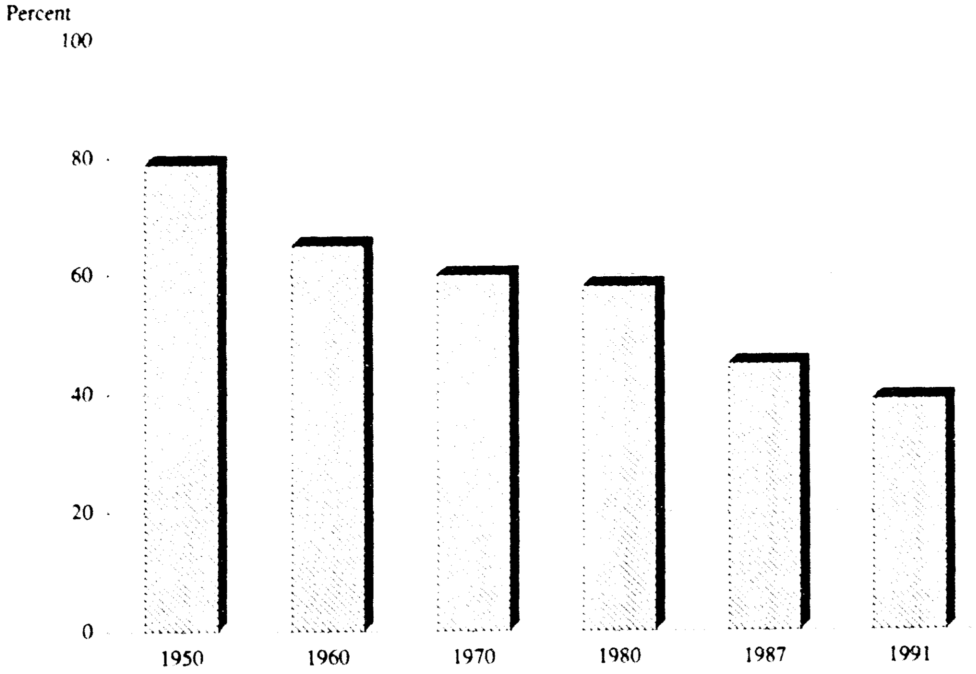


Figure 3

WORLD POPULATION

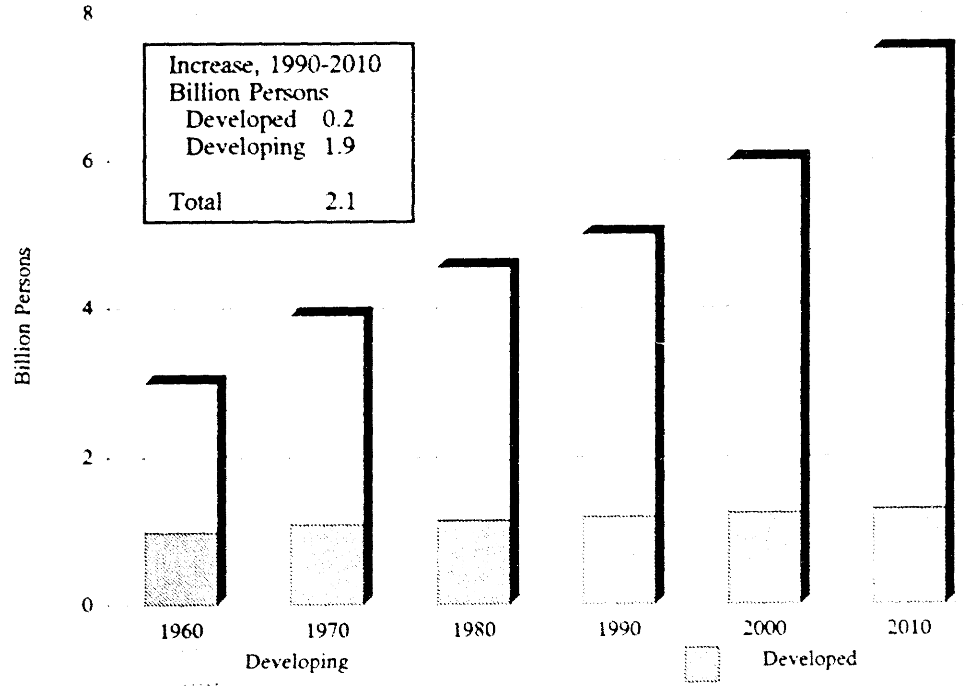


Figure 4

WORLD OIL CONSUMPTION

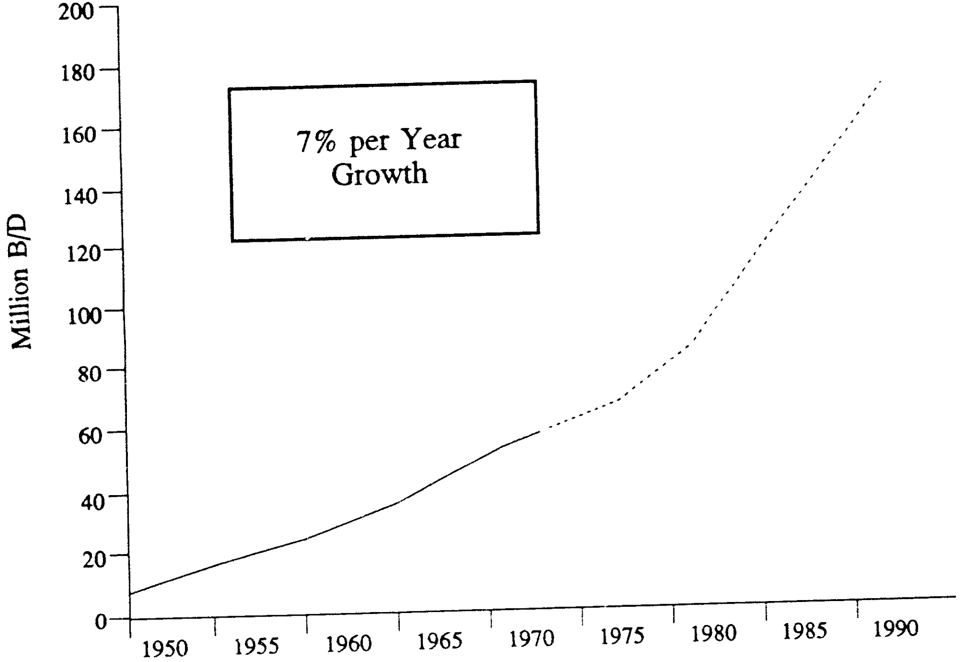


Figure 5

WEST TEXAS INTERMEDIATE - CUSHING

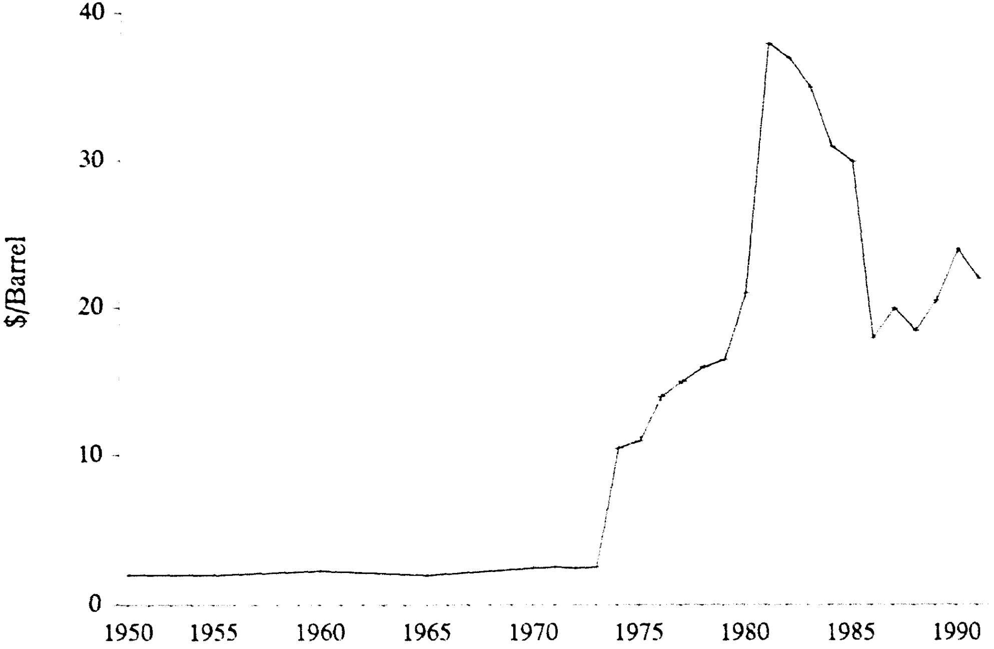


Figure 6

WORLD OIL CONSUMPTION

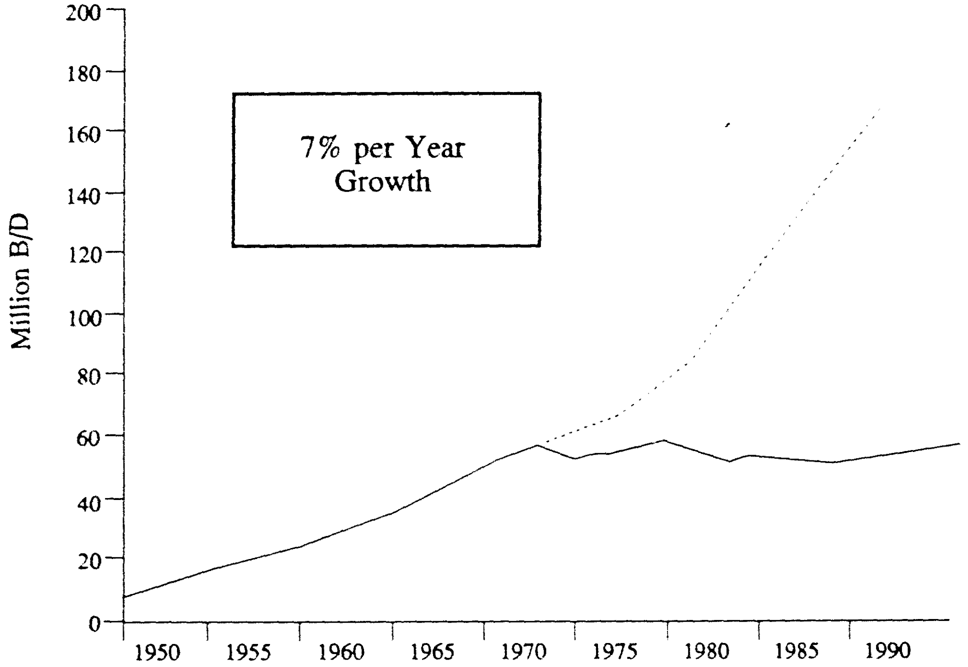


Figure 7

WORLD OIL DEMAND

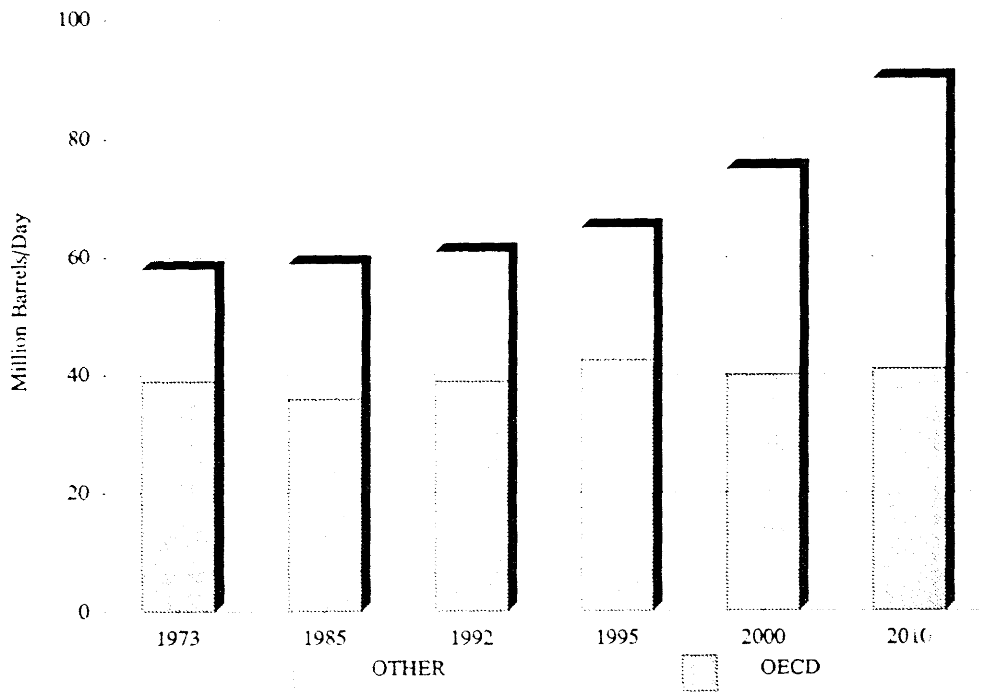


Figure 8

OPEC OIL PRODUCTION

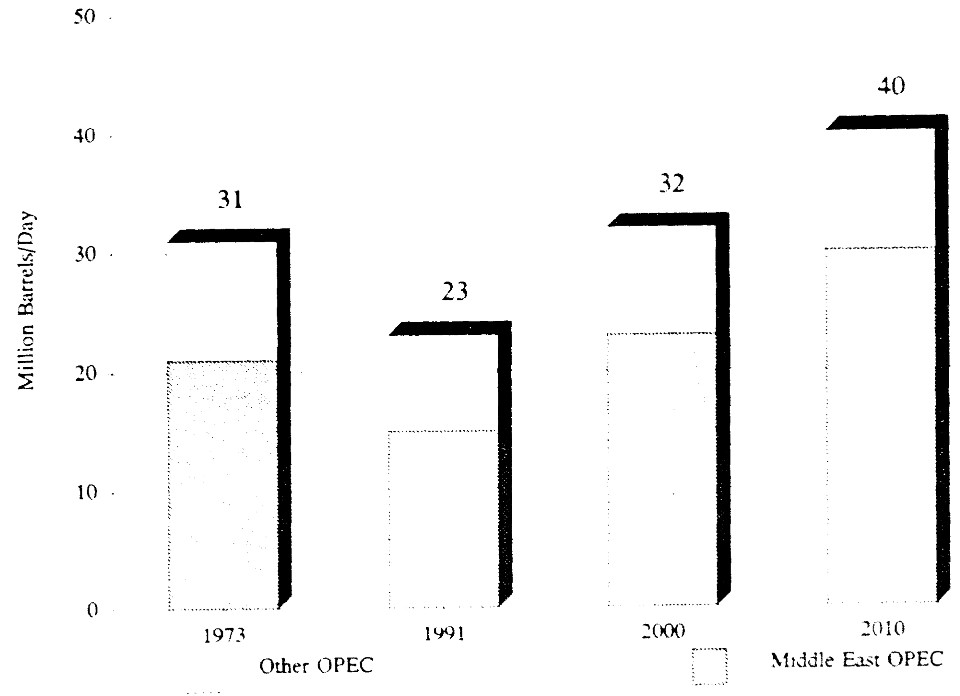


Figure 9

WORLDWIDE PASSENGER CAR REGISTRATIONS

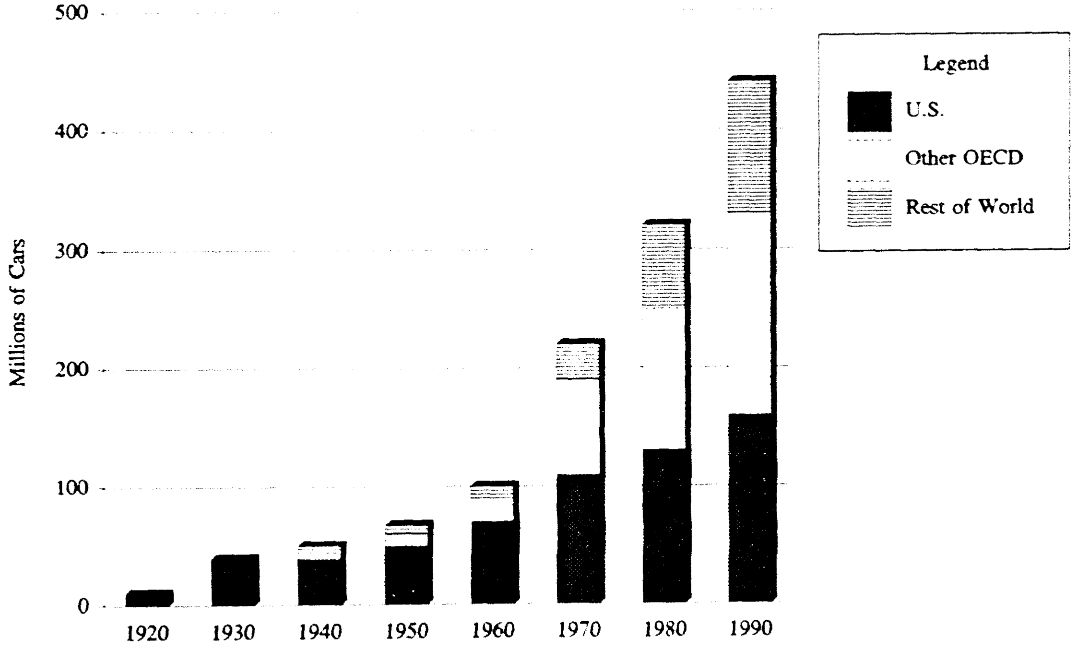


Figure 10

U.S. CRUDE OIL PRODUCTION

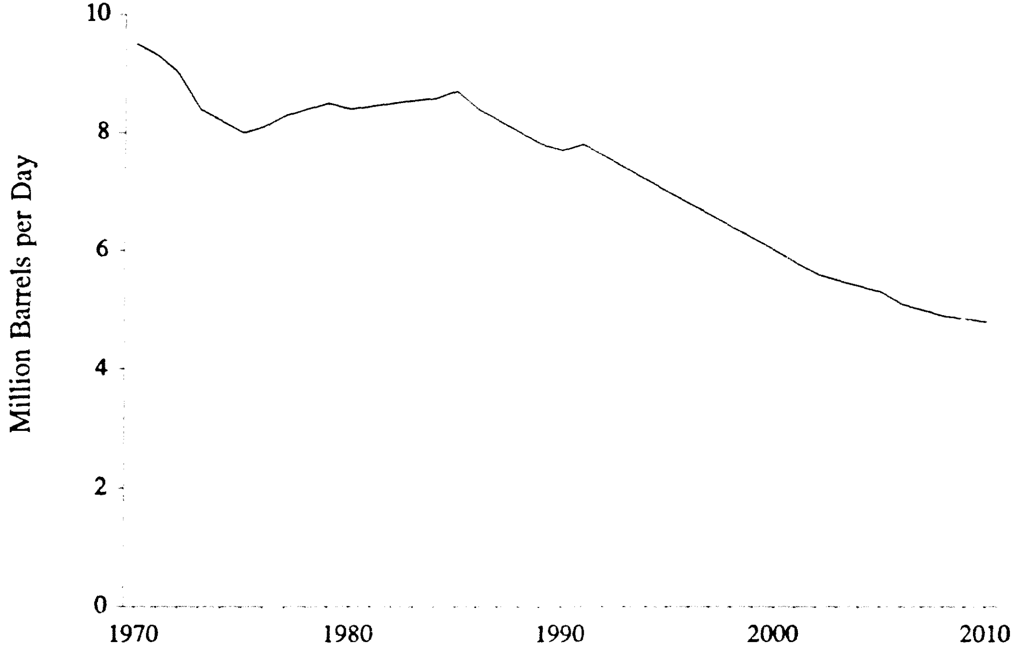
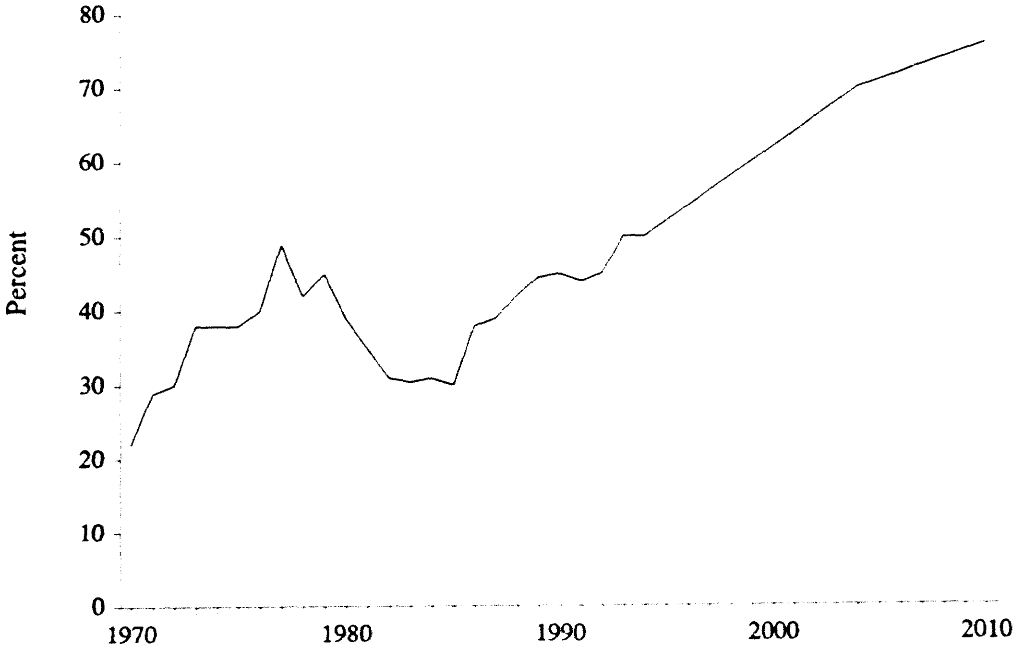


Figure 11

GROSS OIL IMPORTS AS % OF U.S. DEMAND



ELECTRIC UTILITY INDUSTRY: MEETING THE NATION'S FUTURE POWER DEMANDS

Kurt Yeager
Senior Vice-President
Technical Operations
Electric Power Research Institute

The mission of the Electric Power Research Institute (EPRI) is to discover, develop, and deliver advances in science and technology for the benefit of member utilities, their customers, and society.

