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CONVERSATIONS ABOUT ELECTRICITY AND THE FUTURE

FINDINGS OF AN INTERNATIONAL SEMINAR AND LESSONS FROM A YEAR OF SURPRISES

THE FIRST 1990 GROUP ON ELECTRICITY

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Editors

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FOREWORD

In January 1990 thirty-two experts from twelve countries convened for a five-day working Seminar on the Berkeley Campus of the University of California to discuss electricity supply and demand. The participants brought with them deep and diverse backgrounds in energy issues. They chose the name "The First 1990 Group on Electricity".

At that time, the Berlin Wall had just come down; Eastern European nations were holding elections; China had closed itself off, but the Soviet Union was opening its news media and its economy to the Western world. Americans were talking about how to utilize the "peace dividend", but at the same time, thoughtful persons were warning against too much euphoria.

Less than half a year later, Iraq's actions marked another "lifetime" event that has thoroughly tempered this optimism. Once again there is a widespread wariness about the future. Once again, energy is a key factor. As actual war drew near, world oil prices jumped. Americans had vivid memories of the oil embargoes and gas lines of the 1970's. But almost as suddenly, oil prices dropped again, even as it became obvious that neither Iraq nor Kuwait would be back up to its pre-war production for many months or even years.

Less dramatic, less publicized, and less imminent are the risks that may turn into real dangers because of electricity shortages in the coming decade.

A major concern of The First 1990 Group on Electricity was the potential impact of electricity shortages on the environment, just at a time of growing awareness of environmental deterioration. These concerns extend from local problems to nations, regions and global impacts. Indeed, because of the importance of electricity in our lives, potential electric power shortages already foreseeable in this decade could overwhelm public concern for the environment, unless critical, long-leadtime measures are taken very soon.

The First 1990 Group on Electricity's Findings and Conclusions, the thinking that led to them, and the impact of events in the intervening year form the content of this book.

All the prepared papers and statements from the Seminar appear in full-page width. Conversations, arguments, comments and responses are indented, beginning with the speaker's name as a hanging indent. In spots, we pulled interrupted comments together where challenges and cross-discussion became spirited.

As events unfolded during the ensuing year, we were struck by messages in points that were made by various participants. Things changed, but many of the key points were to remain the same. Over the past year, we discussed these developments together, and sometimes with various Seminar participants.

When we occasionally introduce our observations after the benefit of hindsight, we keep them clearly identified by indenting them and putting them in brackets.

As for the body of the text, we have edited for clarity and sometimes for readability in English especially, but we have not changed the substance of the taped transcript or working papers we used. However, the narrow bracketed paragraphs are ours, and we, rather than any of the participants, take full responsibility for them.

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SECTION 1

REASONS FOR URGENCY

TROUBLE AHEAD

Though different from country to country, the symptoms of electricity shortages are worldwide. Shortages, once they impact the public, are likely to force emergency responses which are bad for the environment and bad for any economy.

Everyone at the Seminar agreed that the time was right. Brownouts had begun to show up in the U.S. (Florida and the Northeast). The U.S. Dept. of Energy had embarked upon the preparation of (and since published) a National Energy Strategy. Some experts were talking of a "window of opportunity" to develop new sources of energy.

W. Kenneth Davis chaired the opening round table. "There seems to be an almost complete lack of leadership on energy-related matters in industry and government", he said, "both nationally and internationally. I don't know how to correct it. But I don't know how some of the problems can be solved unless we get some real leadership."

In January, 1990, it was a time for hope. Dr. Melvin Gottlieb commented, "The most important event of our lifetime is that the danger of a nuclear holocaust is retreating. Problems are very different in different parts of the world; this is true. Nevertheless, we know very well how important electric energy has been in improving the way of life in this country and other countries can attest to similar experiences. We do have a common need and we have much common information that we can use to the betterment of life all over the world."

As the decade opened, there was indeed a feeling of hope. Despite warnings about the problems facing nations of the East Bloc as they emerged from several decades of a rigid, closed economic system, speeches rang with excitement for the future. There was a real easing of international tensions. To people concerned about the environment, these developments appeared to offer an opportunity to address problems on a global scale, through trade, through international agencies and through shared scientific research of benefit to all of mankind.

[Less than half a year later, Iraq's actions have already tempered this optimism into a wariness about the future. Once again, energy is at the core of the crisis. The Middle East war was largely about oil. It had many and complex causes, but oil, the money it brings in, and the potential political power that control of huge oil supplies brings is at the heart of it all.

When the word "energy" is used, oil dominates. Oil provides the power to make things move, and also to make chemicals, plastics, and medicines. The concern of this book is electricity. In the U.S. and Western Europe, burning of oil for generation of electricity has been substantially reduced as nuclear power, coal and natural gas replaced oil. But in many nations, oil is the dominant fuel for making electricity, or at least it is the fuel at the margin: if electricity demand is to grow, the additional supply will not come from new nuclear or coal plants, or even natural gas in nations that have it or can afford to import it, but from burning more oil.]

We live in a world in which the economically advanced nations are becoming more concerned about environmental quality, not just within their borders, but about global concerns which might affect all humanity in the future. As huge numbers of people around the globe strive for a better life, they see that they will need to be able to use energy at a rate approaching today's global average. And they will soon recognize that those nations where people have a better life use a larger fraction of their energy in the form of electricity.

As economic leaders of the world, the industrialized nations play a special role. To sustain world economic growth and improve environmental quality, it is imperative that these countries begin now to assure their own electric energy supply in the coming decades, make the best use of existing technologies, and reinvigorate research and development on improved energy technologies for the future.

This is vital because the developing nations must find ways to increase their electric generating capacity many-fold over the next half century. It is these nations, rather than the United States and Europe, that will control most of what enters the atmosphere. Through commerce and international agreements, positive achievements by the industrialized nations can directly benefit these nations and the global environment.

Positive strides are being made in industrialized nations to conserve energy through innovation, efficiency improvements and incentives, which should

lead to the growth of a conservation ethic on the part of people the world over.

However, after reducing projected demand by taking full credit for success of conservation efforts, new electric power plants will still be needed. Old plants must be replaced. A mix of options and enough lead time to make sound choices on both demand and supply sides is far safer than short-term decisions and catch-up policies. Choices need to reflect local, regional and global environmental priorities, as well as the economics and reliability of the entire electric supply and delivery system.

WHAT GIVES US CREDIBILITY?

Participants in The First 1990 Seminar on Electricity were invited because of their knowledge and actual experience in positions of responsibility in energy supply, use and research.

We looked for outstanding scholars and managers, government ministers and scientists. The Group that finally met at the Bechtel Engineering Center on the Berkeley Campus included 21 from the U.S., 11 from other nations and four invited speakers. These are people who have had responsibilities for supplying electricity, or whose studies are recognized in this area. We spoke frankly. Although there were many disagreements on specific details, there was no disagreement with the overall Findings.

Our discussions divided into global concerns, the experience of and the problems facing industrialized nations, and issues of critical importance in the developing world.

In developing the Findings, we set a limit of two pages. That meant reaching consensus on what issues were essential, recognizing that some issues of strong interest to certain individuals could not be expressed concisely enough to be included. Nevertheless, before the Seminar week ended, every participant signed off, either in person or by FAX, on the Findings and Conclusions, and on the Recommendations.

[In addition to approval by the Participants, copies of the Statement, consisting of a one-page introduction, the Findings and Conclusions, and the Recommendations, were sent to 165 persons who had been contacted about the Seminar (some who had expressed an interest in attending but could not schedule it), and others from government, university, research and industry organizations. Eighty of these people were asked to respond by mail or FAX, and a signature form was included if the individual wished to join in approval of the Statement.

There were 61 positive responses and only two declined to approve. Both stated that although they agreed with much of it, they had certain concerns and, since they had not taken part in the discussions, they felt it would not be appropriate to sign the statement. Many offered to assist in further dissemination of the Statement.]

WHAT KINDS OF ACTIONS?

Our goal is to place the Findings of the Seminar in the hands of leaders and policymakers in countries around the world.

[The Findings and Conclusions and the Recommendations were delivered to the White House and the Department of Energy, and were carried back home by each of the international participants for dissemination.]

The U.S. is taken as a special case, in part because of its size, resources, economy, and patterns of energy generation and use. This was reflected by many of the foreign participants, who pointed out that what the U.S. does will certainly affect political positions and policy decisions in other nations.

They expressed disappointment in the failure of the U.S. to emerge with any clear energy policy after so many years of talking about it. They feared that with a lack of leadership from the U.S., their own political decisions could tend toward the expedient and short-term, rather than being long-term, sound and environmentally responsible.

CONSENSUS ON THE NEED FOR ELECTRIC SUPPLY

[In reviewing the Seminar transcripts in order to prepare this manuscript we, as editors, were again struck by the unanimity among so diverse a group of experts, on the key points underlying our Findings. In the end, this diversity served mainly to bring out new points of consensus, rather than to find irreconcilable differences. It enabled us to understand differences, which sometimes arose from misunderstanding of another's positions, but occasionally revealed basic disagreements in personal or nationalistic philosophy.

This consensus was particularly evident when it came to the basic linkage between electricity and well-being, and the certainty that, even with broad success of the best efforts at energy conservation, more electric generating capacity will still be needed.

There was also general agreement that the risks associated with all of the different ways of generating electricity are rather well understood.

In addition, and of even more importance, there was consensus on the evidence that societies with adequate energy had better health, more hope for economic growth, and better environmental quality. And, as the actual discussions reveal, participants felt strongly that the down-side risks of inadequate electricity supply can be much more serious than the risks from any mix of generating capacity.

Large, fuel-efficient power plants, either coal with environmental control technology or nuclear plants, will take about six years for actual construction. Permits, licensing and site preparation can add two or more years to the lead time. This means that power plant decisions made in 1991 will, at least in the United States, result in actual power to the grid no sooner than the turn of the century.

Long lead-time adds urgency to our Findings. This lead time is typical of most of the industrialized world, where public policies have discouraged new power plant construction for two decades. (Japan, France and Korea are notable exceptions.)

But long lead times are also inevitable in developing countries because of the difficulty in obtaining international financing and the lack of hard currency for high technology imports. And as we heard repeat-edly at the Seminar, this dilemma is particularly acute, because shortages of electricity stand in the way of economic growth.]

SECTION 2

FINDINGS AND CONCLUSIONS

THE TEST OF TIME

The First 1990 Group on Electricity Findings and Conclusions are listed below. In this book, we will explain why we arrived at them, share the discussions that formed the basis for our reasoning, and show their urgent importance for the future.

> [We continue to be struck by the timeliness of these Findings and Conclusions, despite the momentous and unforeseen events of 1990 and 1991. In fact, these events and the changes they portend only heighten our concerns about electricity supply in the decade ahead.]

ELECTRICITY IS ESSENTIAL

Electricity is the key energy form for every modern economy. People depend on it. As electricity has become widely available, societies have improved their health, well-being, and quality of life, but also their environment and the global environment as well.

ELECTRICITY AND THE DEVELOPING WORLD

Eighty percent of the world population lives in developing countries. Ever-increasing amounts of energy and electricity are required for any substantial improvement in their living conditions. China, for example, projects the need to triple its coal burning, if it can find ways to haul it. To different degrees, developing countries lack sufficient electricity, and this means constraints on their urgent needs for food, clothing, housing, health and education. Many of the developing countries face severe constraints in mobilizing their own resources and raising capital to finance the power sector, let alone to introduce advanced technologies and efficiency improvements.