Because of its size, diversity, and importance to society, the electric power industry has a particular need for large-scale, cooperative research and development. In this most capital intensive of industries, few utilities can afford to conduct their own R&D in more than a handful of important areas. As a result, utilities pooled their resources in 1973 to create the Electric Power Research Institute — today, one of America's largest private research organizations.

Funded through annual membership dues from some 700 member utilities, EPRI's work covers a wide range of technologies related to the generation, delivery, and use of electricity, with special attention paid to cost-effectiveness and environmental concerns. A 24-member Board of Directors composed of senior utility executives, more than 600 utility technical experts, and an Advisory Council of leaders in industry, government, academia, and the environmental community are actively involved in program planning and review.

At EPRI's headquarters in Palo Alto, California, more than 350 scientists and engineers manage some 1,600 ongoing projects throughout the world. The work is carried out by hundreds of individual organizations, primarily industrial and commercial firms, universities, utilities, and government laboratories. Benefits accrue in the form of products, services, and information for direct application by the electric utility industry and its customers.

In 1991, EPRI adopted a new Research and Development Plan to guide the Institute's activities through the coming decade. Addressing the critical challenges and opportunities of the 1990s, the plan focuses on four issues identified by the industry as central to its changing needs:

- **Electricity Value**

  Customer expectations and end-use technologies are changing making it increasing important to enhance the value of electricity services.

- **Environmental Health, Welfare and Safety**

  Environmental health, welfare and safety is a national and international priority providing both opportunities and challenges that must be addressed by the electric utility industry.

- **Sustainable Electric Future**

  New energy and technology alternatives are needed to assure a long-term sustainable electric future, both nationally and globally.

- **Cost Control**

  The productivity of utility assets must continue to increase to address cost escalation and growing competitive pressure.

The new plan ties EPRI's work more closely than ever to the industry's immediate and long-term needs, while at the same time benefiting utilities' own customers and society at large. The logic built into this approach will ensure that EPRI's research is carried out efficiently and managed according to the industry's most important needs.

LOOKING TO THE FUTURE

The following figures review the progress of the Electric Utility Industry over the last two decades. In addition, they define some of the technological, economic, and infrastructural challenges facing this industry as it moves into the next century.

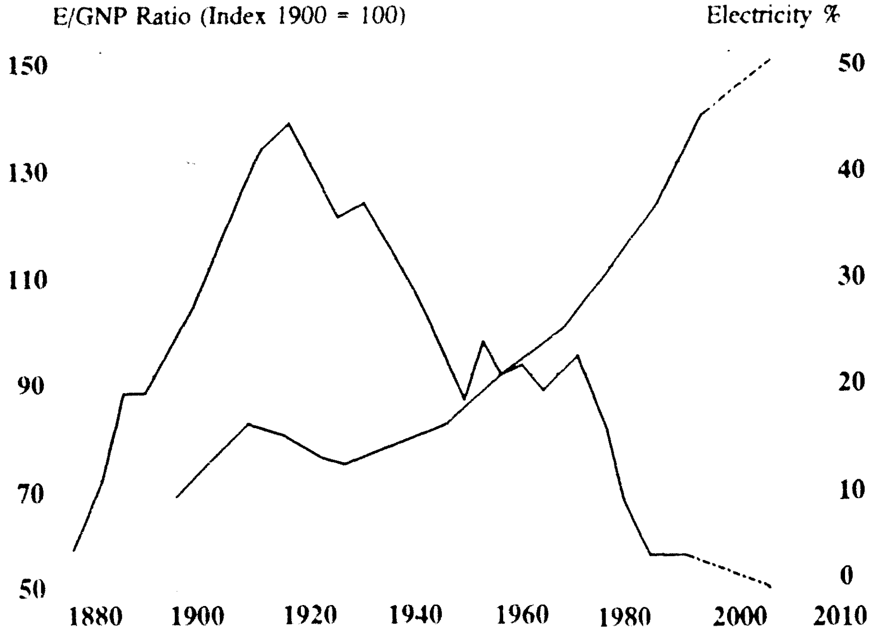
Figure 1

Lessons from the Information/Communication Industry

THE IMPOSSIBLE
TO THE IMPRUDENT
TO THE ACCEPTED
TAKES 3 YEARS

Figure 2

ENERGY CONSUMPTION/GNP vs ELECTRICTY USE



Electricity Will Continue to Substitute for Less Efficient and Productive Energy Forms

Figure 3
UTILITY BUSINESS CRITERIA

Customer Service

£

Competition

$

¥

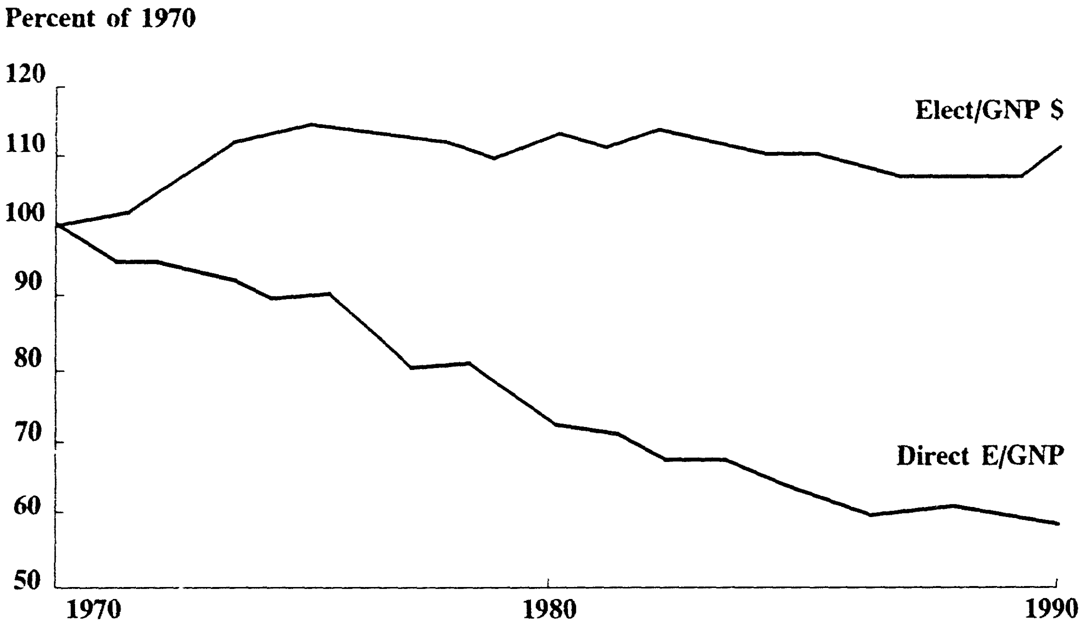
Clean Environment

DM

Conservation

Figure 4

MARKETPLACE DEPENDENCE ON FUELS



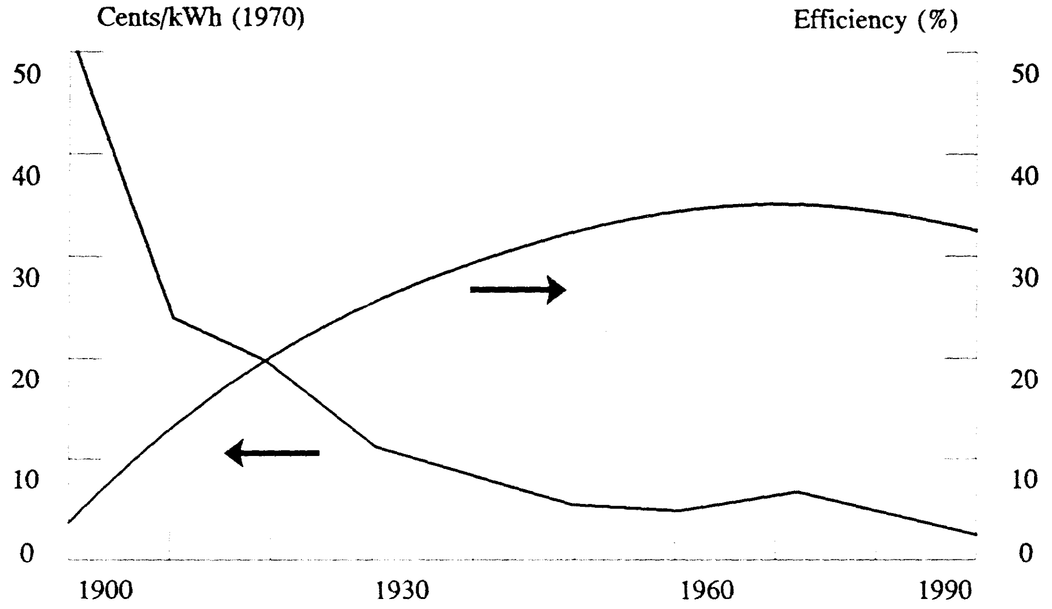


Figure 5

COST & EFFICIENCY TRENDS

Figure 6

CHANGE DRIVERS

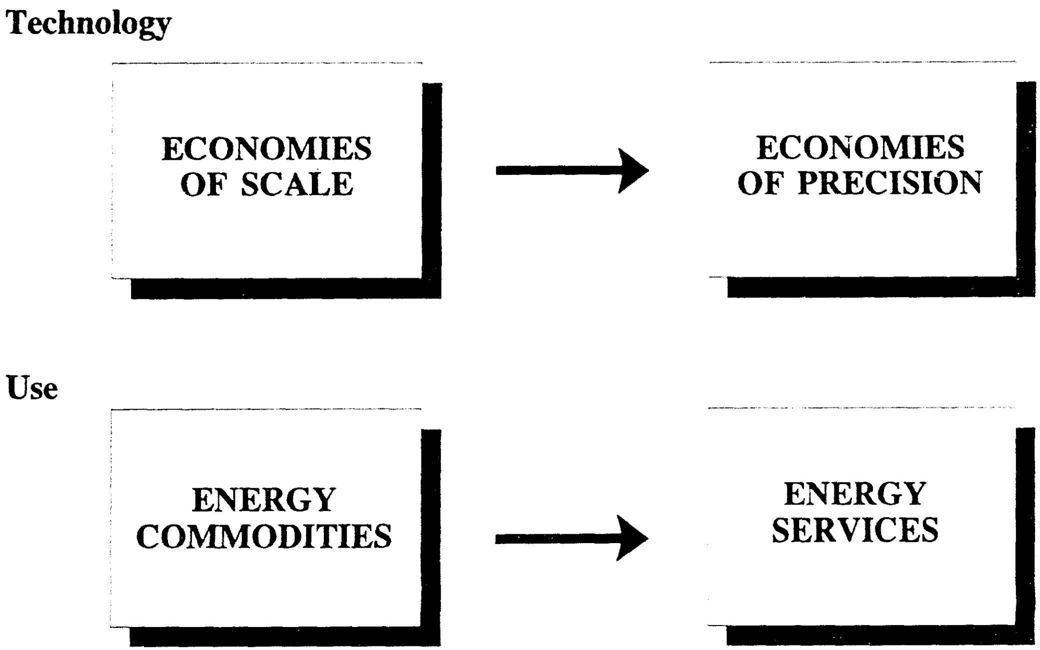


Figure 7

TECHNICAL CHANGE VECTORS

	Generation	Transmission	Distribution	Customer
FROM:	Custom Central Station	Mechanical Control	Reliable Electrons	Bulk Power
TO:	Modular Distributed	Electronic Control	"Smart" Services	Specific Service Needs

Figure 8

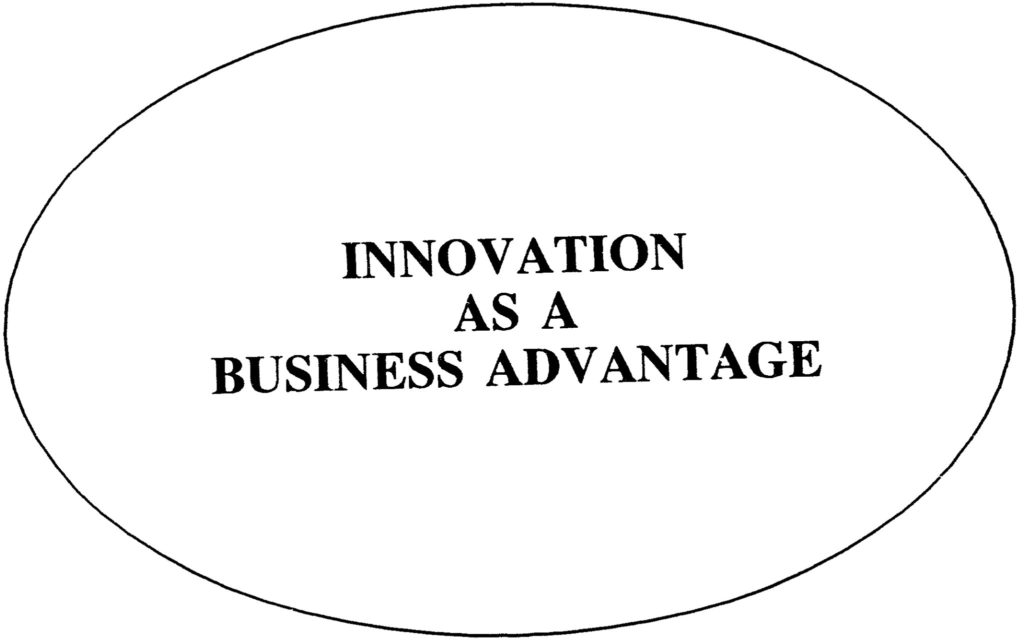


Figure 9

COMPREHENSIVE ENERGY POLICY ACT OF 1992

- Electricy regulation
- Energy efficiency
- Renewable resources
- Climate
- EMF

Figure 10

AVERAGE NATIONAL ELECTRICITY PRICE TRENDS

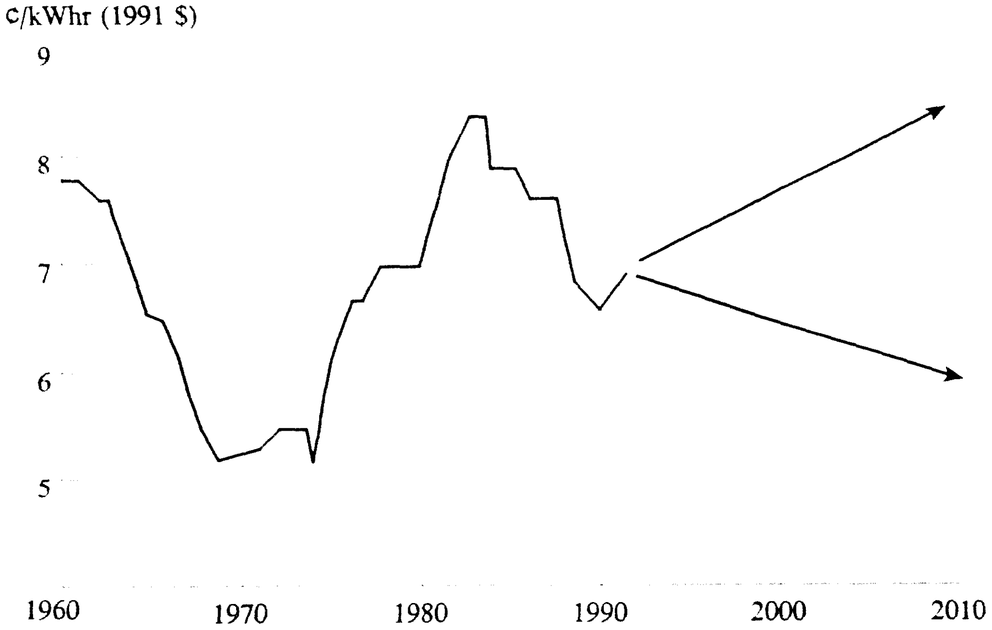


Figure 11

ELECTRICITY GENERATION TRENDS

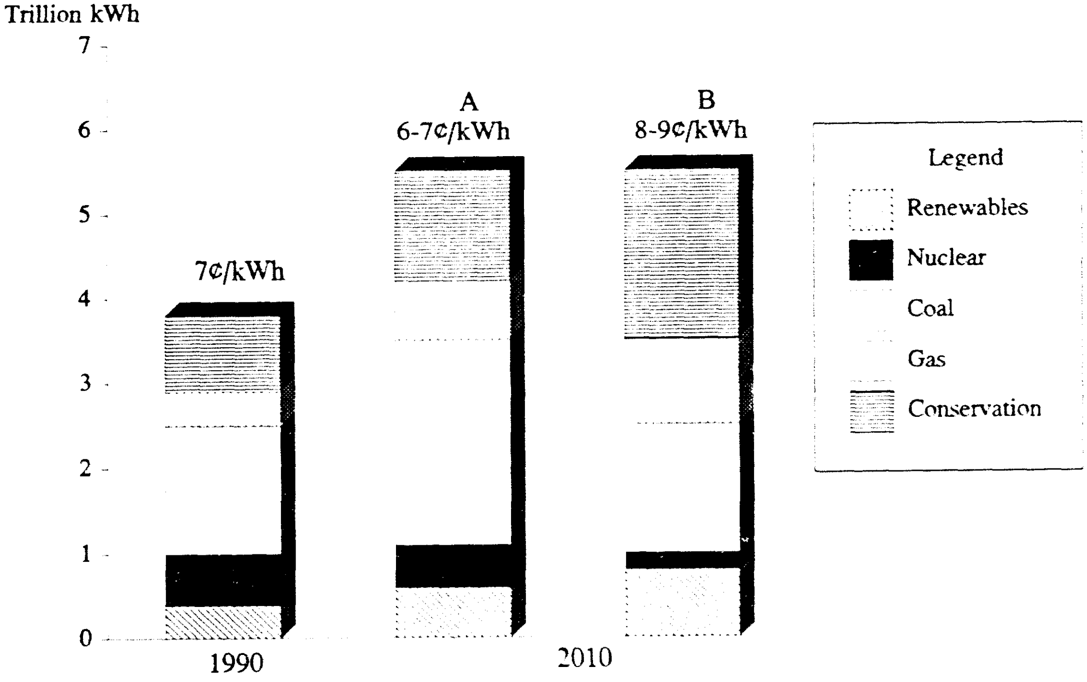


Figure 12

NATURAL GAS ELECTRIC POWER CONSUMPTION

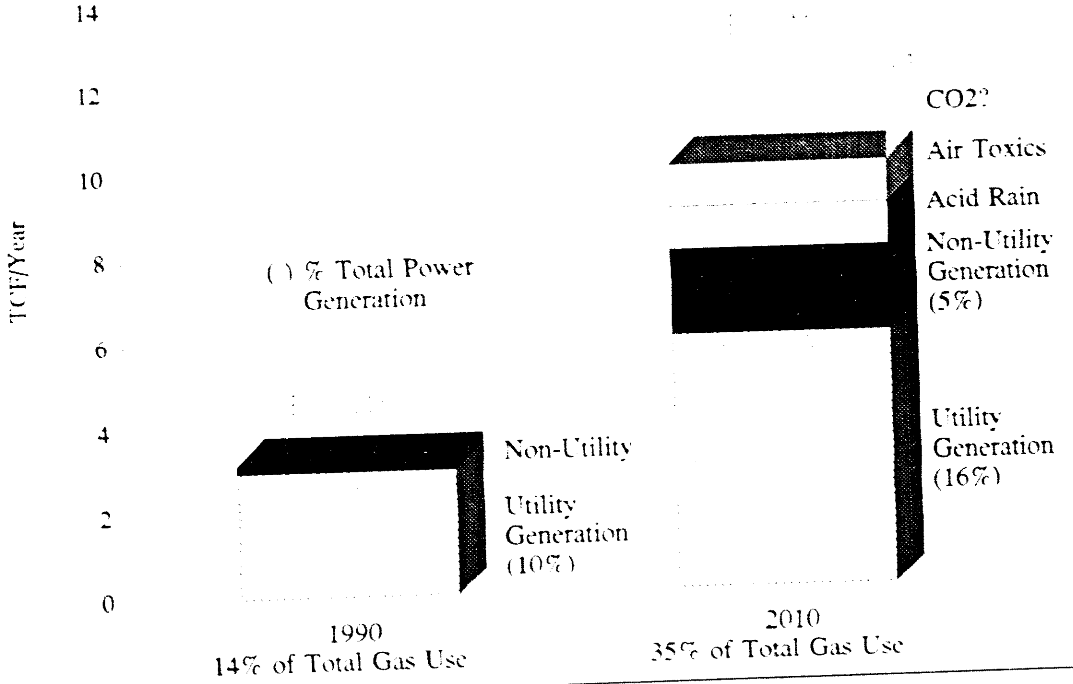


Figure 13

PERCENT OF GENERATING CAPACITY
≥ 30 YEARS OF AGE

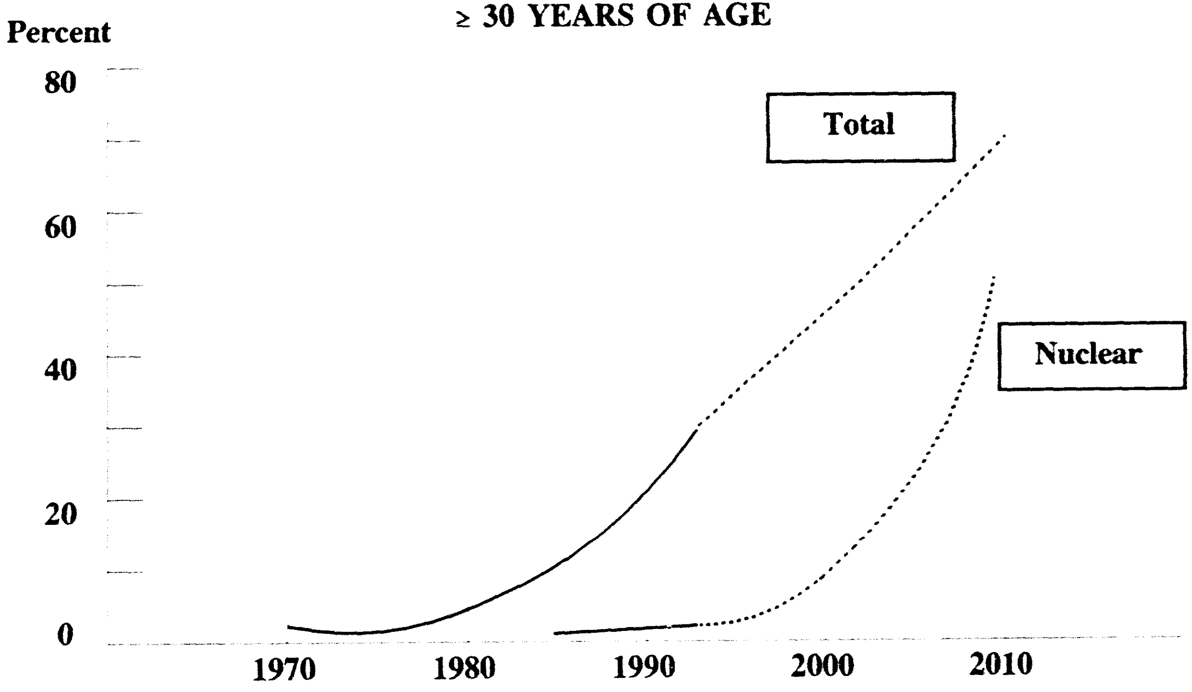


Figure 14

INESCAPABLE REALITY

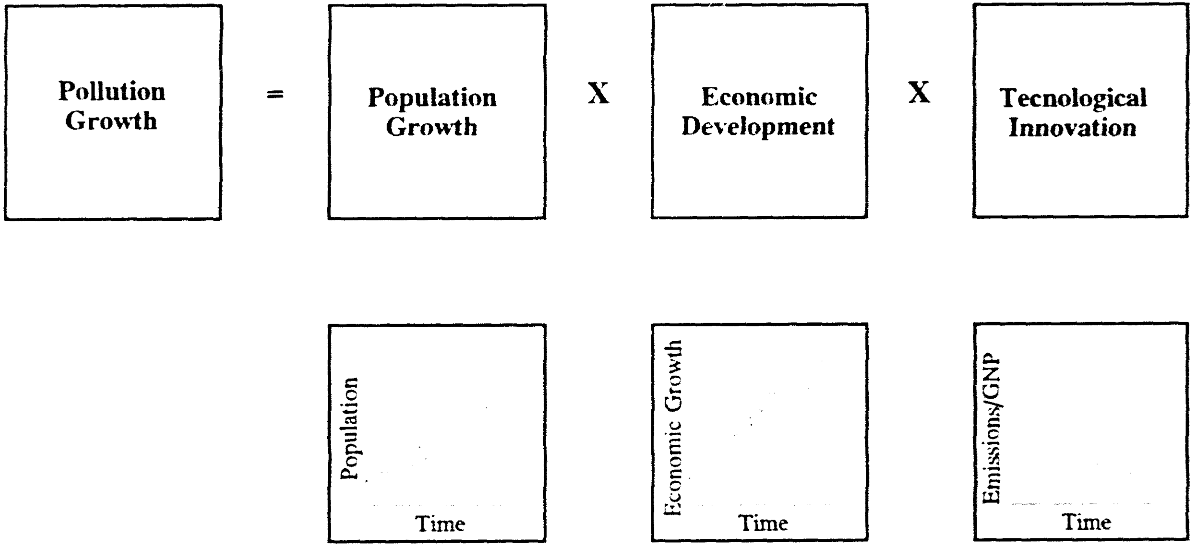


Figure 15

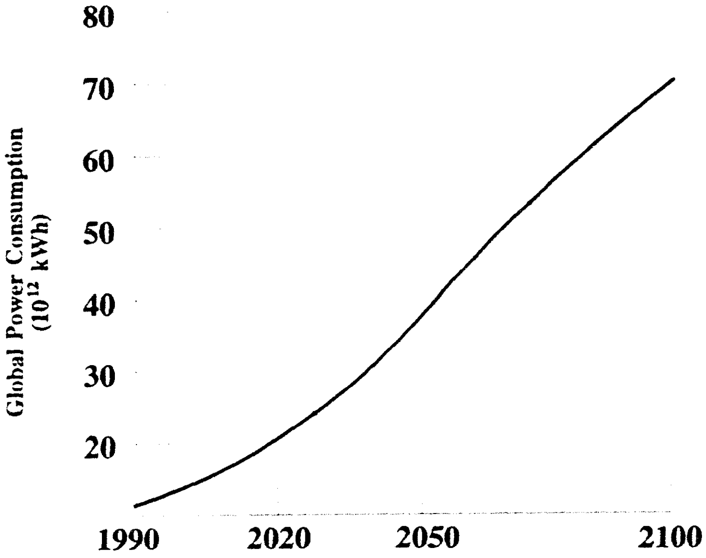
ELECTRICITY: THE GLOBAL STRATEGY

21st Century Goals

- **Imrove global energy efficiency by 50%**
- **Reduce fossil fuels to the margin of global energy consumption**

Results

- **Electricity doubles as % of global energy**
- **Global per capita energy use is 50% of business-as-usual**
- **LDC electricity use increases 10-fold**



II. ENERGY OVERVIEW IN THE END USE SECTORS

U.S. ENERGY EFFICIENCY: PAST TRENDS, FUTURE OPPORTUNITIES, AND THE ROLE OF POLICY

Peter D. Blair
Program Manager
Office of Technology Assessment
U.S. Congress

INTRODUCTION

It is a pleasure to be standing in for my old friend Maxine Savitz. I hope I can be half as insightful as she is in this area. I suppose it is also appropriate that this is a 20th anniversary meeting, since it is for me too a 20th anniversary of sorts — it was 20 years ago this fall that I received an NSF undergraduate research fellowship to look at energy conversion efficiency in power plants, which set me off in the energy business.

I have interpreted my charge today as reflecting on the last 20 years of energy policy particularly with respect to energy efficiency and what legacy this history constitutes for the 21st century.[1] In the almost two decades since the first Arab oil embargo in 1973, our perceptions of the role of energy in the U.S. and world economies have changed considerably. Throughout the 1970s, there was a sense of urgency about energy price and availability that spurred the development of a wide range of new energy supply and demand technologies. The dramatic increases in energy efficiency, in particular, of the U.S. economy were second only to Japan's during that period. Those efficiency improvements coupled with the decontrol of oil and gas prices and other policy actions initiated during the late 1970s led to increases in supply and falling energy prices in the mid 1980s.

The principal legacy of the 1970s and 80s is that current policy concerns about energy are not the sense of urgency about price and availability typical of the 1970s, but rather, are about other factors such as **environmental quality, international**

competitiveness, and **national security**. In addition, our understanding of how energy is produced and used has matured significantly since the 1970s and we are much better equipped to make systematic, long-term decisions about energy policy and its interactions with other social, economic, and environmental policy. Today a comprehensive, strategic national energy policy cannot be viewed as an end in and of itself, but rather, its direction must come from broader and more fundamental national goals of economic health, environmental quality, and national security.

In the final days of the 102nd Congress, the President signed into law the National Energy Policy Act of 1992, which is the broadest package of national energy legislation enacted in over a decade. The process of formulating this legislation began with the President's National Energy Strategy and subsequently included a wide range of other energy-related legislative proposals.

In the course of Congressional consideration of this legislation several Congressional committees asked OTA to undertake a major assessment on U.S. energy efficiency in the 1990s. The first two volumes of this assessment have been published: *Energy Efficiency in the Federal Government* and *Building Energy Efficiency*, which address energy efficiency in the federal government and in the residential and commercial sectors, respectively. Two additional volumes are scheduled to be released in February dealing with energy efficiency in electric utilities and in the industrial sector. Finally, a report on transportation energy efficiency, which will follow up on OTA's earlier work on automobile fuel economy is scheduled for completion next summer. I will draw on the findings of only the released reports in my remarks, but I will also try to give you a sense of the focus of the forthcoming work.

As the nation begins the massive effort of implementing the new legislation in the months and years ahead, and of subsequent initiatives that are likely to be considered with a new Congress and Administration, we are likely to judge their effectiveness in terms very different from the past where we were content with measures that were much more narrowly defined — such as in the 1970s metric of "barrels of oil saved." Today we are likely to judge effectiveness in the context of the three overarching goals noted above: economic health, environmental quality, and national security. This new metric is much more difficult to use, since the goals can conflict. For example, increased reliance on coal could cut oil import dependence, but exacerbate problems of air pollution and global climate change. Nonetheless, some energy options support all three goals, particularly those that improve efficiency of production and use. This history of policy affecting energy efficiency is my principal charge today, but let me first begin with some of the trends in energy use and efficiency.

Since the 1940s the amount of energy consumed by the U.S. economy for each unit of economic output has decreased steadily. Some of this decrease in energy intensity can be attributed to the changing structure of the economy but much of it is due to steady improvements in the efficiency of the use of energy in industry, commerce, and residences.[2] In particular, between 1973 and 1986 the U.S. Gross National Product (GNP) grew over 45 percent while consumption of energy increased only eight percent (see Figure 1). (All figures appear at the end of this paper). One apparent exception to this trend has been in electricity where growth in electricity consumption seems to be more closely linked with economic growth than overall energy use, but even in this instance the sustained linkage is due largely to new and expanded uses of electricity which only offset dramatic increases in efficiency in electricity use (see Figure 2).

HISTORICAL POLICY CONTEXT

Much has changed since the 1970s. The Arab oil embargoes in the early 1970s have come to symbolize the skyrocketing oil and gas price trends of the period and the sense of urgency about preserving future energy supplies. Since that time, however, the energy consumption patterns of U.S. economy have evolved considerably including many permanent structural changes driven by economics, such as increases in both the efficiency and flexibility of energy using technologies. In particular, from the time of the first Arab oil embargo through 1985, the steady decline in energy intensity accelerated in response not only to the influence of improving energy efficiency prompted by rising energy prices and concern over availability, but also to changing patterns of consumer demand, a shifting balance of imports and exports of both energy and non-energy goods, and the changing market basket of goods produced in the United States. Many of these trends were strongly influenced by policy initiatives — both direct energy policy initiatives and, perhaps even more significantly, other economic and environmental policy initiatives, such as broad-based economic policy or the Clean Air Act.

With the precipitous drop in world oil prices in 1986, came yet another chapter in the evolution of the nation's energy characteristics. Between 1960 and 1986 the energy consumed per unit of GNP fell about one percent per year, and between 1973 and 1986, it fell at an average rate of about 2.3 percent per year. Since 1986, however, the decline in U.S. energy intensity has virtually stopped. Analyzing what has happened over the last decade and half may reveal much about what to expect over the next several decades. In the following I explore the forces shaping these trends more closely.

Finally, the nation's thinking about energy policy, particularly the role of energy efficiency in it, has evolved considerably over the last two decades as well. Many of you may recall the first major energy legislation related to energy conservation in 1975, the Energy Policy and Conservation Act (EPCA), which followed nearly two years of debate since the 1973 oil embargo. The debate then centered, much as today's debates in this area do, on the relative effectiveness of market forces versus regulation. This legislation included automobile fuel economy standards, state and local energy conservation programs, and energy labeling, among other initiatives. The next year in 1976 Congress also passed the Energy Conservation and Production Act and the Energy Conservation in Existing Buildings Act, which included new building energy performance standards, low-income weatherization assistance. The Carter Administration formulated its National Energy Plan (NEP) early in 1977 and Congress enacted many of the NEP proposals in the following year in the National Energy Conservation Policy Act (NECPA) and the Energy Tax Act. Many of these initiatives were directed at residential conservation and included such programs as the residential conservation service, expanded weatherization assistance, conservation financing programs and tax credits.

With the 1980s and the Reagan Administration came a fundamental shift in national energy policy perspective toward minimizing the role of government in energy markets. The principal actions affecting energy efficiency initiatives begun under the Carter Administration included:

1. Reorganizing DOE and substantially reducing its size and scope (see Figure 3), most notably by eliminating demonstration projects from DOE supported activities; and

2. Dramatically reducing the role of conservation and renewable energy programs in the DOE R&D portfolio.

Many of the initiatives begun in the Carter years were abruptly terminated and their relative success or failure never determined. In 1990 the Bush Administration initiated the National Energy Strategy (NES), arguably the most comprehensive analytical effort at formulating national energy policy ever but certainly not the first. While the NES rediscovered energy efficiency as a legitimate policy goal, the accompanying legislative proposals included only initiatives that relied principally on research and development to pursue it. The ensuing debates in Congress broadened significantly the NES portfolio of options addressing energy efficiency, but the final bill excluded some of the most controversial elements considered, such as increased Corporate Average Fuel Economy Standards (CAFE) for automobiles. The original CAFE standards constituted, arguably, the most successful of the energy efficiency policy initiatives initiated in the 1970s that survived the 1980s (see Figure 4).

Despite the dramatic changes at the national policy level over the last two decades, actions in the States followed a smoother path, progressively and increasingly pursuing energy efficiency, albeit more slowly in the 1980s than during the Carter years. The terms "least cost planning," "integrated resource planning," and "demand side management" all were coined in the 1980s and have become common both in statute and in practice in many states.

NATIONAL ENERGY STRATEGY: A HISTORICAL NOTE

In 1939 President Franklin Roosevelt appointed a National Resources Planning Board to examine the nation's resources policy options. The Board recommended government support of research to promote "efficiency, economy, and shifts in demand to low-grade fuels" and that a "national energy resources policy" should be prepared that would be more than a 'simple sum' of policies directed at specific fuels."[3]

As the nature of energy policy issues took shape during the Roosevelt years, in 1945 the Department of Interior set forth a collection of "principles" on which to base national energy policy that included:[4]

1. Use of the most economic sources of energy to minimize cost
2. Use of plentiful and depletionless resources whenever possible in place of scarce and depleting resources
3. Sources of energy with special characteristics should not be used for purposes for which other less specialized energy sources are available
4. The best and most efficient technologies should be used without hindrance
5. Market stability is essential to properly functioning energy markets
6. The less labor and capital required to energize our economy is best for the economy; high levels of employment are promoted by efficiency

Many of these sentiments have largely been repeated and refined in 1947 by President Truman's National Security Resources Board, in his 1950-52 President's Materials Policy Commission (known as the Paley Commission after its Chairman, William S. Paley), President Eisenhower's 1955 Cabinet Advisory Committee on Energy Supplies and Resources Policy, the 1961 National Fuels and Energy Study commissioned by the U.S. Senate during President Kennedy's term, President Johnson's 1964 "Resources Policies for a Great Society: Report to the President by the Task Force on Natural Resources," President Nixon's 1974 "Project Independence Blueprint," President Ford's 1975 Energy Resources Council reflected in his omnibus proposal "Energy Independence Act of 1975," President Carter's 1977 "National Energy Plan," President Reagan's 1987 "Energy Security" report, and, of course most recently, President Bush's 1991 "National Energy Strategy." In short, every U.S. President since Franklin Roosevelt has formulated or endorsed a national energy policy, albeit with widely differing degrees of enthusiasm.