SHORTAGES ARE COMING

People depend on electricity for services that are critical to their jobs, lifestyle, health and well-being. The U.S. faces foreseeable shortfalls in electric supply before the end of this decade, based on expected demand and supply.

Certain regions have already experienced transmission problems, curtailments, brownouts or even rolling blackouts.

THE "DOWNSIDE RISKS" OF ELECTRICITY SHORTAGES

The safety and environmental risks of electricity generation have received much detailed review and all of the public attention. But the downside risks of inadequate electricity are not as well recognized even though they are real, more immediate, and potentially much more serious. Downside risks go beyond brownouts or blackouts during severe weather or emergencies. They mean short-term, high-cost, environmentally unsound stop-gap measures like turning to natural gas and oil again for electricity; the imposition by government of enforced conservation, rationing and even allocation of electricity supply between competing uses; potentially severe impacts on technological competitiveness; and limitations on economic growth because of doubts about future electricity supply. Examples of these downside risks are evident today in many parts of the developing world.

DIVERSITY

Diversity means having a variety of *demand reducing options and supply increasing options* to meet new requirements. Different options offer advantages for different load requirements (base load, peaking, seasonal). Considering uncertainty of future fuel prices and regulatory requirements, diversity increases stability in future electricity costs and contributes to the security of energy supply. The cost of electricity is the cost of operating the integrated system, so each addition must fit in well to minimize prices to consumers.

On the demand side, electricity is being substituted for burning of fuels by the industrial end-user. Process control is more precise, the workplace is cleaner and safer, and energy is used more efficiently. This inter-fuel substitution is driving an increasing demand for electricity.

INTEGRATED PLANNING

To escape the stagnation of the past decade requires planning now for action that would produce sound environmental and economic benefits. Integrated plans are recommended which give balanced consideration to environmental protection, public health and safety, reliable service for all customers, cost of electricity, and flexibility to respond to unexpected changes and world events.

The 1989 Ontario Hydro 25-year demand/supply plan is an example of an *integrated plan*. This proposed plan meets future Ontario electricity needs as follows:

Total New Requirements	21,600 MWe
Demand-Reducing Options	5,900 MWe
Renewable and High-Efficiency Supply Options	4,200 MWe
New Base-Load Supply (Nuclear)	7,100 MWe
New Peak-Load Supply (Gas-fired)	4,300 MWe

CONSERVATION

It is important to achieve improved end use electric energy efficiency. The focus is to meet people's needs while reducing the amount of energy required and reducing the associated environmental impact. The national measures undertaken should be decided after considering all advantages and disadvantages, including costs and impacts on the economy.

NEW CAPACITY STILL URGENTLY NEEDED

Even with outstanding success in conservation initiatives and efficiency improvements, substantial amounts of new generating capacity will still be needed, and decisions are urgent because of the long lead-time (6-10 years or longer) to license and build major power plants. Many options need to be available so that responsible choices can be made; no narrow strategy is realistic.

Nuclear power is the most contentious issue, but if industry and investor confidence in the U.S. can be regained through licensing reform and reviving predictable State regulatory treatment, sound long-term market decisions can be made. After reducing demand projections to account for conservation and efficiency improvements, and introducing alternative energy sources where practical, the remaining possibilities for future base-load electric capacity are between nuclear plants, hydroelectric dams where environmentally acceptable, "clean" coal, and burning more gas and oil.

RESEARCH AND DEVELOPMENT

A renewed emphasis on energy research and development, with international cooperation and coordination, is essential. The program should include innovative technologies to conserve energy and a diverse menu of new and improved energy supply technologies including advanced nuclear

designs, geothermai, solar and other renewable sources, as well as cleaner and more efficient coal, oil and gas combustion. For the long term, fusion could mean the opportunity to phase out the least attractive of today's options.

EDUCATION

Programs to meet the world's energy needs will require more scientists and engineers in energy fields, and consequently, more science and engineering teachers and teaching facilities. Programs are needed to stimulate young people, beginning at pre-college levels, to see the energy field as a challenging and rewarding career which can help their fellow man and sustain the global environment.

SECTION 3

ENERGY SHORTAGES: THE DOWNSIDE RISKS

The 1970's were a period of new-found concern for the environment and an awakening to the fact that that natural resources are not unlimited. In many nations this public concern was soon translated into laws. In the United States, these laws have in turn led to a vast array of regulations. The most far-reaching piece of legislation in the U.S. turned out to be the National Environmental Policy Act (NEPA). NEPA requires that environmental impacts and risks must be evaluated, reported, and in some cases, debated in public hearings. Alternatives must be considered before a project can begin.

In the 1980's environmental regulations became a lever for delaying, and in some cases, cancelling projects. Regulations and their applications were tested in court, and then tested again in higher courts.

Meanwhile, the Fuel Use Act, economic pressures, and concern about future supply, led U.S. utilities to do anything they could to reduce their dependence on oil for electric power generation. By 1989, oil produced less than 5% of all U.S. electricity, down from 20% in 1973. The major reasons for the decline in oil burning were conversions of oil-fired plants to natural gas, a few former coal-burners that were converted back to coal, and the more than 65 nuclear power plants that came on line during the intervening years.

Throughout these two decades, the most controversial issue seemed to be nuclear power. First the United Kingdom, then France and Japan, made major commitments to nuclear power in order to move away from their heavy dependence on oil for generation of electricity. Other nations followed, but by the end of the 1970's, and after the Three Mile Island accident, nuclear power was becoming a political issue in country after country. Initiatives stopped plants in Austria and Switzerland, and later at the national level in Sweden and Italy. Violence erupted in Spain, stopping construction.

In the U.S., numerous construction permits and operating license hearings became lengthy battles that have led to huge cost overruns. Two plants (Shoreham and Rancho Seco) have been shut down as a result of concerted political actions. Various activist and special interest groups raise questions and make charges about radiation, waste, safety and weapons proliferation.

Industry and government experts document their answers with thick reports. People wonder whom they can trust.

Nuclear risks are weighed against risks associated with coal (pollution, acid rain, the buildup of carbon dioxide); with oil (spills, fires, tanker accidents, platform collapses, and dependence on the Middle East); with natural gas (rising prices and limited resources), and with new alternatives (unknown economics and unproven technologies). Assessment of health and environmental risks has become a major industry. We have developed the capability to quantify the risks rather well.

But the benefits have to be weighed against the risks. Rarely do people hear about the downside risks: the risks that come with not having enough electricity to meet the legitimate needs of the communities the utility serves. No one claims that nuclear power is the answer to all our energy problems. But nuclear power's contribution is vital. Without it the problem of supplying enough electricity to meet the legitimate demand of a growing economy becomes more difficult.

The First 1990 Group are familiar with the environmental risks of energy production and use. But they agreed that it is time that people start to look at the downside risks of not having enough electric power plants.

In most industrialized nations, young people have grown up with dependable and relatively economical electricity. Utilities, where they are the providers of electricity, have (by law in the U.S.) served all. But with too few base-load power plants being built today (coal and nuclear) and the eight to ten years that it takes to get one built, the odds of an electric generation shortage before the end of the nineties are mounting. Even with zero growth in electric demand, by 1995 in the U.S. alone it would take 8,000 megawatts each year (the equivalent of seven new large nuclear plants) just to replace the old plants that become obsolete. That is with no replacement of oil-burning plants and no growth in demand. Only 6,000 megawatts were ordered in 1989. So the stage is being set today, not just for one of the downside risks, but for any or all of them, perhaps even at the same time.

DOWNSIDE RISK ONE: THE SELF-FULFILLING PROPHECY

Privately-owned utilities used to be accused (sometimes correctly) of building a new power plant, then advertising to promote demand for the power to justify its decision. Some called that a "self-fulfilling prophecy". In the days of 3 per cent interest rates, the new plant would produce power at less cost than what it replaced. It would be more efficient, and cleaner as well. Now there is no financial incentive for any utility to build anything.

Today there is a new, real and serious "self-fulfilling prophecy." Construction plans are not keeping up with projections of future load. Reserve margins are dropping each year. But it will be almost a decade before the real impact will be felt in most regions of the U.S.

Utility executives continue to study the history of activist opposition and denials of rates by their state commissions to cover return on investments. The U.S. Seminar participants described these difficult decision analyses, and some of their experiences were matched by those from other nations. In the last decade, the prudent financial decision has generally been to put off any new construction projects.

But if a utility company cannot promise reliable electric service, the next factory or office complex will go somewhere else. With it go the jobs. Next, other local companies cancel plans for expansion. It could even lead to closing of companies that had been pillars of the community for years. That, again, becomes a self-fulfilling prophecy.

DOWNSIDE RISK TWO: PRIORITIES AND ALLOCATION

The theory of some who oppose new power plants is that growth is unnecessary, that if government provides appropriate encouragement everyone will conserve, the right amount of energy waste will be skimmed away, and that more energy supply and use, with all its environmental impacts, will be avoided.

However, on the downside, there is a risk if there is not enough electricity to supply all users. When there are only so many generating plants, and the various new demands turn out to be greater than the supply, priorities will have to be set.

What new use should have priority for a limited remaining amount of electric supply? A factory with its jobs? A new energy-efficient office building? A hospital? Apartments? One hundred four-bedroom houses? Should each residence have a limit? Should certain appliances be banned?

Just who should set these priorities? Not the utility company; that is not its role under U.S. regulatory law, since a utility has no right to discriminate among users. Should the state order the utility to raise rates or should it tax energy use to depress demand, even though that would increase welfare payments? If not, that leaves allocation. The priorities would be set and enforced, not by the utility, but by government. But not one public official has called for hearings on how to set priorities for electricity when there is not enough to go around.

DOWNSIDE RISK THREE: WAR

The third downside risk sounded so frightening at the time of The First 1990 Group's seminar that it was hard to talk about it: war over energy. But before the end of 1990, war in the Middle East became a bloody reality. That war was not just about oil; it was about power, and the control of oil and the riches that oil exports could bring in that could be used to build more military and political power.

So the downside risk of war over energy is no longer only a risk, but a reality. Its implications are far from clear. Daniel Yergin, in "The Prize", documents the lengths nations have gone to protect and control the world's oil supply. The question now is whether or not the industrialized nations will take this warning seriously for the future.

WHAT IT IS ALL ABOUT

Competing views come into conflict when a new power plant, or even a new energy technology, is proposed. Permits and licenses are required. Some kind of governmental action is required in every nation. There are opportunities for those who oppose a project to be heard, and in some cases, for them to take an active role in opposition, to force delays, or to make their case for rejecting the proposal. Financing must be obtained, and the climate for raising investment capital or allocating government funds must be favorable enough to attract capital.

In the industrialized countries there is broad political support for energy conservation programs. There are also opportunities for investment in improvements that will save energy through improved efficiency. These efforts can reduce the rate of growth in electricity demand. At issue is, by how much? Does this mean that no additional generation facilities are needed? Does it defer the need for the next plant, and if so, by how many years? Does it mean a different mix of base-load and peaking capacity, or suggest a different mix of fuels for better energy efficiency and conservation of resources?

And if more capacity is needed, how much can be delivered by alternative or renewable energy sources? During the late 1970's, it was politically popular to call for "soft" and decentralized energy technologies, which could free the user from dependence of large utility suppliers. The U.S. Congress passed laws that would encourage independent power producers, and these have resulted in numerous investments in solar and wind power generating facilities. However, most of the independent power projects burn natural gas.