MEASURING ENERGY CONSUMPTION CHARACTERISTICS

In 1981 President Reagan defined energy conservation as "being cold in the winter and hot in the summer." I use the term energy efficiency as the modern version of what we used to call energy conservation since it seems to better convey the relationship between economic efficiency and energy use. In particular, we can define *energy conservation* as all steps taken to reduce energy use while *energy efficiency* refers more specifically to improvements in the engineering performance for end uses or for delivery of energy services. Often loosely defined as the energy efficiency of the entire economy is *energy productivity* or the level of economic value per unit of energy consumption in the economy. Energy productivity is often displayed as its inverse, *energy intensity*, or the energy consumed per unit of economic value, e.g., Btus consumed per unit of GNP (as earlier in Figure 1).[5]

FORCES INFLUENCING CHANGE

Confusing energy efficiency with energy intensity can be very misleading. For example, some analysts[6] in the 1980s asserted that if the energy to GNP ratio in effect in 1973 were applied, for example, to the 1986 GNP, the difference between the energy we would have consumed (the so-called trended energy use) and the amount we actually consumed is virtually all attributable to energy efficiency improvements. This, of course, isn't the case since many other interrelated forces are shaping the economy as well . . . the changing market basket of U.S. goods and services . . . a move toward a services economy away from energy intensive smokestack industries . . . changing patterns of final demand and demographics . . . technological change independent of energy efficiency, and a changing trade balance. According to several studies,[7] and more recently confirmed by our own historical analysis[8], energy efficiency improvements accounted for nearly two-thirds of the decline in energy intensity over the decade from 1975 through 1985; the rest came from other sources. The forces affecting energy consumption patterns include the following.

- Economic Growth

  While the link between economic growth and energy consumption is not as strong as it was in the 1960s and before, economic growth is still a substantial factor in energy consumption growth.

- Changing Patterns of Final Demand

  Changing U.S. demographics, patterns of urbanization, and lifestyles will continue to have important impacts on fragmentation of existing product markets, tradeoffs in time versus money in purchasing decisions, and new demands prompted by changing lifestyles such as activities formerly in the unpaid household economy entering the formal market economy (child care or care for the elderly) or shifts of services formerly in the market economy entering the home (VCR's, home health care, or access to information via telecommunications).

- Changing Industrial Structure

  Three trends are particularly apparent:

  - changes in the relative roles of different kinds of businesses (resource industries are playing a declining role while service industries are growing);
  - changes in the scale and scope of individual enterprises (production units are becoming smaller and less tightly managed and parts of the economy once dominated by small business are becoming parts of sophisticated networks); and
  - changes in the locations of business.[9]

- Globalization of the World Economy and Changing Trade Balances

  A decade ago trade was a small part of most U.S. production networks. Today imports are essential to many businesses and have an important impact not only on direct energy use, but also on the energy embodied in those imports.

- Trends in Energy Prices

  Many forecasters predict very modest increases in energy prices. Perceptions of sustained low energy prices will have to continue to diminish energy security concerns.

- Increased Attention to Local and Global Environmental Concerns

  Concerns over acid rain, nuclear waste, CO_2 emissions from fossil fuels and other local and global environmental issues have in many instances supplanted energy security concerns over energy supply. How government policy, industrial investment decisions, and consumer decisions evolve in light of these concerns will profoundly affect future patterns of energy use.

- Continuing Improvements in Energy Efficient Technology

  The 1970s and 80s "primed the pump" of technology innovation in energy efficiency. Despite low and stable energy prices, the frontier of energy efficiency improvements continues to expand. Considerable future energy efficiency gains in all sectors of the economy are possible with existing technology, but more substantial gains are available with technologies in development as well.

THE BALANCE OF FORCES

Figure 5 shows the sources of change in U.S. energy consumption over the last decade and a half. Two possible future scenarios emerge from that history in light of the changing array of forces just discussed.

The first scenario, and the one to which I subscribe more than the others discussed here, is that in contrast to the 70s and 80s, competitiveness pressures on industry are now encouraging energy efficiency investments indirectly, as a consequence of efforts focussed on other factors affecting overall productive efficiency. The evidence to date is only anecdotal, but decisions to modernize industrial plants, primarily focussed on reducing labor costs, for example, are likely to result in improvements in energy efficiency that otherwise might not be considered cost-effective on their own. The U.S. steel industry is very different from a decade ago. It has moved from a high volume, basic steel industry to a focus on specialized, high value products. Hence, while the U.S. steel industry's total value of production of steel products has not declined substantially over the last decade, the composition of its output has changed considerably. On one hand, the investment in transforming the industry, has resulted in dramatically improved energy efficiency. On the other hand, the U.S. now imports much of its basic steel.

The alternative scenario, advanced by many economists is that the real price increases of energy of the 1970s or, in some cases, an anticipated sharp increase in prices precipitated, almost solely, decreased energy intensity. Hogan[10] classifies the structural changes in energy use patterns in the economy as primarily price-motivated and argues that "virtually all the reduction in energy intensity during that period could be attributed to relative price changes and that there is no necessity to appeal to an independent trend in technological change to explain the reduction in energy use relative to GNP." Yet the U.S. economy *is* undergoing fundamental structural change, including using new industrial processes to produce many traditional products that are being adopted for many other reasons than energy price. I think that we do not yet have a very complete picture of the energy consumption characteristics of many these new processes. Jorgenson and others argue further that many new technology processes that contribute to overall economic productivity are "energy using," and especially "electricity using." Hence, they argue, energy price increases diminish productivity growth and the net effect during the 1970s and early 80s was that the "price" effect overshadowed the energy bias in changing technology resulting from decreasing energy intensity. Since the energy price plunge in 1986 and expected stable real energy prices (especially electricity) for the foreseeable future, the price effect has been overshadowed by the energy using "technology bias" resulting in increasing electricity intensity.[11]

I believe we cannot yet pick the scenario that is evolving and it may actually be a mixture of the two. Regardless of which path we are on, over the last decade the immediate sense of urgency about energy issues has diminished considerably. As a result, some of the forces that dramatically moderated our dependence on foreign sources of fuel in the 70s (and helped drive oil prices down) are less effective in resisting new dependence. For example, since the easiest energy efficiency investments have been made, future ones may be more difficult to stimulate, perhaps requiring stronger policy incentives if price and uncertainty of supply are no longer perceived as a concern. Nonetheless, considerable future energy efficiency gains in all sectors of the economy are possible and could constitute the cornerstone to a comprehensive strategy for slowing the increase in oil imports in the 1990s, improving international industrial competitiveness of U.S. goods and services, addressing local environmental concerns such as acid rain and urban ozone, and, finally, global environmental concerns such as global warming.[12]

THE SPECIAL CASE OF ELECTRICITY

Beginning with the 1973-74 Arab oil embargo, forecasts of U.S. electricity demand growth and costs, based solely on past trends, proved virtually useless. Utilities had to pay, on average, 240 percent more for oil and 385 percent more for natural gas, in real dollars, in 1984 than in 1972. These price increases drove them to "back out" of oil and gas-fired generation and go in favor of coal and nuclear plants. Oil dropped from 16 to five percent in the utility fuel mix and gas from 22 to 12 percent between 1972 and 1984. But construction costs of new power plants, particularly nuclear, rose dramatically during this period due to a combination of factors — increased attention to environmental and safety issues (leading to extended construction lead-times and added equipment costs), an unpredictable regulatory environment, an inflation-driven doubling of the cost of capital, and poor management in some cases. The higher costs of fuel and capital meant higher electricity costs, and utilities sought higher rates for the first time in decades. In addition, most utilities seriously underestimated the price elasticity of electricity demand. Growth in demand plummeted from seven percent a year to less than 2.5 percent by the end of the decade as consumers used less electricity and used it more efficiently.

The most important legacy of the 1970s is the uncertainty in electricity demand growth. After 1972, not only did the average annual demand growth rate drop to less than a third of that of the previous decade, but the year-to-year changes became erratic as well. Users of electricity were able to alter the quantity they used much more quickly than utilities could accommodate these changes with corresponding changes in generating capacity. Moreover, as of 1986, some markets are saturated — many major appliances in homes — and the future of industrial demand is clouded as many large industrial users of electricity, such as aluminum and bulk chemicals, are experiencing decline in domestic production due to foreign competition. At the same time, rapid growth continues in other areas such as space conditioning for commercial buildings, industrial process heat and electronic office equipment. Predicting the net impact of these offsetting factors, along with trends toward increased efficiency, has greatly complicated the job of forecasting demand. However, some researchers argue that the role of electricity prices on recent trends of declining demand are overestimated, and that the principal reason for falling demand in the 1980s is lower economic growth and for resurgent demand in the late 1980s is higher economic growth. Nonetheless, uncertain demand is still the principal feature of the electric power business' current investment decision environment.

Since requirements for new generating capacity over the next two decades depend primarily on electricity demand growth (as well as the rate at which aging plants are replaced with new capacity and, in some regions, net imports of bulk power from other regions), planning for new capacity has become a very risky process. To illustrate the demand uncertainty, projections of future electricity demand continue to vary considerably — average annual peak demand growth from one to five percent annually — depending on assumptions about economic growth, energy efficiency, changing economic structure, cost and price of competing energy sources and other factors. The expectations about demand also vary by region of the country. The sense of urgency and hence the intensity of the debate on many electricity issues over the next decade will depend largely on the rate of electricity demand growth. For example, compared with currently scheduled generating resources for the end of the decade, a one percent average annual demand growth could mean about a 75 GW surplus while a five percent growth could mean a 150 GW shortfall (see Figure 6).

The electricity and energy efficiency titles of this fall's energy legislation are also likely to have a substantial impact on the role of energy efficiency in the electric power business. For example, the legislation requires that, "The rates allowed to be charged by a State regulated electric utility shall be such that the utility's investment in and expenditures for energy conservation, energy efficiency resources, and other demand side management measures are at least as profitable, given appropriate consideration to income lost from reduced sales due to investments in and expenditures for conservation and efficiency, as its investments in and expenditures for the construction of new generation, transmission, and distribution equipment."[11] This section alone could have a substantial impact on the relative profitability of demand side investments by utilities and others participating in utility-sponsored demand side programs.

SOME CONCLUSIONS AND POLICY CONSIDERATIONS

Our experience with existing energy efficiency technology and our perspective on the prospects for new technology have evolved considerably since the early 1980s. We are still seeing the effects of changes in the patterns of energy use initiated in the 1970s and 1980s. Some of the changes of this period were reversible, behavioral reductions in use of energy, such as lowered thermostats, but many more were more permanent structural changes driven by economics and policy.

At the same time, new uses of electricity will complicate demand uncertainty even more and demand side options alone will not be sufficient. At a matter of policy it is important to reconcile supply with demand in the planning process. The tools we currently use are not adequate to that task, nor is the available data. Nonetheless, efficiency has and can continue to have a profound impact, but pursuing energy efficiency cannot be along one dimension for any one of those dimensions alone — environmental concerns, international competitiveness, or energy security — may not be sufficient enough to prompt significant action. Taken together, however, they comprise a compelling case. In particular, the collateral benefits of energy efficiency accompanying other economic productivity improvements suggests that significant improvements may come about as by products to such investments. This broader perspective on energy policy, i.e., as drawing its direction from broader economic and environmental policy, is likely to change the policy instruments considered appropriate in the years ahead. More importantly, the likely focus of energy policy may be the implications of other economic and environmental policy initiatives on energy markets, fuel choices, and patterns of energy use. Some analysts still assert that the most significant "energy" policy initiative in the last decade was the set of 1991 amendments to the Clean Air Act.

Despite the dramatically transformed policy environment, considerable future energy efficiency gains in all sectors of the economy are possible and could constitute the cornerstone to a comprehensive strategy for slowing the increase in oil imports in the 1990s, improving international industrial competitiveness of U.S. goods and services, addressing local environmental concerns such as acid rain and urban ozone, and finally, global environmental concerns such as global warming. Pursuing these efficiencies, however, is much more challenging and complicated than our past experience has prepared us for. While the National Energy Policy Act of 1992 is far reaching legislation that will take decades to implement and evaluate, it leaves many options for the Clinton Administration and the 102nd Congress to revisit and consider anew. Nonetheless, I believe meeting the challenge will yield substantial benefits.

ENDNOTES

1. The views expressed in this paper are entirely those of the author and are not necessarily those of the Office of Technology Assessment (OTA). This paper expands and updates an earlier paper, "Energy Efficiency and Electricity Use in the 1990s," *Electric Energy in 2024*, Washington, DC: Institute for Technology and Strategic Research, March, 1990.

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3. *Energy Resources and National Policy*, Report of the Energy Resources committee to the Natural Resources Committee, (U.S. GPO, 1939); also summarized in C. Goodwin (ed.), *Energy Policy in Perspective*, Washington, DC: Brookings, 1981.

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5. For more detailed discussion, see Electric Power Research Institute, "Utility Energy Strategies: The Role of Efficiency, Productivity, and Conservation," EPRI CU-6272, February 1989.

6. Komanoff, C., "Increased Energy Efficiency: 1978-1986," *Science*, Vol. 239, No. x, 1988.

7. Schipper, L., *et al.*, "United States Energy Use from 1973 to 1987: The Impacts of Improved Efficiency," (draft), February 14, 1990; R. Carlsmith, W. Chandler, J. McMahon, and D. Santini, "Energy Efficiency: How Far Can We Go," Oak Ridge National Laboratory, ORNL/TM-11441, 1990; and U.S. Department of Energy, "Energy Conservation Trends: Understanding the Factors that Affect Conservation Gains in the U.S. Economy," DOE/PE-0092, Office of Policy, Planning and Analysis, September, 1989.

8. U.S. Congress, Office of Technology Assessment, "Energy Use and the U.S. Economy," Background Paper, OTA-BP-E-57, June, 1990.

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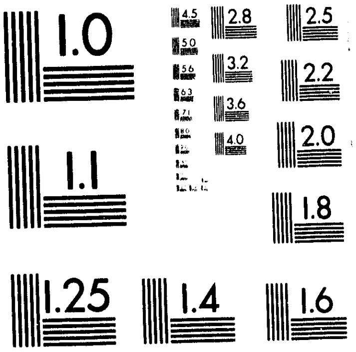
10. W. Hogan, "Patterns of Energy Use Revisited," *Discussion Paper Series*, H-88-1, John F. Kennedy School of Government, Harvard University, Cambridge, MA, 1988 (abridged in W. Hogan, "A Dynamic Putty - Semi-Putty Model of Aggregate Energy Demand," *Energy Economics*, Vol. 11, No. 1, 1989.

11. Jorgenson, D.W., "The Role of Energy in Productivity Growth," Harvard Institute of Economic Research, 1983 or, more recently, Hogan, W. and D. Jorgenson, "Productivity Trends and the Cost of Reducing CO_2 Emissions," Harvard University, John F. Kennedy School of Government, Energy and Environmental Policy Center, January 4, 1990.

12. See Gibbons, J. and P. Blair, "Energy Efficiency: Its Potential and Limits to the Year 2000," in *Energy: Production, Consumption, and Consequences*, Washington, DC: National Academy Press, 1990.

13. 102nd Congress, 2nd Session, "Energy Policy Act of 1992," Conference Report to accompany H.R. 776, October 5, 1992, Title I, Subtitle B - Utilities, Sec. 111, p. 21.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2 of 3

Figure 1

INDEX OF TOTAL U.S. ENERGY USE, GDP AND TOTAL ENERGY INTENSITY

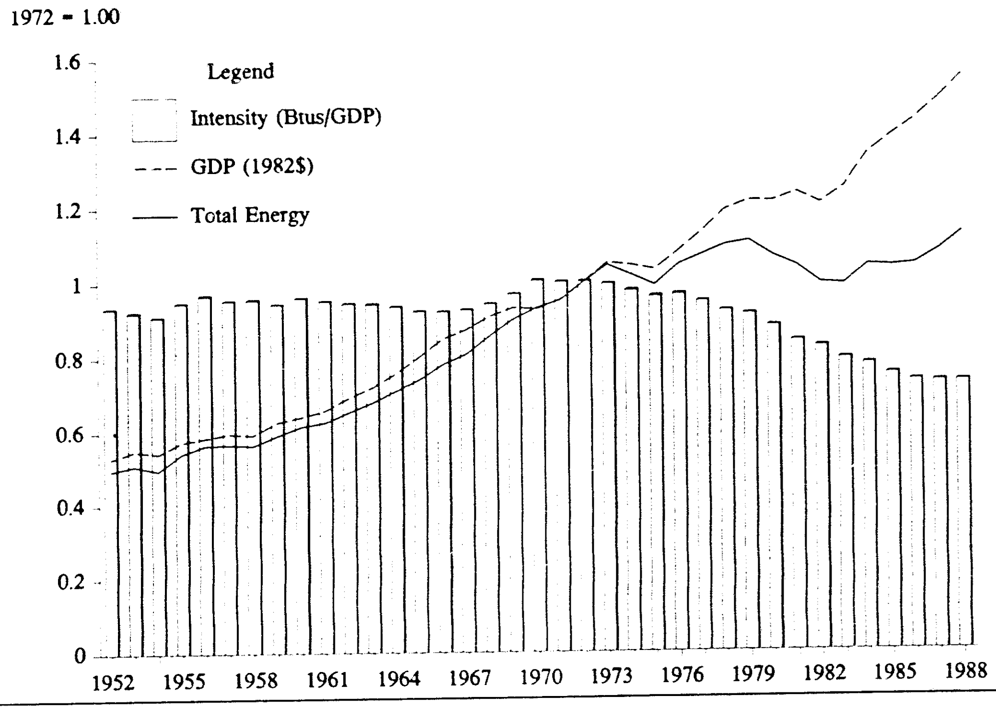


Figure 2

INDEX OF TOTAL U.S. ELECTRICITY USE, GDP AND TOTAL EKECTRICITY INTENSITY

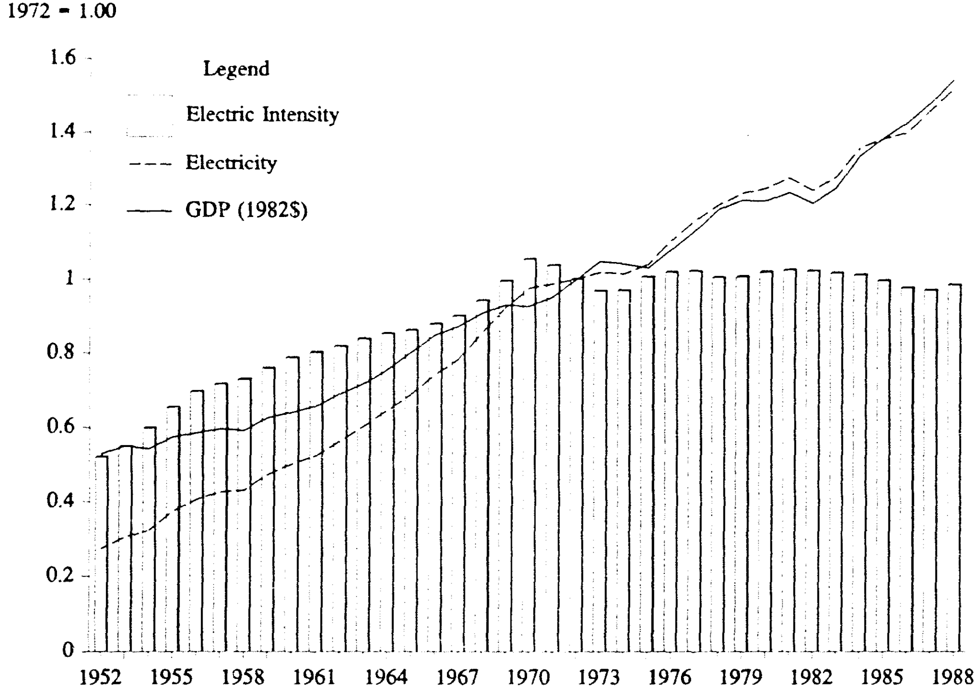
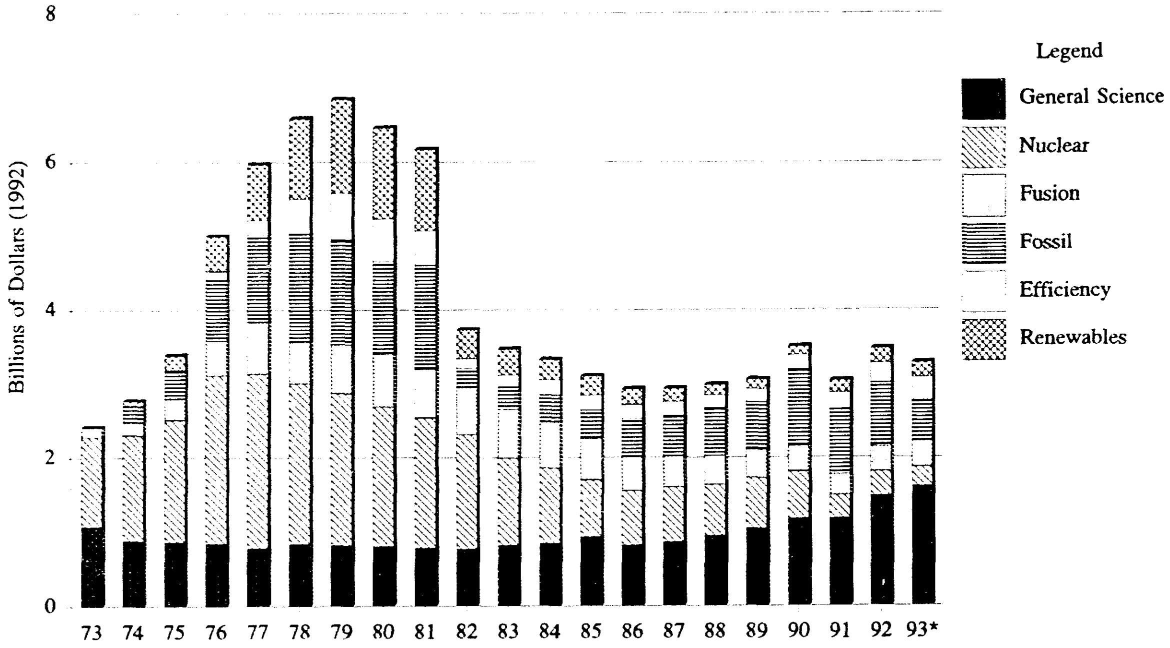


Figure 3

U.S. DEPARTMENT OF ENERGY R&D BUDGET SELECTED BUDGET LINES: 1973-1993



*93 = Adminstration Budget Request

Source: Congressional Research Service, Sissine, F., "Energy Conservation: Technical Efficiency and Program Effectivenesss," CRS Issue Brief, August 12, 1992.

Figure 4

TRENDS IN U.S. AUTOMOTIVE FUEL ECONOMY

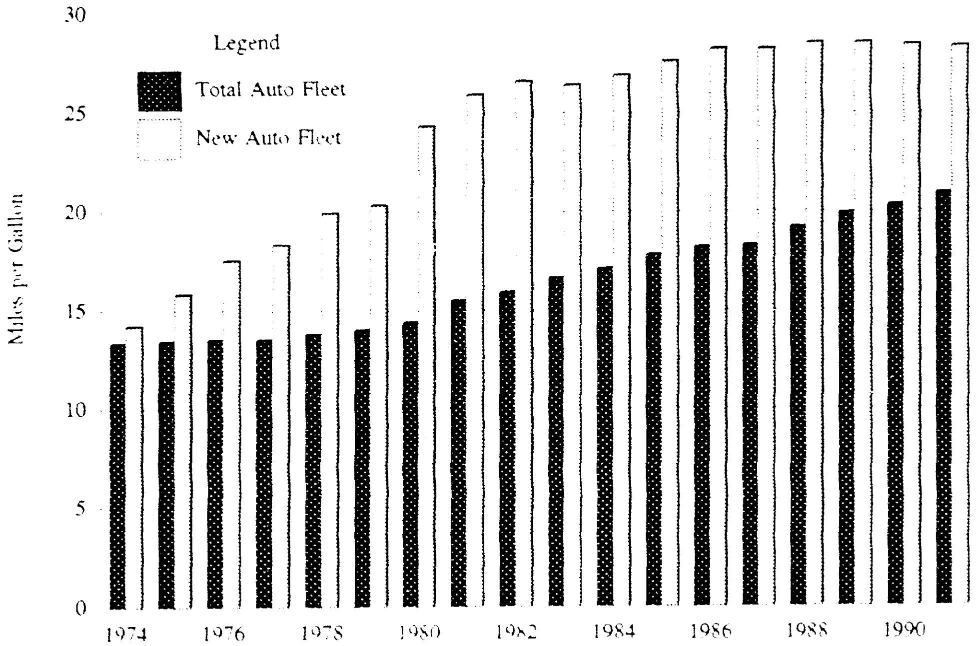
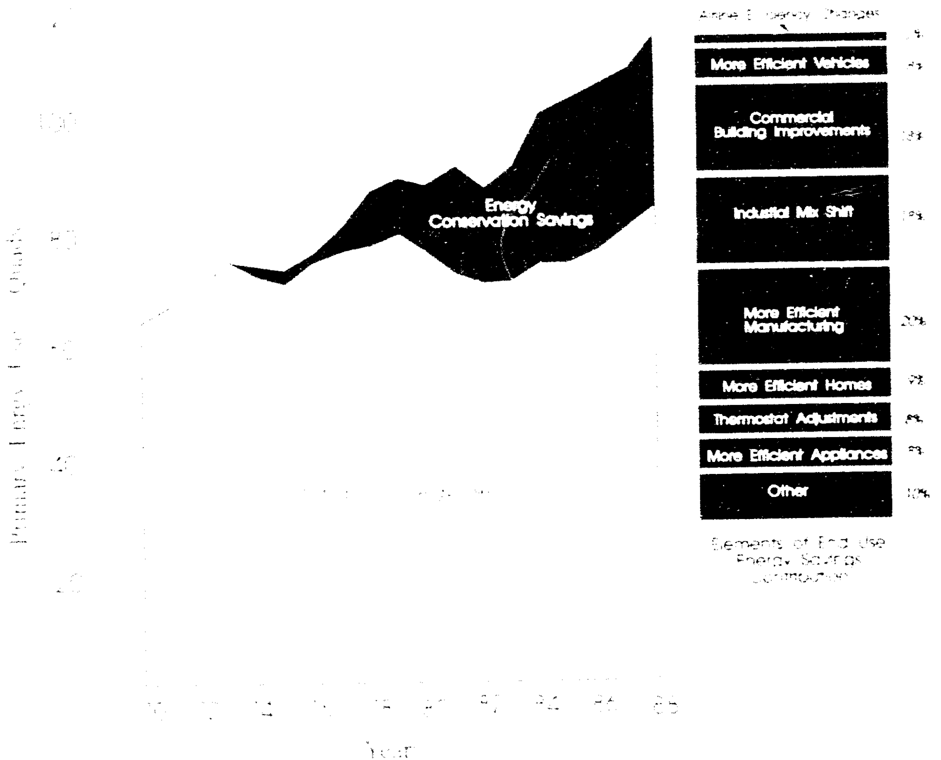


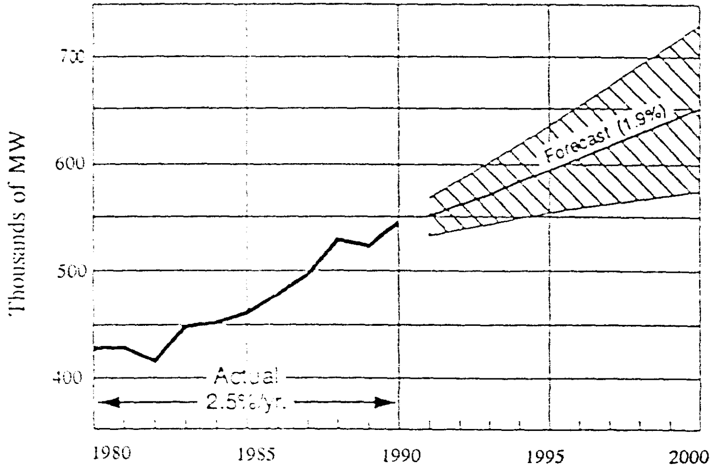
Figure 5
Sources of Change in U.S. Energy Consumption Patterns



Source: U.S. Department of Energy

Figure 6

U.S. Electricity Demand Projection (Summer Peak)



Source: North American Electric Reliability Council, 1991

ENERGY CONSUMPTION PATTERNS IN THE INDUSTRIAL AND ELECTRIC POWER SECTORS

John A. Anderson
Executive Director
Electricity Consumers Resource Council

INTRODUCTION

It is a pleasure to present an overview of energy in the industrial sector. Where is electricity used today? Where will it be used tomorrow? There are few questions as full of mystery and yet as crucial to both the electric utility industry and the industries I represent.

The Electricity Consumers Resource Council (ELCON), as many of you probably know, represents large industrial users of electricity — big companies with facilities in most of the 50 states and numerous foreign countries. We have 21 members at present, and they account for a huge amount of electricity use. Indeed ELCON's 21 members consume more than four percent of all electricity generated in the United States.

Our members represent a good cross-section of United States industry — steel, chemicals, glass, industrial gases, textiles, motor vehicles, electronic equipment, appliances, and food. They have many interests in common.

But probably more fascinating are the enormous differences in how ELCON members — and indeed, all industrials — use electricity. We are not talking about a homogeneous group. We cannot speak of electrification in industry with the same generalities that we apply to residential electrification. This audience knows a lot about the electricity demand of home appliances and a good deal about where home electricity conservation might continue to occur. Although we may have a big problem predicting growth in the number of households, we have a bigger one predicting growth in industrial demand. Why? Industrial firms not only are all different, they also have a proven record of dramatic change.

BACKGROUND

Things have come a long way since 1882, when Thomas Edison first supplied service to a small section of lower New York from his Pearl Street generating station. Back then, electricity was used primarily for lighting; industrial power came from steam and water. However, industry rapidly electrified, thanks largely to advancements in electric motors.

At the turn of the century, less than ten percent of all motor power used in manufacturing was electric-powered. Today, nearly 100 percent of it is.

So the question is, "How to gauge the possibility for change in use of electricity by all of those furnaces, pumps, compressors, saws, shredders, grinders, spinners, heaters, dryers and so forth, out there in United States industry?"

But first, I want to give you some quick examples of the tremendous number of different uses of electricity among U.S. industrials.

- The aluminum industry uses most of its electricity for smelting — that is, turning powdered aluminum oxide (or alumina) into primary aluminum. Smelting involves passing electrical charges through alumina and other chemicals. During this electrolysis process, the oxygen atoms break away from the alumina leaving primary aluminum, which is molded in ingots and other shapes. It takes six to eight kWh to produce one pound of aluminum.

- The steel industry uses huge quantities of electricity to drive rolling mills and pollution abatement equipment. Hundreds of motors are used — some as large as 15,000 horsepower. More recently, with the availability of large amounts of scrap steel to melt down, there has been an expanded use of electric arc furnaces. These furnaces contain three large electrodes — each typically two feet wide — which produce an arc from the electric charge whose heat melts down scrap.

- In the manufacture of industrial gases, electricity is used to drive pumps and compressors that compress air so that its component gases can be separated by distillation. Electricity for these pumps and compressors can account for 70 percent of the total production costs.

- In the chemical industry, chlorine and caustic soda are produced by electrolysis of sodium chloride brine. It can take anywhere from 1,600 to 2,900 kWh per ton for this process. Alternatively, phosphorous is produced through an electric arc process — somewhat similar to aluminum. Phosphate rock is combined with coke and silica and electrically charged in a furnace. This process releases a gas stream containing elemental phosphorous and carbon monoxide.

- The glass industry uses mostly natural gas to fuel furnaces, but many of these furnaces also contain electric "boosters" both to add heat and to create a stirring action.

- Motor vehicle manufacturing involves a number of different processes that are electricity-intensive. Air handling equipment is driven by electric motors; liquids to treat and wash metals are heated and moved by electricity; painting, machining, welding, soldering and compressing air are all done by electricity.

HOW WILL INDUSTRY USE ELECTRICITY IN THE FUTURE?

Electrification of industry occurred because it made good business sense — it lowered total costs of production. Similarly, electrification will occur in the future when it makes economic sense, not simply because a new technology is developed.

Where can we expect additional electrification? Let's break electricity use into end-use applications to target those areas where we might expect growth.

Motor Drives

By far the largest single industrial electrical end-use involves motor drives. The alternative to electromechanical drives is direct conversion of fuels into mechanical energy. The equipment that converts fuel to mechanical energy (diesel engines, steam generators, etc.) is costly to purchase and maintain, it often creates noise, heat, exhaust gases, or other unwanted effects, and it is often relatively inefficient. For example, it may convert less than 30 percent of the energy in the fuel into mechanical power while more than 80 percent of the energy content of electricity is converted into useful work. Not surprisingly, more than three-fifths of all electricity used by industry today is for motor drives.

Although there are few motor drive conversions left to be made, what we will see is: (1) continued movement toward energy efficient motors for retrofits and replacements; and (2) expanded use of electronic, adjustable-speed drives (ASDs).

Energy-efficient electric motors can result in less electricity consumption for the same work than standard motors; however, they cost more. While it might not make economic sense to replace a perfectly good motor today with a more energy efficient one, many industrials have established a corporate policy of replacing old or worn motors with these more efficient ones.

Even greater motor drive electrification potential lies with ASDs. Electricity consumption can be cut substantially (50 percent or more in certain applications) by careful control of the speed of motors. The potential is particularly great for fans and pumps. Mechanical or hydraulic ASDs have limited applicability, but electronic ASDs are relatively inexpensive and well suited for retrofits.

Electrolysis and Electric Melting

Approximately 15 percent of all electricity used by industry today is for electrolysis and electric melting – predominantly in primary metals and chemicals. There is real potential for change in this area.

1. Steel

In 1959, less than ten percent of all steel was produced in electric arc furnaces. In the mid 1980s, due primarily to the availability of scrap, nearly one-third of it is. Between 1970 and 1982, energy use per ton fell by 25 percent, while the use of electricity per ton increased 20 percent. Electricity use in the steel industry is expected to continue to grow. Indeed, some experts see it growing from today's level of 30 percent of total energy use to more than 40 percent within a decade. Beyond that, some predict that plasma arc technology will replace the blast furnace altogether, leading to even further growth in electricity use.

2. Glass

All electric glass-melting furnaces have been developed as an alternative to gas-fired regenerative furnaces, although only a small amount of glass is electrically melted today. Electric furnaces are about 3½ times as thermally efficient as conventional gas furnaces, and are nonpolluting. However, electric to gas prices are below 3½ to 1, which is generally not the case today. Even so, some experts predict changes in relative prices may result in an increasing amount of glass production likely to be done electrically.

Process Heating

Approximately ten percent of today's industrial electricity is used for process or electro-heating. However, since electricity offers simplicity of operation, minimum maintenance, versatility of application, cleanliness and control, direct process heating with electricity seems to have a bright future. Specifically:

1. **Resistance furnaces**

   Heat treating in resistance furnaces permits uniform heat distribution with accurate temperature control. Resistance furnaces range from small, bench-top models to large industrial heating facilities. Electric furnaces eliminate the contaminated atmospheres created in oil and gas-fired furnaces. This reduces scrap losses due to surface defects and reduces the need for mechanical finishing after treatment.

   As an example, an aluminum jobbing foundry switched from oil to electricity for resistance heating. Its electric load increased form 470 to 700 kW, but this was more than offset by a reduction in melting cost per pound and a drop in melt losses. Indeed, in this application, the total cost of production was almost halved!

2. **Induction furnaces**

   In an induction furnace, an oscillating magnetic field generates current in the workpiece so that is heated to the precise depth needed. This can be done in a fraction of the time required in gas-fired furnaces. Induction furnaces primarily are used today for surface hardening. However, they also can be used for annealing, glazing, soldering and billet heating.

   Induction furnaces represent a proven technology. Four kinds of metal fabrication industries (transportation equipment, machinery, electrical equipment, and metal products) used 22 billion kWh in such processes in 1980. Their consumption represented only three percent of total industrial electricity consumption and only one-third of the total electricity used for process heat. The future for expanded induction furnace applications looks good.

Other Technologies Affecting Industrial Electrification

Electrification has the potential to greatly enhance industrial productivity as a variety of new technologies are perfected and implemented. It is beyond the scope of this paper to describe in detail these technologies. However, I would like to cite a few examples.

1. **Robotics**

   Robotics is a rapidly developing industrial trend toward computerized control of the manufacturing process. Robots are computer-controlled, reprogrammable, movable tooling devices. Good data are not available even on the number of robots currently in operation, much less on their future. However, a good guess is that there now are several hundred thousands currently in use, 40 percent of them in the motor vehicle industry. Industries such as machinery and tools, electrical machinery, electronics, metals fabrication and foundries are likely candidates for increased robotics.

2. Program Logic Controls (PLCs)

PLCs represent another aspect of computerized control of manufacturing. Computers monitor and adjust various manufacturing operations to maintain correct speed, content and other critical parameters, for example, an ELCON steel company uses PLCs to control rolling mills. The product must move at increasing speed as it is compressed thinner by each mill stand. PLCs control the precise adjustment of each mill stand and the speed of process to assure the production of a product that meets specifications. Additionally, the company uses PLCs to monitor and take bath samples in electric arc furnaces. A significant problem in melting 100 percent scrap is controlling the content of carbon and alloy, each of which must be kept at delicate levels. Computers can monitor the blend of the bath and quickly analyze the content. This reduces the time required to melt and allows precise predictions of correct power needs.

Another ELCON company, a beer company, uses PLCs to control bottle lines. The PLC coordinates the beer coming to the bottlers, the fillers, the timing of the labeler, and the packaging. The PLC reduces the need for manpower, increases the speed of the bottling operation, increases quality control and lowers cost.

3. Energy Management Systems (EMS)

EMS represent yet another aspect of computerized control of industry. EMS have potential application in virtually every industrial process from controlling electric arc furnaces to turning on and off lights.

For example, the steel company mentioned earlier uses an EMS to monitor power demand. In one application, the computer makes 23 checks on electricity consumption in each 30-minute demand period. The computer checks accumulated consumption and projects consumption at the end of the demand period. If the projection exceeds the programmed limit, the furnace is selected for possible control. Careful demand control both reduces the company's bill and improves the utility's operating efficiency by raising load factors and reducing demand spikes. The utility thus is able to operate with fewer spinning reserves.

The beer company discussed earlier also uses many EMS. In one application, an EMS is used to monitor large (300-400 hp) ammonia compressors used in cooling and refrigeration. The EMS automatically reduces load (or even shuts down completely) lightly loaded compressors.

4. **Freeze Crystallization**

   Freeze crystallization substitutes mechanical energy for thermal energy for separating materials. Traditionally, liquids are boiled (usually with fossil fuels) and vaporized to separate certain elements. Freeze crystallization uses electricity to drive a refrigeration compressor to freeze the liquids, allowing them to be separated. The thermodynamic efficiency may be up to ten times greater than vaporization.

WHAT ARE THE IMPLICATIONS OF THE EXPECTED TRENDS TO ELECTRICITY SALES?

I see exciting new applications of both existing and new technologies that clearly suggest increased electrification in nearly every American industry. Some authors predict a small potential for electrification in non-process manufacturing, since these operations require primarily mechanical energy, which is already electrically driven. However, they suggest that the greatest potential for further electrification lies in process manufacturing such as primary metals, stone/clay/glass, petroleum, chemicals, paper and food.

I see further electrification in both process and non-process manufacturing. However, the implications for utilities may not be as they initially appear. Increased electrification may not add to electricity sales for several reasons.