Some of the most outspoken political activists in the U.S., Canada, Sweden and in continental Europe, demand a commitment now to stop nuclear power. Their argument is that investment in a nuclear plant would both alleviate the need and sap the resources for investments in conservation or alternative energy. What is not yet clear is just how much demand will exist if their recommendations are accepted. Decisions to defer all new baseload capacity without assurance of the extent to which demand-side investments will work also create downside risks.

No one can predict with certainty just how much capacity will be required for decades to come. But the risks of having too many power plants need to be compared with the downside risks of not having enough. This has not been done when the environmental risks of building a power plant at a specific site are analyzed.

A commercial airline considers downside risk. When a London to New York flight takes off, it is carrying a specific measure of fuel over and above what it takes to make the flight. This means higher inventory costs and more weight on takeoff and landing because experience says there may be weather delays or other unexpected developments. Cutting fuel loads close to the line is tempting, but the downside risks of running short are well known, not only to pilots and executives, but to passengers and politicians.

If the debate about energy is to deal with risks, the downside risks of electric energy shortage deserve to be a feature of it. If a free society is to arrive at an energy policy, its people need to be well aware of the downside risks of all its options.

SECTION 4

LONG-TERM RISKS

The ultimate downside risk is to be unprepared when events force society to abandon a fuel source or energy technology upon which it has relied heavily. The risk becomes a reality if lead times for development and substitution of new technologies are long (and they generally are) but societies fail to act when there is still time to do something about it. The task becomes all the more difficult when there is a lack of scientists and engineers to create and implement new technologies.

These issues are the domain of research and education, which are always struggling for priority against near-term needs. Yet, they are essential for the long term.

Since the 1950's, resource experts have warned that the fossil fuels that created the industrial revolution are not renewable, not infinite, and must escalate in cost as more accessible supplies dwindle. Finding and extracting them will get more costly. Others decried the pollution from burning fossil fuels, and in recent years, the longer-term concerns about global warming.

In the 1960's and '970's, these issues first gave impetus to the growth of nuclear power, and then to research and development of long-term options including breeder reactors, fusion and solar power. By the 1980's, it was clear that this forward-looking program was in trouble. Energy research funding waned. The breeder reactor became the target of concerns about diversion of plutonium and proliferation of nuclear weapons. Fission reactors faced technical, economic and political problems, and they turned into a target that mobilized political opposition to nuclear power.

Thus today, as concerns about long-term supplies of fossil fuels and environmental deterioration become all the more pressing, we find ourselves unprepared for the very uncertain energy future ahead of us. The Seminar participants felt strongly that reversing this trend, including a revival of nuclear power, is of critical importance. There was a solid consensus that the time is ripe for action, both at the national and international level.

FUSION - AN INTERNATIONAL EFFORT

Nuclear fusion has emerged as the paradigm for international cooperation in government-sponsored energy research. Research on fusion dates to the 1950's when it was realized that the deuterium in the oceans represents an essentially infinite energy source with relatively benign environmental consequences. The first major milestone is to demonstrate that the difficult process works in the laboratory. After three decades of research on ever larger and more expensive experimental devices, scientists believe that they have proved the feasibility of the process. More challenging scientific work remains, and that must be followed by extensive engineering development, demonstration of practicality, and ultimate deployment on a commercial scale. Fusion reactors could then be integrated into large electric grids of industrialized regions.

Recognizing the long-term costly nature of fusion research and development, leaders in the field, including those in the Soviet Union, began preparing the way to collaborate on an engineering test reactor at the first opportunity. That opportunity came in 1985, at the first summit meeting of President Reagan and Secretary Gorbachev. By 1988, this had led to the joint effort by the U.S., U.S. S. R., Japan and the European Communities to design and construct the world's first experimental fusion reactor, the International Thermonuclear Experimental Reactor (ITER).

[The conceptual design phase, completed in 1990, was an outstanding example of international teamwork that can become a model for other large science projects. By February, 1991, all parties including the U.S. had declared their intention to continue to the engineering design phase at a cost of about $1 billion spread over five years, shared equally among the partners, at about $50 million per year each. If eventually constructed, the device is estimated to cost about $6 billion, again to be shared equally.]

A BALANCED RESEARCH PROGRAM

As fusion has led the way in internationalizing long-term energy research, new international industrial consortia, sometimes partially government-funded, are contributing to the development of a new generation of fission reactors and other energy technologies. Moreover, spurred in part by the global warming issue [and the Mideast War], some governmental leaders in the U.S. and elsewhere are advocating a broad menu of energy research activities. These include innovative technologies to conserve energy as well as new and improved energy supply technologies: advanced nuclear reac-

tors, fusion, geothermal, solar and other renewables, and cleaner, more efficient energy from combustion of coal, oil and natural gas.

A broad-based program for long-term research and development, including demand-side management, supported by the private sector as well as by governments, would give the greatest assurance that adequate generating capacity will be maintained, despite the many uncertainties ahead in the future. The promise of technology improvements to come should help to allay public fears, because they provide the opportunity to phase out the least attractive of today's energy options.

Yet there is a danger if promises become a substitute for action. This is especially true now on the part of those who demand a commitment to stop nuclear power with no clear alternatives in sight. Such a decision could make the likelihood of future electric generating shortages very high indeed.

EDUCATION

After the Second World War, a good many veterans found their service experience led to productive careers in the energy sector. Following the removal of classification barriers from nuclear science and technology, many universities opened departments to respond to the demand for education in this new field. The environmental awakening of the early 1970's and the energy crises that followed attracted many bright young minds into applied science and engineering. But during the 1980's, the decline in support for energy research has contributed to a decrease in student enrollments in science and engineering that has already reached alarming proportions in some countries. In the U.S. the problem has penetrated even to the elementary school level, serving notice that a long recovery period may lie ahead.

At the college level the health of education is closely tied to job availability, and at the graduate level, to support for research. These correlations are easily measured. Thus, it is not accidental that, in the U.S., following a period of strong support for fusion research in the 1970's four out of five DOE Assistant Secretaries for Research have been fusion scientists. The field offered challenges that attracted top students.

THE UNIQUE NATURE OF THE GLOBAL WARMING ISSUE

Students and statesmen alike are attracted to meeting challenges that help their fellow man. In this respect, nothing in recent years has caught the public imagination as vividly as the perceived threat to the world environment by the Greenhouse Effect and global warming. Accordingly, The First 1990

Group on electricity paid special attention to this issue, both to become better informed, and to try to sort out the information and misinformation that impacts policy decisions in energy. For that reason, the chapter that includes Dr. Michael McCracken's update on global warming is a valuable part of this book.

Global warming is closely linked to electricity supply, since CO-2 emitted when fossil fuels are burned to produce electricity is a major contributor to the inventory of man-made Greenhouse gases. The issue is truly global, since worldwide atmospheric conditions disperse CO-2 around the globe and between the northern and southern hemispheres. There is no escaping the consequences of your neighbor's actions.

Moreover, the issue is globally geopolitical! The industrialized nations are now the major generators of CO-2. But it is the developing nations, notably China with its huge population, vast coal resources and little investment capital, and India with its huge population and rising aspirations, that will dominate global emissions twenty years from now and beyond.

The First 1990 Group on Electricity did not discover any magic formula to alleviate global warming, nor could we contribute to reducing the uncertainty in predicting the magnitude or timetable for its effects. We did agree that the global warming issue exacerbates the urgency to develop new alternatives to fossil fuels and to preserve existing options, including nuclear power, that may all prove essential in the future.

SECTION 5

SETTING THE BOUNDS

THE TIME FRAME

Borg: Right at the outset, we need to clarify time scales. What is the time scale we are considering? Are we talking about 2100? About the next fifty years?

Rossin: I would say 20-50 years. We don't need to be totally restrictive. But we're looking for decisions to be made now that will affect the period 20 to 50 years from now. I think that's broad enough that we can probably operate within it.

Stauffer: In looking at the agenda, it seems focussed on technical questions or longer-term forecasts, whereas it strikes me that the problems are financial, economic or perceptual. Insofar as we want to address decisions that might make a difference, we really have to look at decisions that might have to be made in the next year or two. So if we use words that imply long horizons, we would be diluting whatever impact we might have. We really have to focus on something people might listen to because they have to make a decision on it in the next couple of years.

Fowler: Sometimes decisions are required almost immediately that also have long-term impact.

Kaprielian: About 3 years ago, some of us met on this campus and discussed some of these same matters, mostly in terms of how you deal with crises. It sounds to me like we will be discussing here what I would call the very near term, which is 20 to 50 years. That's the near term in the long range scheme of things. I would hope that whatever our recommendations for the very near term are, they would not be in conflict with what are the best interests in the much longer term.

Shapar: It is important that we clarify the time frame, whatever it is, so that our action plan will be comprehensible. I think it is unlikely that we will achieve unanimity or a broad consensus, so I would not take too much time trying to do that. To the extent we approach controversial issues like nuclear power, I would not be diverted from saying that nuclear power should be part of the energy mix simply because in some countries public acceptance is not sufficient to endorse that kind of an approach. If we think it is the right way to go, we should say so.

Li: Your aim is to issue an Action Statement. I think that is very good, and your initial draft is very proper. We must emphasize in the introductory paragraph the importance of adequate electric supply for future development. It is a matter of life, of economic prosperity, and this should be repeatedly emphasized. What do you mean by the future? Now in the place I come from, I will be very frank about it, we don't plan beyond 15 years. We don't! If other countries want to plan for 50 years or the next century, that is a different story. I think we must settle on some sort of definition about the future. Dr. Starr's paper goes to 2060.

Davis: With respect to time frame, we need to talk about decisions that ought to be made essentially now, that is, during the next one, two or three years. We should focus on the things people ought to decide to do now in terms of what's important for electricity in the future. We ought to focus on who ought to do it and what they ought to do. The impact of those decisions depends on what those decisions are and will extend over periods of a decade, two decades or perhaps 50 years. The important thing in coming up with our Action Statement is to try to determine what are the high-priority important things that people ought to do now. That is the time frame from my point of view.

IS *NOW* A UNIQUE OPPORTUNITY FOR ACTION?

Dr. Melvin Gottlieb, now a consultant at Grumman Corp., was a leading fusion scientist at Princeton and Director of the Princeton Plasma Physics Laboratory. He caught the feeling of many that at the beginning of the decade there was a spirit of hope that we could really cut back on war expenditures because of the changes in the Soviet Union. The Berlin Wall had just come down,the East Bloc was opening up, the newly-elected President of Czechoslovakia was coming to the U.S. for a visit, and prospects for a "peace dividend" that might make it possible to invest in long-term environmental improvements and building rational energy infrastructure were on political agendas. Experts talked eagerly of new prospects for the industrialized world helping the developing countries with their financial needs for energy investments.

This is what Dr. Gottlieb said:

"At the present time, it seems to me, the most important and dramatic event of our lifetime is that the danger of a nuclear holocaust is retreating. That is an extremely important element in the lives of every one of us. It's

something that people all over the world are acutely interested in, because it could affect every one of them.

If this is retreating, we now have the luxury to say, let us address the opportunity of improving the lives of people all over the world. A very important element in this would be electric energy. We know very well how important electric energy has been in improving the way of life in this country and other countries can attest to similar experiences.

Therefore, we have an opportunity to look at this in a global sense, in sharing of data on how energy is used, on the environmental aspects, on the economics, on the research and development. We should make use of this opportunity to take a global approach, and organize effectively to help one another in solving these problems. They are very different in different parts of the world; this is true. Nevertheless, we do have a common need and we have much common information that we can use to the betterment of life all over the world.

I think it is on this very positive element that we should proceed, rather than making a declaration that we think nuclear energy is important. That, as a headline, will get you on the last page of the newspaper under Births and Deaths. However, that may be, and perhaps will, be an important consequence of the statements we make."

[The world was hopeful at the beginning of the decade. Scarcely a year elapsed before war devastated the Middle East, but in the same breath it also became clear that the fear of nuclear attack from the Soviet Union that had dominated U.S. defense policy for three decades was changing. The world also learned that utter devastation can be swift without resort to nuclear arms. The window of opportunity for applying major international resources toward solving global energy and environmental problems closed before the year was out. Unfortunately, the most immediate needs now are for rebuilding.]

"GLOBAL" - TWO DEFINITIONS

[As the discussion evolved it became evident that the word "global" was being used in two contexts. One is with regard to global warming. Carbon dioxide in the atmosphere has worldwide (i. e. global) impact, which would be manifested in regional and local changes in climates and geography. The word is also used with reference to problems, policies, initiatives and solutions that apply to all countries, to most countries, or to all countries to some extent.]

Dr. C. Y. Li, Science Advisor to the President of Taiwan, wisely suggested that we had better reach an understanding of what we were talking about:

Li: When I came to this meeting and saw the list of participants — most from the U.S. — I felt that this Seminar will be directed more toward what the U.S. is facing.

I worry about two things: You talk about "global". That is very big. Of course there are problems which are "global". But there are a lot of problems which are not global. So I want to get clear how we are going to deal with global problems and how we are going to deal with regional problems. I think that may be different.

Second: In your draft action statement, you put emphasis on "developing countries". But there are countries which are really neither developed nor developing countries. There are countries in-between. And there are countries that are not even in the developing stage.

So all of this makes me worried. When you issue the action statement, to whom is it aimed? To the U.S. or to *all* countries?

Sanchez-Sierra: I would like to add to Prof. Li's comment. This is a very important and valid point. Our objective has to be on a global basis. This kind of action has to be oriented to a global perspective, not just U.S.-oriented. I think that the problems we have in the power sector, even though they are different by region, are global problems. Most of the problems are totally interrelated, not just from the economic point of view, or from the development point of view, but from the environmental point of view. So that kind of global perspective is crucial for any kind of action statement that we can produce here.

Li: But I still feel that we should subdivide global problems into regional or sub-regional groups, because countries are very different. I come from Asia, and I've worked in Asia for a long time. I always consider that Asia is not one continent. I divide Asia into three: Pacific Asia and facing the Pacific Ocean, that's one. From Burma onward, including India, Pakistan and Bangladesh, that's another one. Then from Iran onward, that's the Middle East. These three Asias are very different. Culturally they are different, their problems are different. Now the reason I said I am worried about the word "global" is that in the old days we tried to compile statistics for all these countries, grouping them together, and the statistics were most misleading. This is because Pacific Asia progressed very fast. But if you combine those data with India and Pakistan, the whole picture

is distorted. That is why I am concerned when you talk about global statistics.

Blue: I'm CEO of General Atomics, the company that has designed the Modular High-Temperature Gas-cooled Nuclear Reactor, which is intended to be a second-generation solution to the issue of political acceptance of fission power, through providing inherent or meltdown-proof safety. Our company has also been involved for many years in fusion research, and under DOE and Government of Japan sponsorship, we operate one of the two most important magnetic confinement fusion devices in this country.

There is only one valid perspective, and that is a global or worldwide energy perspective. That reality is mandated by the fact that global environmental degradation does not respect national boundaries. But more importantly, as Ken Davis has suggested, from an economic point of view in terms of economic growth and world electric power generation requirements, the action is out there in the rest of the world, where the U.S. will play a relatively minor role in terms of percentage of requirements. There's no question, therefore, what perspective is indicated when we attempt to develop an Action Statement and attempt to develop some useful conclusions from this session.

I might specifically suggest when describing this conference some alternative language.I would suggest calling this the "Berkeley Seminar on Global Electric Power Requirements". The suggestion of using Berkeley is not only that this is the site of the Seminar, but also it imparts some measure of identity and recognition. The word global imparts the significance of a global perspective and focus on the purpose of the conference.

Rossin: In drafting material it became obvious that some kind of shorthand to identify regions or groups of countries was very difficult to find a satisfactory word for. I used the word "developing" as contrasted to "industrialized". Prof. Li's point is right on target. It is not a good term to use. It is not very accurate, and yet I do not have a better way to do it.

Sudarsono: It is difficult to categorize all the developing countries into one, because of the variety of the states of development. But we are all in one boat, so we have to deal with certain global problems. We here are looking at 10-20 years. The problem is how societies deal with long-term energy supplies and choices. In most developing countries, energy is

being dealt with by government enterprises. Indeed, the problems are very different, but the financial problems cited in Latin America are also severe in the Pacific.

The problem should be relatively simple; a technical one of design, planning and financing. But is has become complex since the 1960's and 70's because of the incorporation of environmental considerations and public acceptance. Now the media, which of course should not have a decisive role in any country, does have the key role of determining the public perceptions and public points of view, and this impacts the positions of the politicians who participate in the decisionmaking process. Because of all these complexities, making decisions is becoming very difficult in advanced countries. So this is the problem that societies are facing: how to be democratic and at the same time how to resolve the issues in an acceptable manner, and to make decisions which would be acceptable to everybody for the long term. The problem is how do we educate the public in general, going into all the issues, even nuclear energy and global warming. The problem is essentially non-technical, so we should be looking for solutions that are non-technical in nature.

Borg: We haven't even mentioned it yet, but all of the problems we are here to address are really driven by a population problem which varies in its severity from one end of the world to the other. It is something that can't be forgotten. It's basically going to drive the demand in various parts of the world, and is ultimately going to determine what remaining fuels are left to utilize.

SECTION 6

GLOBAL PROJECTIONS OF ENERGY DEMAND AND SUPPLY

Projections of global electricity demand and how it may be supplied provide an envelope of conditions that could occur over the coming decades. No one claims that projections will come true. They serve as a framework for discussion.

Over the last two years Dr. Chauncey Starr has been carrying out studies of global energy use and impact. Dr. Starr explains what his ground rules were, the results that he and his co-author Milt Searl reached, and how he utilizes the research that he's done. The discussion that follows digs into specific findings, assumptions and philosophies about energy and environment.

Dr. Chauncey Starr:

No matter what I've written, I always have to add some new thoughts. I tried to figure out what the real problem is. With an audience like this, which is very sophisticated, each one of us knows fully the answers to part of the questions and generally knows the answers to most of the questions.

What I'm really talking about is a market analysis for global electricity supply: Who wants it? When do they want it? And what will they buy? And what will be the impact of these decisions on a particular global environmental variable: carbon dioxide emissions.

The issue of the timescale doesn't bother me at all. The decisions are made in the short term. The implementation takes another decade or two, and the integration into the energy system takes two, three, four decades after that. You're talking about the whole spectrum of times.

Looking back in time, in the U.S. there once was free competition between electricity generators and coal suppliers and oil suppliers and gas suppliers. Gradually, regulation became a basic factor in energy supply. One can have regulated industries in what is basically a free-market economy. But a society that is based on and believes in free-market competition has a completely different approach than the society that believes in political goal-setting. We have the latter now in this country.

What's political goal-setting? Political goal-setting is where institutions at the top say that the institutions of the country are going to do certain things. For example, use our natural resources efficiently. That's a political goal. If you left it up to the free market, market competition would determine how the natural resources get used. But if you say a political goal is resource efficiency, and then you start putting in subsidies and taxes and legal constraints, that is political goal-setting. The rules that we are setting up with our new Clean Air Act are clearly political goal-setting.

Free market competition isn't going to take care of that one. If we want to enhance the standard of living globally, by various international agreements, like, for instance, the agreement on chlorofluorocarbons, that's political goal-setting. Now, that one has particular significance, because to have global political goal-setting, you have to have global institutions with the authority to override national sovereignty. I want to make this point, because the internationalizing, the globalizing, of environmental issues implies globalization of government in a subtle and hidden way.

But the essence of what I'm going to show you is that the underdeveloped part of the world is going to be determining the environmental future 50 years from now.

The following report was prepared by Dr. Chauncey Starr and Milton Searl, and was presented to the Seminar as a major address:

GLOBAL ENERGY, ELECTRICITY FUTURES AND CLIMATE CHANGE

At present, 3/4 of the world's annual energy production is used by the industrially developed nations (OECD, U.S.S.R., Eastern Europe), and the United States consumes about 1/3 of this, or 1/4 of the global total(1). The projection described in this study shows that by the middle of the next century today's underdeveloped nations will be using about 1/2 of the world's energy, and the U.S. portion will be roughly 1/6 of the world's total. Thus, improving U.S. energy use may have only modest influence on global energy demand and global climate. Nevertheless, U.S. policy and performance will be important as a guide to other nations and to the underdeveloped world on the economic feasibility of improved energy systems with minimal global environmental effect. The future effect of U.S. energy choices on global climate must therefore be viewed in the context of a projected global energy mix.

Energy systems, both supply and consumer end-use, take a long time to

change. The effect on energy demand of a change in consumer life-style shows up in a decade or so. Improved end-use system replacement takes two decades or more to be effective. And it takes anywhere from 30 to 50 years for the capital equipment in energy supply systems to be replaced. Thus a half-century perspective is a useful framework in which to consider current options and decisions in the energy field.

We have also observed that during a half-century many societal goals shift, particularly with respect to economic growth and the quality of life. As an example of new social goals for our energy systems, the recent concern with a global climate change arising from the Greenhouse Effect has stimulated a reexamination of fossil fuels and their emission of carbon dioxide, and climate change now competes with economics for national attention. Further, while new and improved energy options may be forthcoming in the next half century, because of the long time lag for producing substantial changes, we will be depending chiefly on today's known energy options during the coming half-century to meet these future goals.

Regardless of whether the global climate threat is eventually determined to be serious or not, some current technological trends should be encouraged. Certainly, improved efficiency in our conversion of primary energy sources into end-uses is desirable. Efficiency improvements have generally been driven by cost factors and are continuing. Certainly the wasteful end-uses of energy should be discouraged. And R&D on improved technologies should be encouraged to provide a range of options.

What is uncertain is whether governments should interfere with the competitive development of technologies and their economic use in order to favor those options whose emission of CO_2 is likely to be less, such as the group of non-fossil energy sources called "renewables." Non-hydro renewables (solar, geothermal, wind, biomass) have many decades of small-scale experience, and have made some commercial entry into specialized niches where their economics are suitable. (They now contribute about 0.04% of U.S. electricity.) The open question is the degree to which this group should be subsidized in view of the anticipated consequences of a future global climate change. A parallel issue is whether the use of conventional fossil fuels should be discouraged by constraints placed on the total amount of regional CO_2. Fossil fuels are the principal support of economic growth worldwide. Stopping pollution by stopping economic growth is not a popular solution, particularly in the underdeveloped regions of the world where poverty is the greatest social pollutant. In order to provide a rough framework for considering these questions, and global climate change in

particular, this study presents a rough projection of the likely range of global energy and electricity futures (demand and supply) through the middle of the 21st century.