Electrification has both positive and negative impacts on load growth

Electrification in certain industrial processes will increase total electricity consumption. For example, increased use of electric resistance and induction furnaces for heat treating, and other such movements toward electricity-driven technologies, will tend to increase electricity consumption.

However, other electrification applications have been shown to result in decreased electricity consumption. For example, high efficiency motors result in a direct, often significant, reduction in consumption; electronic adjustable speed drives also result in direct electricity savings; and improved electrolysis efficiencies allow the same amount of product to be made with less electricity.

Some of the most dramatic developments in electrification may cut two ways, adding to, while at the same time reducing or controlling, electricity demand. Two examples illustrate this paradox.

1. **Robots**

   Robots are being used increasingly in motor vehicle manufacturing. Certainly they will use electricity. A point often overlooked, however, is that a primary electricity use in motor vehicle manufacturing is for space conditioning. Robots do not need air-conditioned work spaces. Thus, the increase in electricity consumption attributable to the operation of the robot is at least partially offset by reduced use due to changes in space conditioning. It is too early to tell which impact will be larger.

2. **Computers**

   Computers are being used in numerous industrial applications. Operating these devices certainly requires electricity. However, the computer applications of which I am aware nearly always result in net electricity savings by cutting down on wasted, useless and lost energy.

Increased Electrification may Result in Increased Energy Salesb but not Load Growth

Electrification may increase off-peak consumption or may involve manufacturing processes that can be interrupted. Many electric arc furnaces are operated during the night. The steel is then reheated for processing during the day. Additionally, operators of arc furnaces may be willing to have service interrupted if offered an appropriate economic incentive, even when the interruption results in an increase in the number of kWh used per ton of output. Similar situations exist in many other primary metal and chemical operations where opportunities for electric-intensive innovations appear great. All customers of a utility may benefit where electrification results in increased kWh consumption without increases in peak load.

Industry may Self or Cogenerate Significant Proportions of New Load

At the turn of the century, industry generated nearly 60 percent of the nation's electricity. By 1980, industrial generation represented less than three percent of all generation.

However, changing economic conditions are making self and cogeneration more attractive. For example:

- Electricity produced from generating units costing $4,000/kW may cost consumers in excess of 15 cents/kWh.

- Traditional utility accounting methods "front-load" cost recovery from customers.

- Regulatory bodies often approve rates that require industrial customers to pay a disproportionately large share of the total costs of the utility.

- The recently enacted Energy Policy Act encourages EWGs.

Industrial (as well as other) electricity consumers are reacting to these and other pressures by carefully reevaluating the economics of self and cogeneration. Indeed, it now seems likely that industrial cogeneration capacity alone will be in excess — perhaps significantly in excess — of 50,000 MW by the year 2000. These facilities may range from large, coal-fired facilities to small gas-fired turbines. ELCON member companies already operate cogeneration facilities of hundreds of megawatts each. To the extent that industry generates the electricity used for increased electrification, utility sales will not increase and, indeed, may decrease.

Rising Electricity Prices may make Continued Operation of Key Sectors of American Industries Uneconomic in the United States

The industrial demand for electricity is not inelastic. Rising electricity prices will choke off electricity consumption. Rapidly rising electricity prices will significantly impact future electrification. Rising electricity prices may result from the completion of an extremely expensive new generating unit, the cancellation of an unneeded unit, the passage of acid rain legislation, the imposition of energy taxes, DSM or a variety of other reasons. The cause is not the important point in this discussion. The result, however, is very important.

For example, aluminum companies in the United States pay on average more than 25 mills for electricity, while their competitors in foreign countries pay on average less than 17 mills. With electricity constituting approximately one-third of the total costs of production, this differential makes it questionable whether the basic aluminum industry in the United States will be able to continue operation.

Other electricity intensive industries face similar competitive disadvantages, although perhaps to a smaller degree. If significant portions of basic industry (aluminum, steel, chemicals, etc.) find it impossible to continue to operate in the United States, electrification may result in electricity comprising a larger share of a much smaller total market.

POLICIES THAT MAY AFFECT FUTURE ELECTRICITY USE BY INDUSTRIALS

While the potential for increased electrification seems bright, an ominous cloud hangs over the horizon.

Increasingly, electric utilities are being required to implement demand side management (DSM) programs — usually through least cost planning (LCP) or integrated resource planning (IRP). These programs often offer cash rebates for purchases of specified lighting systems, windows, insulation or motors. The recently enacted Energy Policy Act will greatly increase the implementation of IRP.

Industrials have a limited capacity to benefit from these programs. However, there does not seem to be any limit to the ability of DSM advocates to insist that industrials pay.

It is important to note that the *stated* goals of most DSM/LCP/IRP programs are to increase energy efficiency. However, the *actual* numerical targets that are set are ones of reduced electricity consumption. Additionally, the programs *always* result in rate increases — that is, rates go up both to those customers who participate and benefit and to those who cannot (or do not) participate and, hence, do not benefit.

It is also important to recognize that these programs do not distinguish between programs that result in increased energy efficiency (and perhaps reduced emissions as well) and growth in consumption through traditional technologies. For example, a steel mill may convert from basic oxygen furnaces (BOFs) to a much newer technology — electric arc furnaces. The conversion certainly may increase overall energy efficiency, reduce emissions, and lower costs. However, the conversion results in *increased* — probably significantly increased — electricity consumption. Thus, such a conversion may not be supported/opposed since it doesn't comport with the specified goals of the utility's IRP — the goal to reduce consumption.

In essence, society must decide what policy it wants to implement in the future — reduced electricity consumption or the most efficient use of energy. If we decide that the goal should be the most efficient use of energy, we must recognize that achieving this goal may be best achieved through *increased* electricity consumption.

Clearly, there is a difference between energy "conservation" — usually viewed as reduced consumption, and "energy efficiency" — using fewer BTUs per unit of output. Increased energy efficiency may have a positive impact on the environment while simultaneously resulting in increased electricity consumption.

The solution to the current dilemma is complex. For example, trying to have electric utilities encourage increased energy efficiency is very difficult. Primarily, they have control only over electricity, not the other energy resources. We cannot expect electric utilities to be able to implement programs encompassing energy resources beyond their control.

What should we do? First, electric utilities should be encouraged to keep their costs as low as possible. This truly is least-cost!

Second, consumers should be sent proper price signals. Each customer should be charged prices that to the greatest extent possible reflect the actual costs incurred by the utility in meeting that customer's load at the time of consumption.

Third, electric utilities may serve a useful role in disseminating information regarding energy efficient operations and uses. After all, we all know that an informed customer makes better decisions.

Beyond these basic steps, consumers should be left alone to decide when and how they will consume. They may not make perfect decisions. But, in my view, their decisions will be better than those made by central planners or regulators.

CONCLUSIONS

From a technological standpoint, electricity has a bright future. Increased electricity use may increase the efficient use of energy, reduce environmental damage, and lower costs.

Unfortunately, some advocates of IRP focus on the wrong goal. They strive for reduced electricity consumption to the extent that they are successful, such a focus may result in increased electricity prices and reduced economic activity. It's time to re-focus IRP to capitalizing on the opportunities.

TRANSPORTATION ENERGY POLICY: BACK TO THE PAST OR AHEAD TO THE FUTURE?

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ABSTRACT

The past 20 years have been both a great shock and a great experiment for the U.S. transportation system. Our predominantly internal combustion engine (ICE) powered, petroleum-based transportation system has proven to be robust and able to adapt. After nearly 20 years, the U.S. transportation system is still 96 percent fueled by petroleum, ICE-powered, and consuming greater quantities and a greater percentage of U.S. oil use than ever. But the costs to our nation of the OPEC cartel's monopolization of the world oil market have been enormous, as have the environmental consequences of ever greater production, transportation, and combustion of petroleum. As we look toward the future, the experience of the past 20 years gives us reasons for both confidence and concern. The future appears to hold still greater challenges from local and global environmental problems, and a resurrected problem of oil dependence. Among many possible technological and economic solutions, none clearly emerges as the single best alternative. Yet we can learn much from our past mistakes and successes that can help formulate plans and policies for the future. The future will not be identical to the past and we must be prepared to envision, experiment, adapt, and change the course of history. Given the enormous uncertainties, it would be easy to do little and rely on the robustness of the oil-driven transportation system to muddle through. It would be easy to try to go back to the past. But we could lead the world into the future, not by promoting any one particular technology or fuel, but by sending the right signals through the marketplace and aggressively pursuing research and development of technologies that hold promise for solving the problems of tomorrow.

INTRODUCTION

In 1972 the Interstate Highway System was substantially built and the new commercial jet air transport industry was rapidly expanding. Americans were experiencing unprecedented mobility. Energy was cheap and gasoline plentiful. The automobile had established itself as a quintessential part of American culture in the 1950s and 1960s. Although the family car was growing larger and heavier, a new type of car, the economy subcompact, had been introduced from Europe and Japan and was making such significant inroads in domestic sales that Detroit felt obliged to respond with subcompacts of its own. Struggling to meet the new motor vehicle emissions standards of the 1970 Clean Air Act, automakers began to detune engines, retard spark timing, and recirculate exhaust gases. These sometimes hurried and inefficient fixes for the emissions problem, combined with greater weight and larger engines, drove the average fuel economy of new cars toward an all-time low of 14 miles per gallon (MPG). It was in the midst of this energy feast that the newly formed Organization of Petroleum Exporting Countries decided to exercise its monopoly power and boycott oil shipments to the United States in retaliation for the United States' support of Israel in the 1973 "Yom Kippur War."

Despite some early warnings of an impending crisis,[1] one must conclude that the U.S. was unprepared to cope with the "energy crisis" of 1973-1974. Oil prices doubled, and gasoline prices jumped by over 25 percent (U.S. DOE, EIA, 1992, Tables 71 and 73). Much worse, the country's outdated system of petroleum allocation and price controls combined with panic buying by consumers produced regional fuel shortages and the loathed and feared gasoline lines. Recession *and* inflation ensued. The public demanded action. But what to do? Ration gasoline? Travel less, turn down the thermostat, drive 55, buy a smaller car, share a ride, share a shower? Appoint an "Energy Czar," form an Energy Department? Slap an import tax on oil, make gasoline out of shale oil?

Out of a blizzard of ideas and confusion emerged a fairly simple energy policy for the transportation sector which has been followed consistently, if not faithfully, for the past two decades. It has three elements:

1. Mandatory, federal corporate average fuel economy (CAFE) standards for passenger cars and light trucks (backed by a "gas guzzler tax" and gas mileage labeling);

2. Deregulation of fuel prices (without imposing energy taxes); and

3. Increasingly well targeted and comprehensive federally sponsored research and development of long-range, high-risk automotive technologies.

If one adds to this the Strategic Petroleum Reserve, similar R&D for other sectors, a spectacular failure in synthetic fuels, and military readiness, one has, arguably, a reasonable precis of the entire U.S. energy policy of the past 20 years.

Federal policy centered on the highway mode and fuel economy standards for light duty vehicles. Government actions affected energy use in nonhighway modes but generally indirectly. A very substantial federal military and civilian aerospace research effort led by the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) produced technological advances that were critical to subsequent improvements in commercial aircraft efficiency. There was a voluntary truck and bus fuel economy program consisting of demonstrations and information sharing. And although similar low-effort programs existed for every mode at one time or other, laissez faire was the essence of energy policy for the nonhighway modes.[2] In recent years most of these policy initiatives have been de-emphasized or abandoned. Laissez faire has been the goal. Fuel economy standards, for example, have not been raised above the level specified in 1975 for 1985, despite substantial evidence that MPG could be cost-effectively increased using available technology. By continuing to neglect proven policies and failing to search for still better alternatives, we risk a return to the conditions prevailing in 1972, and possibly worse.

The experience of the past 20 years contains several significant lessons, lessons that can help prepare us for the difficult task of devising policies for the next 20 years. In this paper I first examine key successes and failures of the past 20 years of transportation energy policy, and attempt to extract those lessons. From this perspective, one may consider what strategies will work best in the future. Technological progress, economic expansion, and population growth will require changes in our transportation system. It is time to reconsider which policies are most likely to create the future we want to live in.

PROBLEMS OF THE PAST AND PRESENT: OIL DEPENDENCY, AIR POLLUTION, AND GLOBAL WARMING

Due to ever increasing transportation activity, transportation energy use grew substantially over the 20 years from 1970-1990, despite brief reductions following the oil price shocks of 1973-74 and 1979-80 (Figure 1). (All figures and tables appear at the end of this paper). Most of the growth came not from light duty vehicles (cars and light trucks), but from heavy trucks and the nonhighway modes. Though energy use increased by more than a third, the rate was far slower than in previous decades. The driving factor behind increasing energy use was growth in travel. Long-term trends in the growth of highway and air travel from 1940 to 1990 show that, following an explosion of travel after World War II, vehicle travel increased at rates of between four percent and five percent during the 1960s and early

1970s and fluctuated around three percent during the late 1970s and 1980s (Figure 2). Air travel grew faster still, falling from ten percent/year in the early 1970s to six to seven percent during the 1980s. Though the trends suggest some reason to expect *rates* of growth to decline in the future, they provide no indication of an end to the growth of travel in the U.S.

Energy intensive motorized travel grew even more rapidly in the rest of the world. In Europe and Japan, vehicle ownership increased faster than in the United States. From 1970 to 1990, automobile registrations grew at average annual rates of 7.2 percent per year in Japan, 5.8 percent in Italy, and by over three percent per year in France, West Germany, and the United Kingdom. Outside of the developed market economies, automobile registrations grew by 6.4 percent per year (Davis and Morris, 1992, Table 1.1). Worldwide trends in motorized transport imply that the rest of the world is not headed in a different direction from the U.S. with respect to the role of transport in their economies. It is more accurate (though not entirely accurate) to view the rest of the world as catching up to U.S. levels of motorization and mobility. The importance of this trend can be appreciated by noting that the U.S., with five percent of the world's population, accounts for 25 percent of the world's annual petroleum use (17 MBD out of 65 MBD in 1990; U.S. DOE, EIA, 1992, Table 123).

Nowhere has demand for transportation and transportation fuels increased more rapidly than in the developing economies of the world. If developing countries are to make economic progress, motorized transport and transportation energy use must continue to grow. Growth in oil use in developing countries has been the greatest component of the increase in world oil use between 1973 and 1986. Developing countries' share of world oil demand grew from 14 percent in 1970 to 23 percent in 1986 (Meyers, 1988). It is difficult to imagine how the economies of developing countries can achieve significant growth without enormous increases in motorization and consequently in the use of transportation fuels. If the rest of the world is headed for U.S.-like demand for transportation fuels (petroleum unless things change drastically), then pressure on world oil resources will become severe unless something is done. A fundamental premise of U.S. energy policy must be an acceptance of the fact that the demand for mobility will increase both in the U.S. and around the world, and that in developing countries energy use in transportation can and should increase significantly.

Despite enormous economic costs, transportation remains almost entirely dependent on petroleum.[3] Based on direct energy use, the U.S. transport sector is 96 percent dependent on petroleum. Taking into account the petroleum used to generate electricity for pipelines and electrified railroads, the sector is seen to be 97 percent dependent (Davis and Morris, 1992, Table 2.8). If one subtracts the natural gas and electricity use by pipelines, the remaining modes are 99 percent oil dependent. During the 1970s and 1980s, other sectors of the economy have been reasonably successful in substituting other energy supplies for oil. As a result, it is not an exaggeration to say that the transportation sector *is* the U.S.'s petroleum dependence problem. Transportation accounts for two-thirds of U.S. oil consumption but 85 percent of consumption of the light products (gasoline and distillate) that drive oil market economics. Transportation alone uses more petroleum than the U.S. produces: 22 quads of transportation use in 1991 versus 15.6 quads of crude oil produced (U.S. DOE, EIA, 1992, Tables 2 and 5).[4]

U.S. import dependence is approaching the historic highs of the 1970s. Not only is the U.S. as dependent on imports as it was 15 years ago, but it is nearly as dependent on imports from the politically unstable Persian Gulf region (Figure 3). U.S. import dependence is only part of the story, however, and not the most important determinant of the cost of oil dependence. *World* dependence on the OPEC cartel is the key factor in the stability of the world oil market. The market power of the cartel depends on three interdependent factors:

1. The world elasticity of demand for oil;

2. The world supply response (if the cartel cuts production by one barrel, how much will the rest of the world increase production); and

3. The cartel's share of the world market.

As the cartel's share of the market increases, its incentive to charge a higher price for oil and its ability to make it stick, increase. Instability in the world market occurs because there are very large differences between the long-run and short-run demand and supply responses for any given OPEC market share. Thus, the cartel can charge a much higher price in the short run than it can sustain in the long run (Greene, 1991). As market share increases, the short-run market power of the cartel increases greatly, creating an overwhelming incentive to increase prices. Although current OPEC market share is still below its high point of over 50 percent for the 1973-79 period, it has rebounded considerably from its low of 30 percent in 1985 and has already reached 40 percent (Figure 4).

In the future, OPEC dominance of world oil is almost certain to increase. Over the past 20 years, world proven reserves of oil have actually *increased* by 200 billion barrels. All but a minuscule fraction of the increase occurred in the Persian Gulf region. As world demand for oil continues to grow, reliance on the Persian Gulf as a source of supply will almost surely increase. Unfortunately, the return of OPEC to market dominance appears to be only a few years away.

Oil dependence has cost the United States dearly over the past 20 years. The emergence during the early 1970s of OPEC as a cartel willing and able to exercise monopoly power transformed world oil and energy markets. The cartel exploited the gap between short-run and long-run oil market response to create windfall profits by means of oil price shocks. Following the price shocks, the cartel restrained its oil output in an attempt to hold market prices at elevated monopoly levels as long as possible. As the cartel's market share eroded as a result of long-run declines in demand and growing rest-of-world supply response, so did its market power, until in 1986 it was no longer able to hold on and oil prices collapsed.[5] The higher monopoly prices and price shocks hurt the U.S. economy in three ways:

1. Higher than competitive market prices for oil increased the economic scarcity of oil to the U.S. economy, reducing its potential to produce (potential Gross National Product was reduced);

2. Price shocks created additional macroeconomic adjustment costs, since the economy is not able to adjust instantly to a major change in the price of as fundamental a commodity as oil and thus suffers further losses of output due to the underemployment of factors of production;

3. The monopoly rent OPEC was able to collect on its oil transferred economic wealth from U.S. citizens to foreign owners of oil.[6]

One recent estimate of the total economic losses from all three sources over the past 20 years amounts to $4 trillion (Greene and Leiby, 1992).[7] This number is so large that it may be useful to provide some points of reference. It is larger than total interest payments on the national debt over the same period (about $2T) and smaller than total expenditures on national defense (more than $5T over the same period). Though one may legitimately question how avoidable these costs were and will be in the future, there is no doubt that the OPEC cartel's actions cost the U.S. economy dearly and that it would be highly desirable to avoid similar costs in the future, if we could.

The undesirable environmental effects of transportation energy use have also been substantial. The transportation sector remains a major contributor to air pollution, especially in urban areas (Figure 5). Transportation is the major source of carbon monoxide pollution, and a significant contributor to emissions of smog and ozone-forming hydrocarbons and nitrogen oxides, as well as fine particulate matter. Indeed, a recent National Academy of Sciences study (NRC, 1990) indicated that estimates of certain motor vehicle emissions may be low by a factor of two to four. If this is true, then transportation is a far greater contributor to hydrocarbon and nitrogen oxide emissions than Figure 5 suggests. Transportation emissions continue to be a problem despite enormous improvements in control of motor vehicle emissions. A properly operating 1992 vehicle emits on order of magnitude less pollution per mile than a similar vehicle of 1967 vintage. Unfortunately, there are many more vehicles being driven more miles. It is also becoming increasingly apparent that our motor vehicle emissions control system is not as robust as it needs to be. Operation of vehicles in ways not anticipated by the federal emissions test procedures, deterioration of control equipment after 50,000 miles, and improper maintenance and tampering with control equipment are all contributing factors. This lack of robustness on the part of vehicle emission controls is the primary motivation for the call for "clean fuels" embodied in the Clean Air Act Amendments of 1990.