GLOBAL DEMAND

The factors that will have the largest influence on global demand are:

(1) population growth,
(2) economic growth,
(3) improvement in efficiency of energy use, and
(4) advent of improved technologies.

In view of the uncertainties associated with long-term trends for each of these factors, a half-century projection must be perceived as a framework for thought, rather than a prediction. However, energy history shows that the continuation of present trends provides a plausible base case for considering future scenarios.

The historical impact of new technology is clearly illustrated in Figure 6.1, which shows how the move to electrification in 1910-1920 altered the energy/GNP growth rate in the United States(2). Prior to this, the wood and coal-fired steam engine provided the muscle for the economy. The 19th century growth of U.S. heavy industry based on these fuels gave rise to the rapid increase of the energy/GNP ratio prior to 1910. After 1910, electricity and the electric motor radically altered all systems of production and improved the efficient use of all resources, as shown by the subsequent decrease in the energy/GNP ratio(3). Electrification continues to reduce this ratio. Electrification is clearly an imperative for the future industrial growth all nations.

In the complex of economic output, a rough encompassing parameter is the gross national product (GNP) of a society. Figures 6.2 and 6.3 show the U.S. historical relation of total energy versus GNP, and electricity versus GNP. The patterns are not the same. A close look at the energy data in Figure 6.2 for the past decade shows that large discontinuities developed in this relationship in 1973 and 1979 in response to the two oil-price shocks. Energy consumers reacted to higher-priced energy by either reducing consumption or using energy sources more efficiently. This was very evident in industrial energy use, and in the heating and cooling of buildings. The history of energy-using devices (e.g., stoves) shows a cost-effective balance between the cost of fuel and the capital investment in improving efficiency of use. As fuel cost increases, more is spent on efficiency improvement. Based on the use of best available technologies, the likely

Figure 6.1

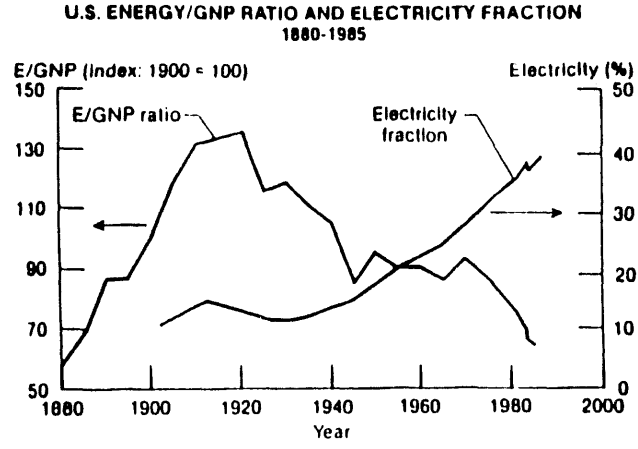
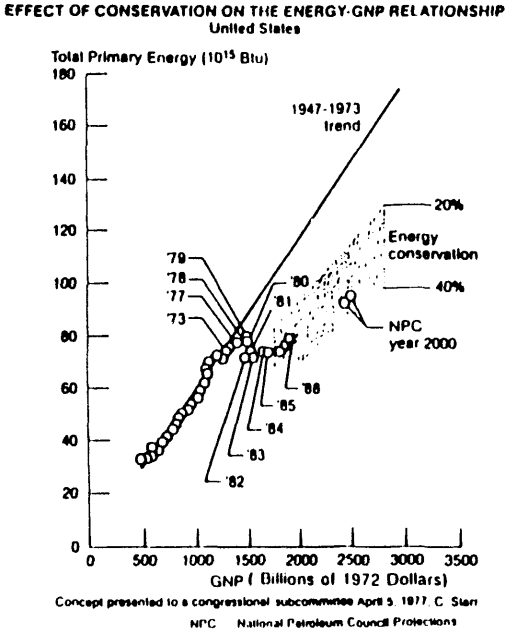


Figure 6.2



potential for such future conservation by improved efficiency is shown by the trapezoid area(4) of Figure 6.2. Unlike U.S. primary energy use, electricity use, and thus the electricity fraction, continued to increase during all this oil-shock period, as evident from Figure 6.3. The likely potential for improved efficiency in electricity use is also illustrated by the trapezoid in Figure 6.3.

The strong connection between GNP and electricity use has been found in every industrial country where data have been available(5). The aggregate worldwide electricity-GNP data are shown in Figure 6.4. The slope in some countries has been altered by a major shift in national energy patterns: positively by the French stimulus to electrification from low-cost nuclear power, or negatively by the U.K. development of low-cost North Sea gas. The net slope has always been positive.

The world's future population is very uncertain because of constantly changing demographic factors. Figure 6.5 illustrates the range of projections by the United Nations(6), the Worldwatch Institute, and present trends. The base case assumed for this study is shown in Figure 6.6 in more detail. It is evident that the less developed countries will be the chief source of global population growth. This is a crucial parameter worthy of much policy consideration.

With these historical relationships as a guide, a synthesis of these individual projections provides the base case global energy and electricity projections to the middle of the 21st century. The base case assumed the continuation of the present trends for the per capita growth rate in energy and electricity. The period 1983-1986 was used to establish the energy growth trend of 1.1% per year for energy per capita, and the period 1973-1986 was used to establish a growth of 1.75% per year for electricity per capita. Multiplying by the population projection, total energy and electricity demand can be estimated to provide a base trend case.

Three cases were considered:

(1) continuation of the present growth rates, (the base case as given above);
(2) a "full conservation" case, described below; and
(3) a zero growth in energy and electricity per capita.

We believe these provide upper- and lower-bound perspectives. The "full conservation" case assumes that direct energy use is reduced to 1/2 of the present trend value and electricity use reduced to 2/3 of the present trend value, both of which already incorporate post-1973 conservation achieve-

Figure 6.3 **EFFECT OF CONSERVATION ON THE ELECTRICITY-GNP RELATIONSHIP**
United States

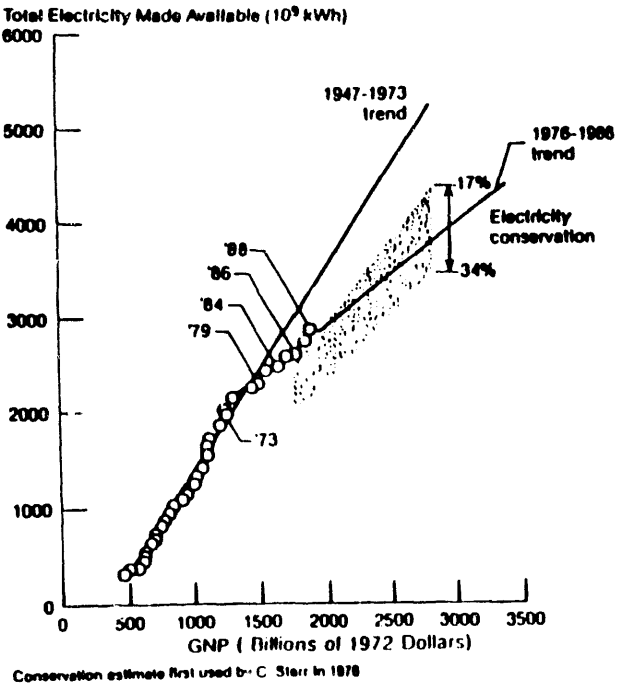


Figure 6.4 **GROSS PRODUCT VS KILOWATT HOURS**
1960-1986

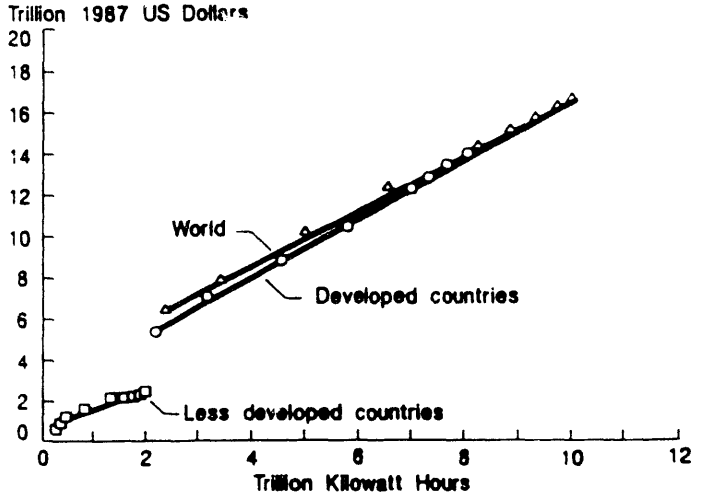


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Figure 6.5

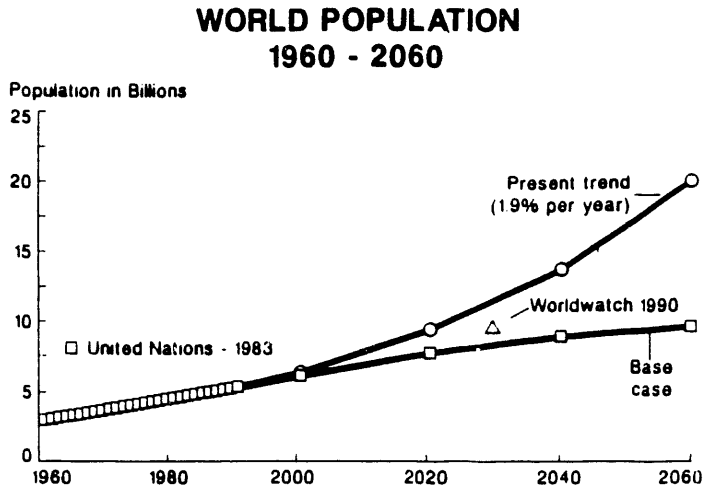
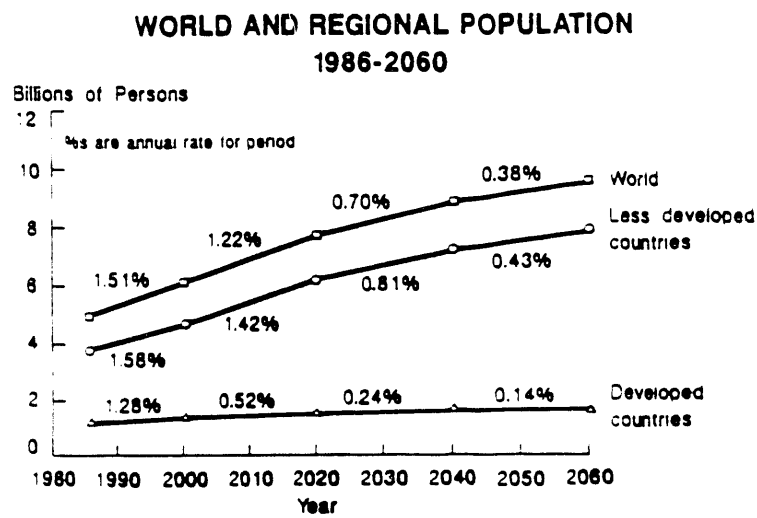


Figure 6.6



ments of about 25% for total energy and 10% for electricity. Direct energy use is that portion of primary energy applied to end uses that does not involve an electrification intermediate. These assumptions are based on the previous estimates of a reasonable maximum for total conservation (Figures 6.2 and 6.3).

The range of global total energy projections for 2060 are shown in Figure 6.7. For purposes of comparison, the energy-GNP trend from 1960-1973 provides the highest projection; the 1983-1986 per capita energy trend projection is consistent with a 25% embedded conservation from this earlier trend, and is equivalent to a 1.1% per capita growth rate. The 1.1% per capita growth rate is our estimate of the present trend, and is our base case. Then follows, in Figure 6.7, the full conservation estimate for 2060, and finally the zero per capita growth estimate. The latter three cases are shown in Figure 6.8 for both the Developed Countries (DCs) and the Less Developed Countries (LDCs).

The results are startling for year 2060 energy demand: an increase of 4.4 times 1986 levels with present trend; 2.5 times with full conservation; and 1.5 times with zero per capita growth. The less developed regions show the largest total growth, mostly because of their greater population increase. The implications for the future and the growth of global fossil fuel emissions are obvious.

The electricity projections are even more startling. Because of the higher per capita growth rate of electrification worldwide, the total increase is greater than for energy, as shown in Figure 6.9. For the year 2060, present trends result in a 7 times increase in electricity demand; with full conservation this is reduced to a 4.7 times increase; and with zero per capita growth, it is reduced to 1.6 times the 1986 global demand. As shown in Figure 6.10, the implied annual electricity growth rates for each case are higher for the LDCs than for the DCs, primarily because of their higher population growth rate.

The LDCs now use 20% of the world's electricity, and in the year 2060 are projected to use 46%. As shown in Figure 6.11, the global fraction of primary energy being used for electricity generation increases from a present 33% to 52% in the year 2060 for the full conservation case.

GLOBAL ELECTRICITY SUPPLY

Where can all this electricity come from? We have speculated on the maximum contribution from the non-hydro renewables, and the results are shown in Figure 6.12 for solar and Figure 6.13 for biomass. Solar is a surrogate which also includes geothermal and wind, as they are likely to be

Figure 6.7

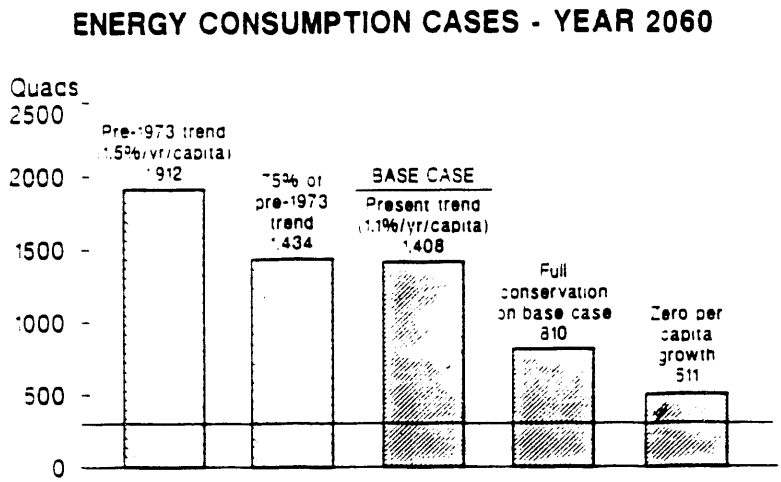


Figure 6.8

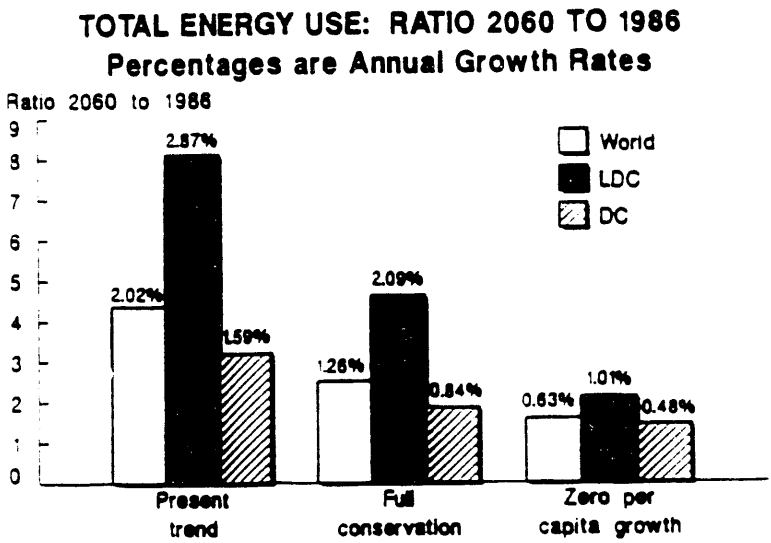


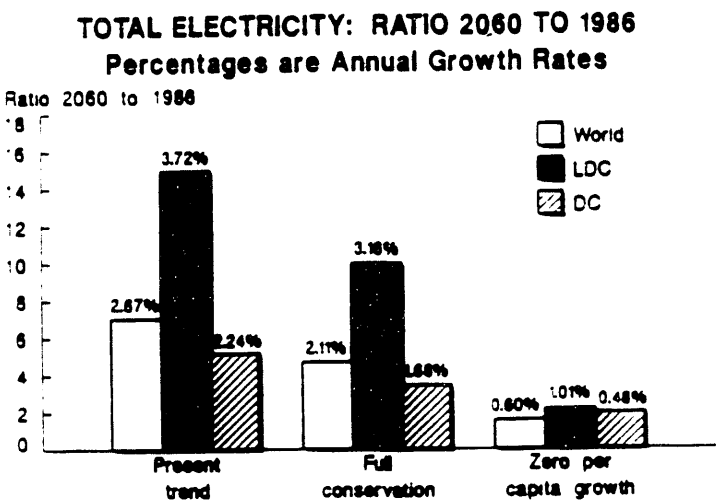
Figure 6.9

ELECTRICITY DEMAND

	Year 2060			
	Actual 1986	*Trend*	*Full Conservation*	*Zero per Capita Growth*
Electricity (kWh/capita)				
LDCs	500	3,590	2,390	500
DCs	6,850	24,730	16,480	6,850
World*	2,010	7,240	4,830	1,600
Total kWh (trillions)				
LDCs	2	29	19	4
DCs	8	41	28	12
World*	10	70	47	16

*Population weighted average of less developed countries (LDCs) and developed countries (DCs)

Figure 6.10



relatively small. As explained in Figure 6.12, a reasonable upper limit for the solar electricity contribution is the peak portion of the daily load, roughly about one-third the operationally available capacity. Such a massive solar component is unlikely to be approached for many practical reasons in the foreseeable future. The biomass estimate in Figure 6.13 is also an upper limit estimate, achievable only if land and water availability can accommodate to global food supply needs. It appears that, with full conservation, these non-hydro renewables might be able to contribute about one-third of the world's needs as a practical maximum, as discussed below. The remainder will come from fossil fuels, hydro, and nuclear.

Figure 6.14 presents the full conservation electricity projection with two arbitrarily chosen illustrative cases for the year 2060. The first case assumes that fossil fuel and hydro are fixed at about present levels, and that solar and biomass are developed to their maximum. Nuclear power expansion provides the remainder. In the second case, fossil and hydro sources grow to share equally with nuclear the demand not supplied by solar and biomass. This second case is probably more representative of the direction that the global energy mix will take. The pragmatic and economic difficulties of expanding solar, biomass and nuclear sources to the massive quantities shown in Figure 6.14 will be so great that a major expansion of the fossil fuel component beyond that shown appears unavoidable.

SIGNIFICANCE FOR CO_2 EMISSIONS

The pragmatic significance of these projections for the issue of global climate change is that for the next half century annual CO_2 emissions are likely to increase, even with an intensive global program on conservation and non-fossil sources. This is primarily a consequence of the foreseeable global population growth and the common desire for an improved scale-of-living. The economic issue is illustrated in Figure 6.15 which shows our base case projections of the per capita energy use in the United States (a developed region), and South Asia (an underdeveloped region). The disparity between an industrial country like the United States and the underdeveloped regions such as South Asia is now more than thirty-fold in per capita use of energy. This emphasizes the motivation that the underdeveloped countries have to increase energy intensive productivity so as to approach the present scale-of-living of the major industrial nations.

Thus, the combination of their high population growth and probable economic growth will make the LDCs substantial contributors to global CO_2 by the year 2060. This is evidenced by the past growth rate of their CO_2

Figure 6.11

YEAR 2060 ENERGY & ELECTRICITY SUPPLY
Trend & Full Conservation Cases
(primary energy input in quads)

	Non-Electric	Electric	Total	Percent Electric
1986 Base	216	105	321	33%
Trend Case				
2060	773	635	1408	45%
Full Conservation Case				
2060	387	423	810	52%

Figure 6.12

Maximum Solar Electricity in 2060

- Typical electrical load patterns consists of base, intermediate, and peak loads.
- Assume solar supplies peak with roughly 1/3 of available capacity.
- Assume a high diurnal availability of 29%

Then: Solar electricity output is 12.7% of the total.

Global contribution is 0.127 x 47000 Twhr = 6000 Twhr.

Figure 6.13

Biomass Potential

DRY MASS YIELD PER ACRE PER YEAR ESTIMATES FOR LARGE SCALE COMMERCIAL PRODUCTION - BASED ON EMPIRICAL DATA

United States		*1990*	*2060*
Dry mass yield (tons per managed acre per year)		6	12
Per ton energy content	(gigajoules)	16.4	
Energy per acre per year	(gigajoules)	98	197
Biomass Electricity Potential: 5.45% of land area			
United States estimate 124 million acres converted at 35% efficiency	(trillion kWh)	1.2	2.4
Global estimate 575 million acres converted at 35% efficiency	(trillion kWh)	5.5	11.0

Figure 6.14

YEAR 2060 WORLD ELECTRICITY SUPPLY

Full conservation case:

- Limited fossil and hydro
- Maximum solar and biomass

(1000 TWhr)

Year	*Total Electricity*	*Fossil and Hydro*	*Maximum Solar*	*Maximum Biomass*	*Nuclear*
1986	10.0	8.4	--	--	1.6
2060					
	• Fossil fuel and hydro at 1986 level				
	47	8	6	11	22
	• Fossil fuel and hydro = nuclear				
	47	15	6	11	15

emissions since 1973, as shown in Figure 6.16. The industrial world, represented by the OECD nations, had no growth in CO_2 emissions since 1973 due to price-induced conservation and nuclear-generated electricity. The U.S.S.R. and Eastern Europe have had a 2% per year increase in emissions, and the rest of the world had a 4% per year growth rate. Because the OECD nations represent about 75% of current energy consumption, the world's average increase is about 1% per year. It is evident the LDCs will be an increasing factor in future greenhouse emission sources.

Projecting the CO_2 emissions to the year 2060 involves so many uncertainties that it is useful to present the spectrum of outcomes provided by our various energy estimates. These are shown in Figure 6.17 for three illustrative cases:

(1) a fossil fuel base trend case with nuclear fixed at present level, maximum hydro, and no other renewables;
(2) full conservation case with maximum renewables and with a low nuclear component, and
(3) full conservation with a high nuclear component and a smaller fossil share.