The most difficult emissions challenge may be that posed by the threat of global warming caused by the build-up of greenhouse gases in the atmosphere as a result of the burning of fossil fuels. Carbon dioxide, a fundamental product of the combustion of fossil fuels, is the major greenhouse gas. While scientists know little about the timing and magnitude of future temperature increases and their impacts on society and the environment, there is a strong consensus that global warming is occurring as a result of the world's ever-growing use of fossil fuels. The transportation sector does not dominate the global climate change picture as it does the problem of oil dependence, but it is a major source of carbon dioxide and other greenhouse gases.[8] Over the past 20 years, transportation emissions of CO_2 have increased at the same rate as energy use, 1.2 percent/year from 1972 to 1991 (EIA, 1992, Table 5). Energy use grew at three times that rate (3.2 percent/yr.) during the 20 years before 1972 (1952-1971). The growth of energy use slowed because of transitory energy price shocks and lasting improvements to the energy efficiency of transportation equipment.

PAST SOLUTIONS: WHAT HAVE WE LEARNED?

Over the past two decades a variety of energy policy actions have been tested. We have been able to observe the responses of the economy as a whole, the transport sector, and the various modes and submodes to higher energy prices. This hard-won experience can teach important lessons about what is and what is not likely to work in the future.

Passenger car and light truck fuel economy improvements are the greatest single achievement of transportation energy policy of the past 20 years. Fuel price hikes and gasoline lines caused by the Arab OPEC Oil Embargo sparked an interest in fuel economy among consumers, carmakers, and Congress.[9] Consumers responded by buying smaller cars with smaller engines and more manual transmissions. Producers began to redesign vehicles to deliver more MPG. Congress passed the Energy Policy and Conservation Act of 1975 (EPCA) which established fuel economy standards for passenger cars and required the Department of Transportation to set standards for light trucks. Each manufacturer's new car fleet was required to achieve a corporate average fuel economy (CAFE) target in each year, starting at 18 MPG in 1978 and rising to 27.5 for 1985 and beyond. These standards were set by Congress based on an intensive study of what was technically and economically achievable. Light truck standards, which were established by DOT rulemakings, required less improvement;

they began at 17.2 MPG in 1979 and increased to 20.5 by 1987.[10] Although fuel prices provided the early impetus for fuel economy gains, it was the mandatory regulations that kept new car MPG improving during periods of falling fuel prices (Figure 6; Greene, 1990). The standards served as a key goal for long-term product planning. Because completely redesigning a company's product line may require eight to 15 years, the setting of standards well in advance was crucial to their effectiveness.

There are many reasons why, in theory, improvements in new car fuel economy may not translate into real fuel savings. First, higher MPG implies lower fuel costs per mile driven, thus lowering the total cost of travel. Cheaper travel should translate into more travel, creating a "rebound" effect on energy use. Second, for purposes of enforcing the CAFE standard, a standard "laboratory" test procedure was developed by the Environmental Protection Agency. It quickly became apparent that real drivers were obtaining lower MPGs in real-world driving. This "efficiency gap" fueled fears that CAFE MPG improvements might be illusory. Finally, it was argued that consumers might not like the design changes necessary to increase MPG, and would therefore hold on to their older, less energy efficient vehicles longer, slowing the rate of fuel economy improvement. The first two phenomena did occur and their effects have been measured. The rebound effect ranged between five percent and 15 percent, depending on the price of gasoline (Greene, 1992). That is, 85 percent to 95 percent of the increase in vehicle efficiency was realized as reduced fuel consumption. The test to in-use fuel economy shortfall has fluctuated over time and varies across vehicles, as well (Hellman and Murrell, 1984). On average, however, the shortfall has fluctuated around 15 percent.[11] Thus, even though a 40 MPG car may get only 34 MPG on the road, a 50 percent increase in test MPG still roughly equates to a 50 percent increase in on-road MPG. There is conflicting evidence about whether fuel economy improvements caused motorists to hold on to their vehicles longer. On the one hand, average passenger car lifetime has increased by about one year over the past two decades (Davis and Morris, 1992. Table 3.7). On the other hand, it is not clear that this is due to fuel economy gains and not other factors such as the approximately 50 percent increase in the average value of a new car over the same period (MVMA, 1992).

Despite the possible pitfalls, the actual fuel economy of light duty vehicles did increase substantially, and real fuel savings resulted. As Figure 7 shows, fleet fuel economy improvements lagged the improvements in new vehicles due to the relatively slow turnover of the stock of vehicles. While new car and light truck MPG improved by more than two-thirds, from 15 to 25 MPG, fleet MPG has increased by less than 50 percent, from about 13 to about 19 MPG. These fuel economy gains broke a 25-year trend, during which fuel use was rising faster than vehicle travel (Figure 8). Despite the fact that fuel prices have once again fallen to historically low levels, fuel use has increased at only one-third the rate of vehicle travel since 1973. Had no fuel economy improvements occurred, light duty vehicles would be using at least 40 billion gallons more motor fuel each year. Motorists are saving about $50 billion each year, and the national economy about $35 billion (the difference being fuel taxes) as a result of new car and light truck fuel economy improvements. Consumers, by and large, seem to be satisfied with the changes and trade-offs made to improve MPG, as evidenced by the fact that the fuel economy standards enjoy overwhelming public support.

What about safety? The scientifically established correlation between vehicle size and weight and the probability of occupant fatality given a collision between vehicles (see, e.g., Evans, 1991) has been used as an argument against further mandated fuel economy improvements. It has been claimed that the current CAFE is responsible for a 14 to 28 percent increase in traffic fatalities in current model year cars (Crandall and Graham, 1989). The trends in overall traffic fatalities suggest no such relationship. Fatalities per 1,000 vehicle miles have continued to decline throughout the period of dramatic passenger car and light truck fuel economy improvement (Figure 9). This despite the fact that the average weight of a 1991 model year passenger car was 3,188 lbs., more than 20 percent lighter than a typical 1975 car weighing 4,058 lbs. (Heavenrich, *et al.*, 1991).[12] If safety is so strongly related to vehicle weight, why did fatality rates not increase? One argument is that fatality rates would have been lower still, had weight not been reduced. There may be some merit to this argument, but the overwhelming reason is that the safety-weight theory rests on three serious fallacies.

1. Assuming that *all* passenger car fatalities have the same relationship to weight as those of car to car collisions, overstates impacts of weight changes. In fact, car-to-car collisions account for only about a fourth of highway fatalities. There are a greater number of fatalities in which only a single vehicle is involved. There are also nearly as many pedestrian and cyclist fatalities as vehicle occupant fatalities in car-to-car collisions. Weight and size affect each category differently and some not at all. Pedestrians and cyclists might well benefit from a population of smaller, lighter vehicles.

2. Using relationships describing the relative probability of fatality for the occupant of a smaller car in a two-car collision to compute the increased risk of weight reduction in all cars overestimates the social (versus individual) impact of weight on safety. When a heavier car is replaced by a lighter car there are winners as well as losers. The former occupants of the large car are at greater risk, but the risk their large car imposed on other smaller cars is reduced. Thus, if the weight distribution of cars on the road changes such that the largest cars are eliminated but the numbers of the smallest, least safe cars does not increase, then there may actually be more winners than losers. As one can see from a comparison of passenger car weight distributions for 1976-78 versus 1986-88 model year cars, this is approximately what took place (Figure 10). The heaviest weight categories were eliminated, but the

percent of drivers in the lightest cars did not increase. Also shown on the figure are curves of relative risk for the occupants of lighter cars struck by a heavier car. Risk is dramatically greater for the smallest two classes. Fortunately, their proportions did not increase. In short, the weight distribution changes that did occur in conjunction with fuel economy improvements were such that potential negative impacts were mitigated.

3. Finally, historical trends in downsizing and downweighting should not be attributed entirely to fuel economy. In fact, the emergence of subcompact cars in the U.S. began in the late 1960s and early 1970s, with the growth in popularity of European and Japanese imports such as the VW Beetle, the Datsun 210, and the U.S.-made Pinto and Vega. Increasing market penetration of these smaller cars was already underway before the fuel crisis hit in 1973-74 and well before fuel economy standards were enacted in 1975 and went into effect in 1978. Present day smaller cars have improved greatly on the safety deficiencies of these early subcompacts. More importantly, fuel economy standards had little or no impact on some aspects of vehicle size, such as interior volume. From 1975 to the present, the average interior size of passenger cars has fluctuated within one to two percent of its current average of 104 cubic feet. Exterior dimensions have decreased, largely as a result of the conversion to front wheel drive, but interior size has remained unaffected.

Selling smaller cars is, in fact, a very inefficient route to improving fuel economy. It takes a very large sales shift (achieved over great opposition from consumers) to achieve a fairly modest fleet average MPG improvement if the efficiency of each size class is held constant. For example, Table 1 shows the market shares of each passenger car class in 1975 and 1991, along with their associated MPG. Keeping size class MPG constant at 1975 levels but using the 1991 market shares results in a fleet average of 15.7 MPG compared with the actual fleet average of 15.8 MPG for 1975.[13] The actual fleet average MPG in 1991 was 27.8 MPG. Essentially none of the MPG improvement from 1975 can be attributed to consumers' buying smaller cars (based on interior volume). Fuel economy improved not by making cars smaller, nor by consumers choosing smaller cars, but by making all cars, large and small, much more efficient.

The efficiency revolution spurred by fuel shortages and price shocks and secured by the federal Automotive Fuel Economy Standards, brought the U.S. up to world class fuel economy levels. Whereas in 1974 new cars sold in the U.S. were grossly inefficient in comparison with those of Europe and Japan, by the mid-1980s we had drawn even with other OECD countries. Today, U.S. cars are roughly equal in efficiency to cars sold in countries where gasoline prices are two to three times higher than what American motorists enjoy. Is it any wonder that American motorists favor fuel economy standards over higher gasoline prices? Now that our vehicles are no longer the gas-guzzlers of the world, what should we do next?

For other modes, highway freight and nonhighway transport, efficiency gains depended on both technological advances in vehicles and improvements to operating efficiencies. By far the most impressive gains in energy efficiency per passenger mile were in commercial air passenger travel (Figure 11). From 1970 to 1989, seat miles per gallon of jet fuel increased by 77 percent and passenger miles per gallon by 120 percent (Greene, 1992). No other mode, including light duty highway vehicles can match this record. This was achieved without regulatory intervention of any kind. The combined incentives of higher fuel costs and the availability of more fuel efficient technology and operating procedures produced the dramatic progress. Among the most important factors were increases in seats per aircraft (both from using larger aircraft and cramming more seats into existing airframes) and various operational changes such as improved flight planning and higher load factors, that is, more passengers per available seat (Smith, 1981). Since 1984, however, only aircraft technology and higher load factors contributed to higher efficiencies (Greene, 1992). Though aircraft manufacturers and airline companies made these improvements without government mandates or incentives, they did have the benefit of decades of cooperative government and industry research on jet engines and airframes, both military and commercial (Greene, 1992). This research created a store of technology on which the manufacturers could draw when it was needed (Ethell, 1983).

The most striking feature of trends in the energy intensiveness of passenger modes is the apparent convergence of efficiencies. The data presented in Figure 11 suggest that the least energy intensive modes have become significantly more efficient, while those historically most efficient have changed little. While gross modal comparisons such as these are always somewhat misleading in that they compare different kinds of services in different environments, it is no less clear that whatever energy efficiency advantages existed in 1975 have been narrowed considerably. The United States has done little to encourage one mode over another for energy reasons. Trends over the past 20 years suggest that there may be even less reason to consider modal energy policies in the future.

The picture for freight transport is less clear, in large part because the available data on freight vehicles and operations are so inadequate. What data we have suggest that consistent improvements have been achieved by rail, but contain too much noise to discern consistent trends for truck and waterway transport (Figure 12). We know that energy intensiveness per vehicle mile has improved only slightly for over-the-road freight-hauling trucks, but it is quite possible that truck ton-mile efficiencies have improved much more. The Surface Transportation Assistance Act of 1982 allowed larger, heavier trucks as well as double trailer trucks to operate nationwide. Larger, longer, heavier trucks should be delivering more ton-miles per truck mile, and so it is reasonable to guess that the fuel economy per vehicle mile understates truck fuel economy improvements.

Energy policy has had, and probably should have, little impact on the modal structure of transportation. There are three sound reasons for this. The *first* is that differences in modal energy intensities are usually not as great as one thinks. The convergence of Btu/passenger-mile shown in Figure 11 tend to support this view but such average comparisons can easily be misleading. Modes carry different types of freight over different distances with differing costs, speeds, and reliability. More to the point, differences among modes tend to narrow when one examines more comparable services. Comparing long-haul coal shipments by rail to small-package delivery by urban truck will show an overwhelming energy use per ton-mile advantage for rail. This advantage will narrow considerably (but still favor rail) when interstate truckload shipments in double trailers are compared to rail trailer-on-flat-car (TOFC) including the energy used at both ends by trucks to provide equivalent point-to-point service. *Second*, it takes relatively large modal shifts to achieve relatively modest energy savings. Suppose there were only two modes, each with 50 percent of the market, and one was twice as energy efficient as the other. Increasing the efficient mode's share by 20 percent would be an enormous change in modal structure but would increase overall energy efficiency by only about seven percent. This is much like trying to increase fuel economy by means of shifts in the market shares of vehicle size classes. Large changes in shares are needed for modest increases in total MPG. Across-the-board improvements in technology have achieved much more. *Third*, modal choice decisions by a shipper or traveller are made by considering and trading off numerous modal attributes. To make them effectively requires intimate knowledge of the shipper or traveler's needs. Such decisions are best made by individuals in a market setting acting in their own best interest. This is not to say that government policy has no role in the modal structure of transportation. The government has a crucial role in infrastructure investment and taxation. Thus, government policy influences modal choices indirectly, through fuel taxes or highway and airport investments.

In general, behavior-based, operational or transportation systems efficiency improvements have been small in comparison with technology-based vehicular efficiency improvements. Furthermore, operational improvements, such as ridesharing or increased use of mass transit, have proven to be transitory, reversing when fuel prices dropped and fuel shortages disappeared. Systems efficiency improvements played a major role in air travel efficiency gains of the 1970s and early 1980s but, since 1984, load factors have been the only increasing systems efficiency measure. This may be due to greater use of the practice of "hubbing," which trades off trip circuity for higher occupancy rates (Greene, 1992). For highway travel, the average number of persons per car actually decreased from 1.9 in 1977 to 1.6 in 1990 (Davis and Morris, 1992, Table 4.10). Automobile occupancy rates also decreased for work trips where one might expect that traffic congestion, if not energy conservation, would be a strong motivation for ridesharing. The clear lesson is that systems efficiency improvements in a market economy are dependent on the continuing presence of the right market signals in the form of energy costs. Behavioral efficiency improvements, though significant at times of rising fuel costs, are readily reversed when fuel prices fall.

Military energy use (by air and marine) is substantial and should not be forgotten. In 1990, U.S. military operations, mostly jet aircraft, consumed 0.8 quads of petroleum-based fuel, 3.5 percent of total transportation energy use (Davis and Morris, 1992, Table 2.9). Although this may decrease somewhat in the future, there are two good reasons to pay attention to energy efficiency research for military operations. First, energy efficiency gives aircraft and ships a tactical advantage. Second, technological advances in military aircraft have been readily transferred by the aerospace industry and NASA to benefit civilian aircraft. Airframe and propulsion research that expands the envelope of performance, whether for military applications or for super to hypersonic transport, has also produced important benefits for the commercial aircraft market.

Though the transportation sector has achieved prodigious energy efficiency improvements in many areas, it has done nothing to break its near total dependence on imported oil. The greatest substitution for oil was achieved by blending ethanol produced from corn into gasoline. In 1991 gasohol consumption amounted to 8.6 billion gallons, comprising 8 percent of total U.S. gasoline use. Gasohol contains ten percent, or less, ethanol, and with ethanol having two-thirds the energy content of gasoline, this amounts to a petroleum displacement of just over half a billion gallons per year. Gasohol sales depend heavily on state and federal fuel tax subsidies, as well as air quality driven oxygen content standards for gasoline in certain areas. Nonetheless, gasohol is the U.S. most significant and successful alternative fuels policy for transportation. Despite spending billions on the synthetic fuels corporation, no contribution was forthcoming from fuels derived from oil shale, coal, or tar sands. Liquefied petroleum gases, compressed natural gas, electricity, and other fuels were consistently limited to minor niche markets or experimental demonstration programs.[14] Two key reasons for the failure of alternative fuels to successfully replace petroleum were their higher cost, and lower energy density. A recent study (NRC, 1990) illustrated this point by comparing the leading fuel alternatives on an equal footing. None could compete with gasoline made from $20 per barrel oil (Figure 13).[15]

Though we have limited experience with alternative fuels, and limited ability to predict how consumers will react to novel fuel and vehicle technology, we do know that both vehicle and fuel choice are very sensitive to fuel prices. The disappearance of the substantial price advantage of diesel fuel by 1984 was the primary factor in the collapse of diesel passenger car sales (Greene, 1986; Sperling and Kurani, 1987). Nearly every study of fuel type choice has shown great sensitivity to fuel price differences (e.g., Greene, 1990, 1989; Phillips and Schutte, 1988; Golob, *et al.*, 1992). If alternative fuels are not economically competitive, consumers will not want to buy the vehicles or the fuel. Either the technology must be advanced to the point where the fuels are economically preferable, or government policy must intervene and, by taxing or subsidy, make alternative fuels cost competitive. Fuel subsidies are likely to be not only politically difficult but also economically risky. Brazil's annual subsidy of its alcohol fuels program reached $3 billion in the late 1980s. In the U.S. the cost of an ill-conceived alternative fuels policy could easily be ten times that amount. Each year, U.S. highway vehicles use 110 billion gallons of gasoline and another 20 billion gallons of diesel fuel. An extra $0.10 per gallon would cost motorists $13 billion.

THE FUTURE: BACK TO THE PAST OR A LEAP OF FAITH?

The problems of oil dependence, urban air pollution, and greenhouse gas emissions will not be solved quickly or easily. Twenty years ago, the Clean Air Act initiated a series of very substantial technological improvements which drastically reduced the emissions of new vehicles but were insufficient to attain air quality goals in many cities. The new Clean Air Act Amendments of 1990 also contain promising, long-term provisions that will substantially improve urban air quality. Yet as long as oil-dependent vehicle travel continues to increase, the problem of motor vehicle emissions will remain. Controlling GHG emissions seems to be even less tractable because it appears to require technological revolutions in both transportation propulsion *and* electricity generation. Even electrically powered transportation will have substantial CO_2 emissions unless the electricity is produced by means other than the combustion of fossil fuel. Such a transition is not anticipated within the next several decades. Ultimately, solutions to transportation energy problems must be long term and based on technological change. In the near term, however, there are important actions that can and should be taken to mitigate the problems and keep us headed in the right direction.

First, we must continue improving the energy efficiency of transportation by making advances in vehicles and propulsion systems. A recent report by a committee of the National Research Council concluded that passenger car and light truck fuel economy could be improved by one-fourth to one-third using proven, marketable technology (NRC, 1992).[16] The technologies considered were all available in at least one car mass produced somewhere in the world today. Although there was a considerable difference of opinion about the costs of technology, estimates derived from studies for the U.S. Department of Energy indicate that the MPG gains would very nearly pay for themselves in fuel cost savings. The NRC report suggested that manufacturers need ten to 15 years lead time in order to minimize the costs of making the required changes in vehicle designs and production facilities. Thus, it is in our best interest to get started immediately.

A major obstacle to immediately pursuing these practical fuel economy improvements is the lack of a consensus on what policy will best achieve them. The issue is one of fairness and the competitiveness of U.S. firms. Although the previous CAFE standards were successful in nearly doubling the average MPG of U.S. manufacturers' products, they had a much smaller effect on the average fuel economy of imported carmakers (Figure 14). Domestic and foreign products now have equal fuel economy. The problem is that domestic manufacturers produce and sell proportionately more of the largest cars. Thus, another uniform corporate average standard might put them at a competitive disadvantage.[17] Various alternative forms of a mandatory standard have been proposed (see, OTA, 1991; NRC, 1992; for discussions), the most promising of which are based on interior volume (either size class standards or volume times miles per gallon).[18]

An alternative mechanism for establishing fuel economy standards is the voluntary or negotiated standard. It is widely believed that only the U.S. among developed countries had a fuel economy standard. In fact, every other member of the OECD had fuel economy standards but they were voluntary, or negotiated (IEA, 1984). Certainly, voluntary standards are less sure and more difficult to negotiate than mandatory standards. Their chief advantage is that they do not put the U.S. government and U.S. industry in an adversarial position. This is extremely valuable for one reason: solving the problems engendered by oil use in transportation will require a long-term effort extending over decades. A 33 percent fuel economy improvement is nowhere near adequate to solve the problems of global climate change or petroleum dependence. For these goals we must ultimately achieve far greater increases in fuel economy and must also make a transition away from fossil fuels. Undoubtedly, the most effective way to develop the technology this will require is through cooperative government and industry research and development. It would be highly desirable to be able to conduct that research in a spirit of cooperation rather than under the implied threat that, should it be successful, the result will be still more stringent mandatory regulations.

There is every reason to believe that in the next three decades, with the development of known technologies that are not now in widespread use, transportation vehicle energy efficiencies can be improved by 100 percent over present levels. A recent study conducted for the U.S. Department of Energy described technologies that could lead to a 55 MPG fleet average MPG beyond the year 2010, or even 75 MPG allowing for higher risks and more speculative technology (EEA, Inc., 1990). To get to a fleet average of 50 MPG without sacrificing attributes consumers want requires significant advances over current technology in the areas of engine friction and pumping losses, rolling resistance, and aerodynamic drag, diesel or two-stroke emissions control, and lightweight materials. Going beyond about 50 MPG is likely to require hybrid vehicles with severely downsized internal combustion engines and peak power requirements for hill-climbing and acceleration supplied by energy storage devices, such as batteries or flywheels. Similar improvements in other modes are possible. Improving the fuel economy of commercial air travel, for example, from its current level of approximately 50 seat miles per gallon to the range of 100-150 SMPG is technically feasible and may be economically practical if jet fuel costs increase by 50 percent to 100 percent (Greene, 1992). Even heavy truck MPG could be increased by as much as 100 percent through a combination of engine advances (e.g., adiabatic diesel with a bottoming cycle), plus reductions in rolling resistance and aerodynamics. All of this will require significant technological advances beyond the current state of the art and, therefore, substantial R & D. The public must promote and help to finance this R & D because its goal is primarily to reduce the social (nonmarket) costs of transportation energy use. This research will be most effective if done in collaboration with the industries who design and produce motor vehicles and components.

Alternative fuels are now a hotbed of activity thanks to the requirements of three recent pieces of legislation.[19] These acts provide tax incentives for purchase of flexible fuel, dual fuel, and dedicated alternative fuel vehicles. They also contain mandates for the purchase of alternative fuel vehicles by governmental agencies and by certain large fleet operators. Fuels covered include alcohols, natural gas, liquid petroleum gases (e.g., propane), and electricity. The CAAA of 1990 requires the use of "clean fuels" in nonattainment areas. It is now clear, however, that the clean fuel performance requirements can be met by "reformulated" gasoline. The concept of reformulated gasoline was introduced by the petroleum industry to match the emissions performance of M85, a blend of 85 percent methanol and 15 percent gasoline (Boekhaus, *et al.*, 1990). By a combination of reducing vapor pressure, adding oxygenated fuels such as alcohols and ethers, and balancing critical gasoline constituents, the petroleum industry has proven that it can produce a gasoline that meets the CAAA clean fuel requirements (Hadder, 1992). There should be little doubt that reformulated gasoline (RFG), not alcohols or gaseous fuels, will be the "clean fuel" of choice. It will also be the United States largest alternative fuels program ever. It seems likely that 35 percent to 60 percent of gasoline sold in the U.S. will be RFG by the end of the decade (Hadder, 1992). RFG is likely to contain 11 to 12 percent MTBE which will require approximately 30 percent methanol to produce, on a volumetric basis.[20] As a result, perhaps two percent of the total volume of gasoline sold will be derived from alcohol feedstocks. The success of RFG will be yet another example of the adaptability of the petroleum and internal combustion engine system.

Though two percent of U.S. fuel use is an enormous amount of fuel, it will not adequately address the need to reduce dependence on oil or cut greenhouse gas emissions. What we have learned about vehicle and fuel purchase behavior instructs us that forcing the sale of vehicles will not force the sale of fuel, especially for fuel flexible vehicles. If alternative fuels are not cost-competitive, consumers will not buy them and will not want to own alternative fuel vehicles either. On the other hand, if alternative fuels are economical, consumers will buy the fuels and demand the vehicles as well. The "chicken-or-egg" problem of alternative fuels (if fuels are not available no one will buy vehicles; if vehicles are not present no one will market fuels) has been exaggerated. The real issue is the cost-effectiveness of alternative fuels from the motorists' viewpoint. The solution to this problem is simple in concept but very difficult to execute. We must assess the social costs of oil use, assign a value per gallon to them, and tax petroleum-based fuels accordingly. It is true that we do not and probably cannot precisely estimate the correct value of such a tax. This does not excuse us, however, from making our best estimate and proceeding. We know for certain that $0/gallon is too low.

A promising design of a social cost fuel tax might be a layered tax, with components reflecting different social costs, and with the proceeds from each component going to a different, appropriate purpose. The first layer might be a *carbon tax*, levied on *all* fossil fuels according to their carbon content. Since the rationale for such a tax would be that CO_2 emissions are harmful to future generations, it is appropriate to use most of the proceeds of this tax to compensate future generations, i.e. by reducing the national debt. Some fraction should also be allocated to research. A second component would reflect economic costs of *oil dependence*. Since some of these costs relate to the total quantity of oil used, there would be a tax on all petroleum. Since others depend on the quantity of oil we import, there would be an additional *oil import tax*. The proceeds could go to financing the Strategic Petroleum Reserve, research programs to increase energy supplies (especially alternatives to oil) and efficiency, and mitigating the regressive impacts of energy taxes.[21] Finally, there would be an *air quality* component, assessed on all transportation fuels, according to their emissions impacts. This could be devoted to helping to finance a national health system, for research, and for mitigating regressive income effects. This is a somewhat complex tax structure (but simple by comparison to the income tax). It will not be possible to determine exactly the correct tax levels or the "best" allocation of revenues to achieve maximum economic efficiency. No tax, however, is almost certainly worse.

A social cost tax on petroleum fuels may or may not be sufficient to promote *any* alternative fuel. Furthermore, it may lead to unanticipated solutions, such as low petroleum gasoline (gasoline with even less petroleum content than RFG). This would be all to the good, since it would be a signal that there were no socially preferable, cost-effective alternatives to petroleum. The objective is to harness the creative power of the market by sending it a signal that less petroleum use is socially desirable. At the same time we should continue to support R & D aimed at reducing the costs of producing more socially desirable alternative fuels.

Transportation systems changes to promote energy efficiency should be considered, but it must be kept in mind that energy efficiency is not *the* primary goal of the transportation system. Personal mobility, economic efficiency, and environmental quality are all more important goals. The chief objective of advanced highway technology, such as Intelligent Vehicle and Highway Systems (IVHS), should be to permit growth in vehicle travel with less wasted time and energy. Increased ridesharing, improved traffic flow, telecommuting, even more efficient spatial structure can contribute perhaps as much as ten percent each to improving system energy efficiency. The recent Intermodal Surface Transportation Efficiency Act provides a more flexible framework for allocating transportation revenues among types of system improvements and modes. This should allow greater ability to take into account the social costs and long-run impacts of transportation infrastructure decisions.

In the long run, if global climate change requires drastic reduction in fossil fuel use, reformulated gasoline, increased use of natural gas-derived methanol, and even a 100 percent increase in fuel economy will not be enough. The only known fuels that can ultimately solve the greenhouse gas problem are electricity produced by nuclear or solar energy, and biofuels (also produced from solar energy). Eventually, the transportation system must make a transition to solar, as opposed to fossil, energy. While it is not possible to predict how or when this transition will take place, it is interesting and possibly useful to speculate about transition paths. One possible path from today's conventional internal combustion engine to a fuel cell electric vehicle powered by hydrogen derived from solar photovoltaic electricity is illustrated in Figure 15. The first step in the transition is more widespread introduction of flexible fuel vehicles (FFV), able to use methanol, ethanol, or RFG. The presence of these vehicles creates a market for alternative fuels, allowing a supply infrastructure to develop. Initially, methanol is produced primarily from low-cost natural gas, supplemented by alcohols produced from biomass as production costs are reduced. Next, the power-assisted internal combustion engine (ICE) hybrid vehicle is introduced to boost fuel economy beyond 50 MPG. Hybrids may also be flexible fuel, or even dedicated alcohol engines (fuel availability is no longer a problem). What engine will power the hybrid (diesel, turbine, two-stroke, etc.) remains to be seen. Next, the fuel cell-battery electric hybrid vehicle is introduced, initially fueled by methanol which must be reformed to produce gaseous hydrogen, but later fueled directly by gaseous hydrogen stored in compressed form at ultrahigh pressure (8,000 psi; see, e.g., DeLuchi and Ogden, 1993). The fuel cell electric (FCEV) hybrid is much more energy efficient than the ICE hybrid, so that fossil fuel use is gradually eliminated. Finally, continued advances in solar photovoltaics lead to the ultimate solution, a transportation system that runs on sunlight and emits only water vapor.

Is this exactly how it will happen? I doubt it. But it is a vision of a future we could create and that would solve transportation's energy and environmental problems. Other desirable futures are possible. The choice we face is whether to continue to muddle through and face a return to a past of energy dependence, price shocks, urban air pollution, and the threat of global warming, or to turn toward the future and forge a path towards an environmentally benign, secure, and economically efficient transportation energy system.

ENDNOTES

1. For example, the Ford Foundation Study (1974) foresaw an impending energy crisis and called for a policy of energy independence.

2. As we have already pointed out, aerospace research, though generally motivated by defense goals, was a notable exception producing enormous energy efficiency gains in turbojets and airframes.

3. The total economic costs of oil dependence for the 1972-1991 period amounted to approximately $4 trillion, according to a recent study (Greene and Leiby, 1992). The study compared actual conditions over the past 20 years to a competitive world oil market with stable prices.

4. If one includes natural gas plant liquids in petroleum production, U.S. petroleum production increases to 17.9 quadrillion Btu in 1991.

5. Even so, oil prices did not collapse to pre-1973 levels but rather to the long-run monopoly price levels the cartel could sustain (see Greene, 1991).

6. This transfer of wealth occurs whether or not OPEC reinvests its monopoly rents in the U.S. economy. The issue here is who owns what, not how efficiently the economy operates.

7. This estimate is in 1990 dollars but not inflated to present value. That is, it does not consider the opportunity cost of the loss of wealth in the past.

8. Clorinated fluorocarbons (CFCs), potent greenhouse gases and a principal cause of the stratospheric "ozone hole," are produced from a variety of sources but especially from refrigeration systems, including automotive air conditioners. A United Nations agreement of 1989, subsequently modified, provides for the total end to production of CFCs for all applications by 1996. This agreement, to which the U.S. subscribes, will gradually eliminate emissions of CFCs by the transportation sector as newer vehicles equipped with non-CFC air conditioners replace older vehicle stock.

9. Price controls and regulation were responsible for gasoline lines, not the price hikes. By preventing prices from rising to market-clearing levels, price controls forced a rationing of fuel by waiting in line.

10. Light truck standards were decreased to 20.0 in 1990 and 20.2 in 1991. Passenger car standards were reduced to 26.0 for 1986-88 and 26.5 in 1989, but restored to 27.5 for 1990 and 1991. These modifications were made within the requirements of the EPCA by means of DOT rulemakings.

11. The best estimates indicated a factor of 0.90 for the EPA city MPG value and 0.78 for the EPA highway MPG estimate (Hellman and Murrell, 1984). The composite MPG estimate is a weighted harmonic average of the city and highway values with weights of 0.55 and 0.45, respectively. The mathematically inclined reader may verify that this results in a combined factor of 0.84.

12. Average light truck weight for model year 1991 is essentially identical to the average weight for 1975; 4,036 versus 4,072, respectively (Heavenrich, *et al.*, 1991).

13. We compute a salesweighted harmonic mean MPG. This is the inverse of the sum of the quotients of class market shares divided by the class MPGs. If we expressed fuel economy in terms of gallons per mile, we could take a simple weighted arithmetic average.

14. In fact, pipelines are responsible for nearly all the nonpetroleum energy use in the U.S. transportation sector, accounting for nearly 100 percent of natural gas use and 80 percent of electricity use (Morris and Davis, 1992, Table 2.8).

15. All the alternative fuel either had higher costs on a gasoline equivalent energy basis or require expensive modifications to vehicles that, when amortized on a per-mile basis, make the fuels more costly.

16. The technologies included a ten percent weight reduction by means of cost-effective substitution of lighter weight materials. Such a change should have little or no effect on the overall safety of the highway system.

17. This must be considered a real possibility, since a manufacturer who is not constrained by a standard is free to optimize his design decisions to cater to his customers. This should give him a competitive edge. Since competition among carmakers within a market segment is intense, even a small advantage can translate into a large difference in sales and profits.

18. Standards based on interior volume are not as vulnerable to "gaming" by manufacturers as one might think. This is because interior volume is not measured as the absolute interior volume of a car, but in terms of usable occupant space (headroom, legroom, shoulder room, etc.). One may choose to include cargo volume or not.

19. These are the Alternative Motor Fuels Act of 1988, the Clean Air Act Amendments of 1990, and the Energy Policy Act of 1992. These acts place a number of alternative fuel vehicle purchase requirements on government and privately operated fleets of vehicles. The CAAA also allows states to "opt in" to the California Low Emission Vehicles program, which requires that by 2003 ten percent of all cars sold be Zero Emission Vehicles (battery powered electric vehicles).

20. MTBE is an abbreviation for methyl tertiary butyl ether, produced from methyl alcohol and isobutylene. An alternative oxygenate for RFG is ETBE, produced by substituting ethanol for methanol. ETBE contains more alcohol (almost 40 percent by volume) and would thus be slightly more effective in replacing petroleum (Piel, 1989).

21. The reason is that a gasoline tax will be regressive, impacting rural and suburban lower income groups relatively more severely. Progressive income tax policy could partly redress this undesirable effect.

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Table 1

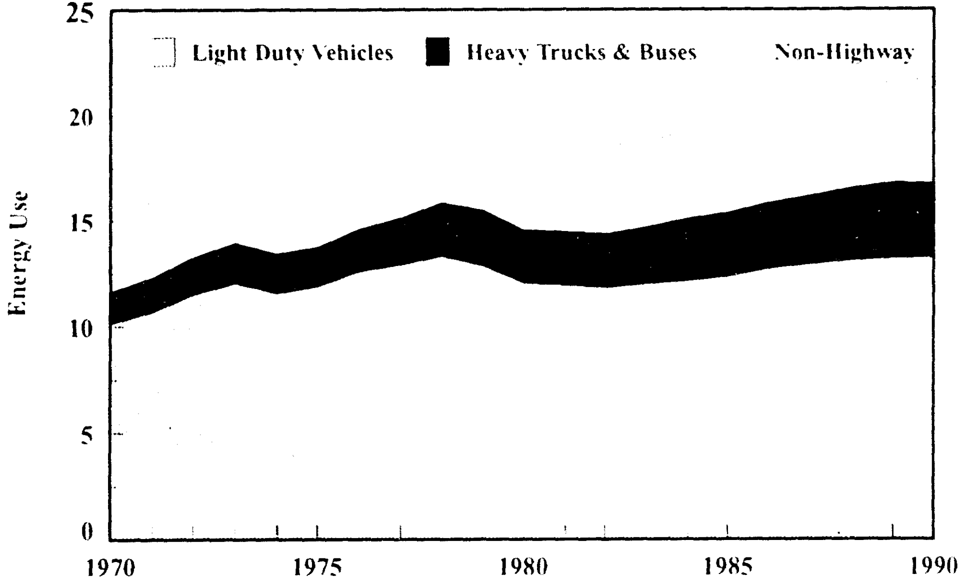
PASSENGER CAR MPG AND SALES DISTRIBUTIONS, 1975 AND 1991

	1975			1991		
Class	Sales	Share	MPG	Sales	Share	MPG
Two-seater	244	3.0%	19.7	143	1.8%	27.9
Minicompact	941	11.4%	23.0	104	1.3%	28.8
Subcompact	1011	12.3%	19.2	2048	25.8%	31.2
Compact	1893	23.0%	16.2	2185	27.6%	29.2
Midsize	1631	19.8%	13.6	2011	25.4%	25.8
Large	1555	18.9%	13.1	1033	13.0%	23.7
Small Wagon	477	5.8%	22.4	195	2.5%	30.3
Mid. Wagon	289	3.5%	13.2	163	2.1%	25.9
Large Wagon	197	2.4%	11.9	44	0.6%	22.8
	Ave. MPG		15.8	Ave. MPG		27.8
	1975 MPG, 1991 Shares		15.7	1991 MPG, 1975 Shares		27.2

Source: Heavenrich, Murrell, and Hellman, 1991

Figure 1

U.S. TRANSPORTATION ENERGY USE, 1970-1990
(Quads)



Source: Davis and Morris, Transportation Energy, Data Book Ed. 12, Oak Ridge National Laboratory

Figure 2

LONG-TERM TRENDS IN U.S. TRAVEL GROWTH
(Averaged Over the Previous Ten Years)

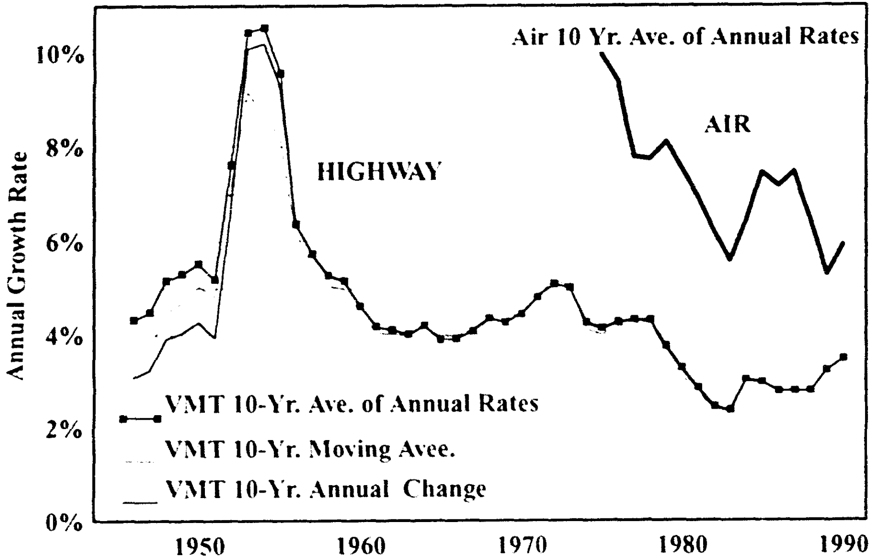


Figure 3

U.S. DEPENDENCE ON IMPORTED OIL, 1973-1990