The projections are given for the world, the DCs, and the LDCs. In all three cases, the hydro component was taken as an estimated global maximum of four times the 1986 level. For the year 2060 the hydro was arbitrarily divided equally between the DCs and the LDCs. The non-hydro renewables were assumed to be at a maximum level for the two full conservation cases and divided in proportion to their electricity use. It was also arbitrarily assumed (as a limiting case) that none of the LDCs would have new nuclear sources because of their foreseeably limited capital. The resulting fossil fuel use was converted to carbon equivalent and compared with 5.5 gigatons of carbon emitted in 1986. The ratio is shown for each case, and for the DCs and the LDCs. The conversion ratio of 0.2 gigatons of carbon per quad of fossil energy assumes the current mix of coal, oil, and gas.

These estimates show the benefit and limitations of pursuing the target of full conservation and the development of non-fossil sources. In none of the cases was the annual global CO_2 emission less than the 1986 value. Even the most extreme target of full conservation, maximum renewables, and a high nuclear component (13 times present levels), projects an annual carbon emission 160% of present values. It is interesting that this extreme case does show the Developed Countries' contribution at 80% of their present emissions, but this is overwhelmed by the 370% increase in CO_2 from the Less

Figure 6.15

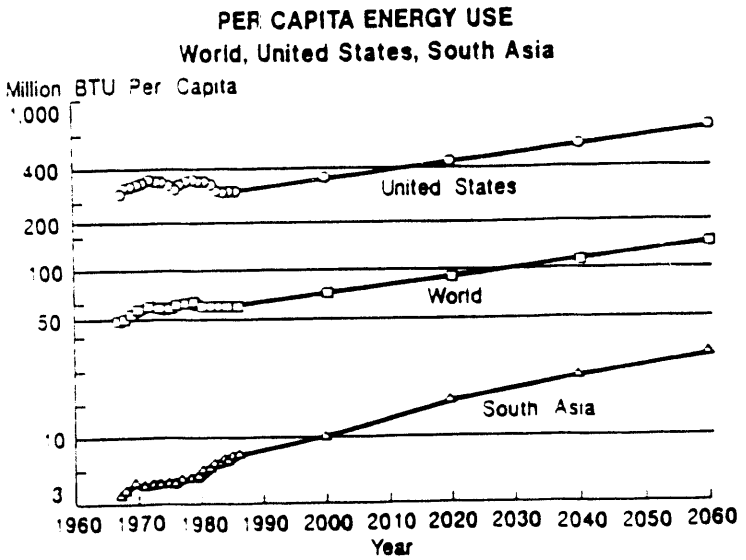
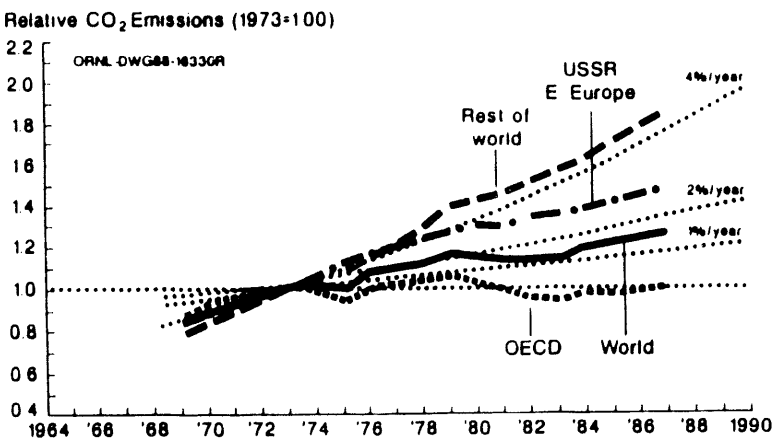


Figure 6.16



Developed Countries. While these example projections are clearly not predictions, they do provide a perception of the relative importance of the factors that will determine future global CO_2 emissions.

Although this study has focussed on the feasibility of carbon emission reduction, as determined by growth in both population and economy related energy use, it also provides some insight to the effect of a drastic curtailment of energy use. It can be shown from the tabulation in Figure 6.18, that with zero energy per capita growth globally, by the year 2060 global energy use would be about 36% of the projected trend case. The average per capita GNP for the LDCs would be reduced about 10% and the DCs reduced 6% from their 1986 levels; the weighted global average would be down about 27%. In such an impoverished world, it is unlikely that substantial investments in energy efficiency would be made, so we have not speculated on further reduction of carbon emissions by this means. If the energy mix of the base trend case remains, the year 2060 carbon emission would be 1.8 times the 1986 level even for the case of zero energy increase per capita.

As the LDC's appear to be the principal source of carbon emission increases, such a projected economic plight would have serious consequences both environmentally and sociologically. A more likely future for the LDC's is a combination of some economic growth and some energy conservation. Assuming that there would be strong resistance to reducing the present scale-of-living in both the LDC's and DC's, the application of conservation measures and associated investments is likely to be dependent on some economic growth. There does not appear to be feasible intermediate mix which would prevent carbon emissions from increasing. Even our high economic growth case (2.3% per year) with full conservation showed a substantial increase in annual carbon emissions.

The sequestering of CO_2 from the atmosphere by capture in new forest growth is frequently suggested as a means of reducing the greenhouse effect. The projected year 2060 maximum biomass potential of 99 quads (Figure 6.17) is about a third of the total present fossil fuel usage of about 300 quads. Thus, if new forests are grown primarily for capturing CO_2 (instead of for fuel), the amount sequestered would be about a third of present CO_2 emissions—and about a fifth of the projected fossil fuel use in 2060 in the full conservation case. This is certainly a significant annual reduction in CO_2 emissions, but it requires that the annual production of biomass is stored long-term (century) in wood construction, paper, etc. The energy deficit would then need to be filled by the other non-fossil alternatives (probably nuclear) if emission reduction is sought. Such a biomass sequestering

Figure 6.17

ENERGY CASES FOR YEAR 2060 CO_2 ANALYSIS

Energy Source	Annual energy in quads per year World	DCs	LDCs
Base case (nuclear at 1986 level, maximum hydro, no other renewables)			
Fossil*	1,365	753	612
Hydro**	28	14	14
Nuclear	15	15	0
Solar	0	0	0
Biomass	0	0	0
Total energy	1,408	782	626
Gigatons of carbon***	27.3	15.1	12.2
Ratio of Carbon to 1986	5.0	3.8	8.1
Full conservation cases with maximum renewables (solar and biomass allocated between the DCs and the LDCs in proportion to their electricity production)			
Low nuclear power version:			
Fossil*	494	214	280
Hydro**	28	14	14
Maximum solar	54	32	22
Maximum biomass	99	59	40
Low nuclear	135	135	0
Total energy	810	454	356
Gigatons of carbon***	9.9	4.3	5.6
Ratio of Carbon to 1986	1.8	1.1	3.7
High nuclear power version: (same as above except for nuclear and fossil)			
Fossil*	431	151	280
Hydro**	28	14	14
Maximum solar	54	32	22
Maximum biomass	99	59	40
High nuclear	198	198	0
Total energy	810	454	356
Gigatons of carbon***	8.6	3.0	5.6
Ratio of Carbon to 1986	1.6	0.8	3.7

*The fossil component includes input to electricity production, transportation, and all other consumption of coal, oil, and gas.

**World hydro maximum is about 4 times 1986 level; year 2060 hydro divided equal the DCs and the LDCs.

***Carbon calculated at 1986 ratio of 0.02 gigatons per quad of fossil energy consumed carbon in 1986 was 5.5 gigatons, with the DCs producing 4.0 and the LDCs 1.5

Figure 6.18

COMPARISON OF YEAR 2060 VALUES FOR VARIOUS CASES

	Actual 1986	Year 2060 Trend	Full Conservation	Zero per Capita Growth
Population (billions):				
World	4.967	9.686	9.686	9.686
Less developed countries	3.793	8.012	8.012	8.012
Developed countries	1.174	1.674	1.674	1.674
Population (percent):				
World	100.00	100.00	100.00	100.00
Less developed countries	76.36	82.72	82.72	82.72
Developed countries	23.64	17.28	17.28	17.28
Per capita energy (million Btu):				
World	64.7	145.3	83.6	52.7
Less developed countries	20.3	78.1	44.5	20.3
Developed countries	208.0	467.3	270.9	208.0
Total energy (quads):				
World	321.3	1,407.8	809.7	510.8
Less developed countries	77.1	625.5	356.1	162.6
Developed countries	244.2	782.3	453.6	348.2
Electricity (kWh/capita):				
World	2,005.6	7,240.9	4,826.8	1,602.4
Less developed countries	505.0	3,587.1	2,391.8	505.9
Developed countries	6,850.1	24,731.1	16,481.5	6,850.1
Total kWh (trillions):				
World	9.96	70.14	46.75	15.52
Less developed countries	1.92	28.74	19.16	4.05
Developed countries	8.04	41.40	27.59	11.47
Heat rate (kiloBtu/kWh)	10,500	9,054	9,054	10,500
Electric input (quads):				
World	104.6	635.0	423.3	163.0
Less developed countries	20.2	260.2	173.5	42.6
Developed countries	84.4	374.8	249.8	120.4
Electricity (% of total energy):				
World	32.55	45.11	52.28	31.90
Less developed countries	26.13	41.60	48.71	26.17
Developed countries	34.58	47.91	55.08	34.58
Gross world product billion US $1987)				
World	16,600	90,595	90,595	23,484
Less developed countries	2,438	28,962	28,962	4,603
Developed countries	14,162	61,633	61,633	18,881

program would be a valuable, even if partial contribution to CO_2 reduction.

Extreme hypothetical technical solutions are not practical options. For example, while a theoretical combination of solar conversion with massive storage facilities could speculatively supply global needs, it is not economically feasible, as the foreseeable cost barrier is so enormous: about 20 or more times alternative options. This would consume the bulk of the worlds' capital resources.

Expanding the nuclear option is also theoretically unlimited, technically feasible, and now marginally economic, but this requires a global expansion of about 30 times present nuclear generation for all electricity supply, and it would need to start soon. This would contemplate roughly 15,000 nuclear stations (1,000 MW each) worldwide, and a massive global fuel cycle infrastructure servicing such stations. Such an expansion appears pragmatically and politically unrealistic in the foreseeable time scale, particularly for the Less Developed Countries.

In view of all the uncertainties, it is obviously wise to seek improved efficiency and conservation worldwide, and encourage the development of solar, biomass, hydro, and nuclear. Such steps may buy us a few more years to learn more about the potential global climate change and to accommodate effectively to it. In the meanwhile, we should recognize that the economic and population growth of the underdeveloped and less developed regions will be the chief determining factors in future energy demand growth and its consequences. The industrial world's role may be most important as a model for efficient energy use.

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DISCUSSION

Question: What was your assumption about population?

Starr: The bottom line is that the energy input into any population (it could be the global population) depends on population growth, the change of the standard of living of that population, and the change of the energy intensity.

Now this is very important, because if I have to bring in a principle character, and I'm not trying to make any religious implications, but if I had to bring in a principle character to be involved in world energy planning, I would bring in the Pope. I'm serious about that. He should have been invited. Incidentally, some decades or so ago, I attended a Papal Academy Issue on Energy, and the Pope isn't uninformed in terms of the literature. I don't know whether he read the report, but the fact is that population is one of the biggest driving forces on energy and environmental impact. Because regardless of economic level, it's been very difficult to manage family planning. You and I, and my wife and children, see on TV all these starving babies in Ethiopia and other nations. It's heart-rending.

You keep wondering why they keep having more children in the numbers they do under those circumstances. Whatever the driving force is that keeps the population going, it certainly is a serious issue. In fact, family planning is, I think, a bigger issue than global warming, energy supply or anything else. The fact that the issue of family planning gets so little coverage is, to me, one of the great tragedies of public communication, because that's the driving force.

For our analysis we have taken the accepted compromise between the World Energy Council and the UN projections on population out to the year 2060. We picked the year 2060 because that's as far as they had numbers.

The difficulty is that even with a slowdown in the less developed countries, the population of the world is pretty well dominated by them. In fact, if this continues to be so, we're going to end up, depending on what you want to believe, with somewhere between 8 and 9 billion people in the year 2060. That's not quite double where we are, but the less developed countries will certainly be the biggest population group.

The developed country problem is fairly easy. We have a situation, for example, in a country like France, where the population has changed only very slowly. So, the developed countries are not the issue. Family size control in the United States is an inevitable social development. Our population growth has already been primarily by immigration. I think that's going to be true in all the industrial countries. The issue is the less developed countries, and the reason is that their economic future is the one that's going to determine what happens to global fuel use and emissions.

Borg: You've made a pretty strong assumption about the relationship between energy and standard of living. Do you believe it will remain so?

Starr: This is a political problem. There isn't an economy anywhere in the world that doesn't want to improve the standard of living. If you listen to economists talk about the U.S., they're grumbling about the fact that the GNP is going to go up only 1 or 2 percent in the next year and it will hardly keep up with population growth, and so on. The political drive, the cultural drive, in almost every country in the world is to improve the standard of living.

There's a good reason for this. The standard of living includes a lot of things. If you don't produce excess wealth, you can't improve health, you can't improve sewage disposal, you can't improve cleaning the streets, keeping the whole infrastructure of roads, and of course, education. These all require continuous investment. And you have to have excess wealth production to do that. This controls the standard of living. This is a driving force.

Energy intensity is where the technology comes in. It's only in this part that technocrats, like myself, play a real role. Because it's in this part that, in fact, we can do something about improving energy systems, improving the way they function, improving their use of resources, and reducing their environmental impact. We tend to forget there are two kinds of customers. There's the industry that produces goods and services and there's the end-user: the guy who turns on his TV set or his toaster at his house. It is the industrial technology part of it, the productive system, its

design and management, which is one of the great potential areas for energy improvement.

You can make an enormous difference in the amount of energy you need in industrial processes if you have a very good system for production, design and management. I'm not talking about the basic technology, but the way materials and work hours are used. Inefficiency is a big factor, a big place for improvement.

The end-use operation is what you hear all about in the literature from the environmental movement. The environmental movement rarely talks about this industrial part, which is one of the big energy users. They'll talk about how we ought to have refrigerators that have better insulation or a different cycle, or that our home heating system ought to be different and more efficient and so forth. These are all the end-use examples.

What this says is that as far as economic analysis can show, the economic output of a country follows electricity use closely. Or to put it the other way, electricity use follows economic growth closely. We found this to be true all the way through the period of the big gasoline crises, where the U.S. total energy dropped but electricity use did not drop. It tracked with almost no perturbation the economic output of the U.S. This has happened in every industrial country, and even in the underdeveloped parts of the world.

The other thing is that, assuming this is correct, simple mathematics says that the change in standard of living in any country or any social group will really be dependent on the change of electricity per capita. That's just an assumption, but it is based on the observation that those two lines roughly track each other. This is important, because we assume that this will be the electricity per capita growth, and it is based upon economic growth projections for different parts of the world.

Fulkerson: But won't an effective conservation program change that relationship?

Starr: When you plot energy versus economic output, one sees a sharp upward slope up to 1973, then the first oil shock, and then the second in 1979. The energy curve flattened out, and that's when all the environmental groups said we had broken the tie between energy and economic growth. It started up again in the last few years.

In 1977 we finished a study at EPRI on all the things that could be done using modern technology without regard to cost to reduce energy consumption and to reduce electricity consumption. It was published in

a book which is now available in libraries. It's called "Efficient Energy Use", put out by Pergammon Press. Nobody was particularly interested in it. But now it's still the only compendium that shows a cross-section of all the things you can do to conserve energy in a technical sense.

Forty percent was the most savings that they could come up with in total energy consumption. That includes all the building improvements that the enthusiasts are talking about, and a lot of improvements in industry. Twenty percent was the upper-bound guess that the authors made that could be done with reasonable economic investments. If you apply energy conservation without regard to cost but with reasonable expectations of the capital required, you ought to find yourself somewhere in the feasibility range, below the 20% bound.

We have assumed that on a global basis by the year 2060 (which is now 70 years away), 50% of all the direct energy use could be saved, just to set an arbitrary upper bound for discussion purposes. That is substantially higher than either the economic feasibility range or the "technological feasibility at any cost range".

But when you look at the same relationship for electricity vs. GNP, it never dropped, even in the U.S. in 1973. It actually went up! Starting from the projection of the old 1947-73 trend, a projected saving of 34% for electricity was about the most that they could see, using the same type of analysis. One of the key reasons is that much of the end-use equipment is already reasonably efficient. There are improvements, but we are starting from a relatively efficient base.

> At the World Energy Conference in 1990, Amory Lovins stated that the U.S. could save 75% of all the energy it uses and also 75% of all the electricity it uses with no sacrifice in standard of living ("End-Use/Least-Cost Investment Strategies", A. Lovins, 14th Congress of the World Energy Conference, Montreal, Canada, Sept. 18, 1989). Fickett and Gellings of EPRI performed a critical analysis of Lovins' paper, and then the three coauthored an article ("The Potential for Energy Conservation", A. Fickett, C. Gellings and A. Lovins, Scientific American, April, 1990) discussing their areas of agreement and disagreement. The EPRI calculations indicated a theoretical upper limit of about 30% for conservation investments that could break even or better. The required changes in energy use patterns and efficiency would require massive capital investments up front and total penetration of the potential market to achieve the calculated savings. The time required to achieve

projected degrees of penetration in specific areas is not something that can be predicted at this time.

Starr: It turns out the best you can do with all the varieties of conservation, lighting and efficiency improvements and everything else for total energy use is about a third. So, we've assumed for the year 2060 that one-third of all electrical growth by the year 2060 would be saved. We call that the "full conservation case."

The full conservation case assumes that half of the primary energy fuel that would be used, just based on the trends alone, would be saved. That would be a cut of half in fuel burned and a saving of a third of the electricity.

What this means is that the average world energy use would go up close to two and a half times the world energy use per person that we have today. Now, you can see why that's frightening: If we're talking about being worried about the Greenhouse gases, we're up against a terrific problem. If we're going to allow the population of the world to grow, and some economic growth to occur, the resulting economic growth is very small: between one and two percent in the per capita energy growth per year.

We also calculated an extreme case (Case 3 above) in which we assumed continued population growth but zero economic growth throughout the world, specifically no energy growth per capita from now to 2060. The less-developed countries will end up just a little higher. The world goes down slightly because the total amount of energy used by the less developed countries per capita is less. They're the dominant population.

But I don't believe the world can accept zero economic growth (or zero per capita energy growth) and the zero electricity growth that goes with it. To me, the most informative case is our full conservation case (Case 2 above).

Prof. Lu mentioned the enormous increase in energy demand expected in China. It's a factor of eight over today by 2060 based on the present trend. With our full conservation case assumptions, the total energy increase is still a factor of four.

Blue: What about the possibility that today's LDC's catch up with the industrialized countries?

Starr: I think anyone who studies these issues knows that within the next 50 or 60 years that's not likely to occur. But as long as the developed part of the world continues with its improved life-styles, improved health and

services, it will form a target for the less developed part of the world. The wealthy countries can't go back and tell the less wealthy countries: you can't do this or that because of the global environment, when those very actions opened the way to economic growth.

We've been told in a half-joking way by some of the people we visited in some of the less-developed countries: if environmental pollution is the price we have to pay, you paid it, you got the benefits, now we'll pay it and then get the benefits ourselves. They're not very keen about doing much in the way of sacrifice to reduce environmental pollution.

As a technologist, I think we can achieve much by pushing the conservation issue. Actual figures for 1986 show 500 kW-hr per capita in the less-developed countries; and over 10 times as much in the developed countries. You can see why the developed countries always dominate the world energy use picture. Per capita there's no question about it. We would end up, with the full conservation case, about a five times improvement in the less developed countries. In the developed countries there would be about two times improvement. And for the world as a whole, about a two times improvement.

I said in my paper that we would need all of our options to provide the energy and electricity people will need, even after successful conservation.

Two trillion kW-hr are now being produced in less developed countries, eight in the developed countries. The total for the world is 10. Now if we take the present trend, in other words, we don't invest in massive efficiency improvement, and there is no breakthrough in population control, and hold average per capita energy use constant (Case 3) by 2060 seven times as many kW-hr of electricity will be needed globally. Developed countries will need five times as much, but in the less developed countries the increase would have to be about 15 times as much, simply because of the population growth.

If I take what is to me a more reasonable case (the full conservation case), because I think the economic pressures will be there to do it, I get about 10 times as much electricity in the less developed countries, and about 3-1/2 times in the developed countries. But all together I get about 4-1/2 times more electricity being made in the world than is being made today, and that's with the maximum efficiency that we can get into the systems.

To win acceptance of this analysis, I had to slay two dragons. Dragon number one is, "We're going to do it all with solar." Dragon number two

is "We're going to do it all with biomass." Well, we have a big section at EPRI that works on solar energy, a group of professionals that work closely with the Solar Energy Research Institute. And with biomass, we have a cooperative program, mostly with Oak Ridge, but there are people working on biomass all over. We're enthused about both. They are good adjuncts; we need them; there are places for them; they should be developed. That's not the argument. The argument is how much can they carry?

Here's the problem: The typical load pattern in any electrical system, if you look at a classic example, can be divided into base, intermediate and peak load. Let's arbitrarily make this assumption for the year 2060: that solar is one-third of the installed capacity to provide the peak load. But all of the variable load is not going to be supplied by solar. No solar enthusiast has ever proposed as much as this; so this is an extreme upper limit. Let's just say it can be done. (And frankly, I think it could be done, except for economic realities.)

A high diurnal availability factor is 29%. To convert this to kW-hr I have to average what fraction of the time the solar installations are going to be working, and it is at best 29%. So I have to multiply my capacity by 29% availability factor. The answer: solar electricity can supply a maximum of 12-1/2 percent of the total kW-hr required, or six trillion kW-hr.

So in theory, it could provide one-eighth. Now that is not a trivial number! But it's the upper limit.

Biomass is an absolute delight because we have great opportunities, on an economic basis, for biomass to be used today in terms of the wastes from the forest products industry. It's being done all over now, wherever you can get the forest products producers to sit down and listen. If they take the stuff that they leave behind when they collect the forest materials — if they take the sawdust, the mill filings, and all the waste products, and really make the capital investment for developing their own steam and electricity, it's in their economic interest to do this. And we're seeing it begin gradually throughout the world. It's a good thing and it's going on. But how far can it go?

Biomass energy includes growing forests, or growing agricultural products like sugar cane, specifically for energy purposes. The forest products people are very interested in this because it gives them a second market for forest products. So they've looked at this very carefully. And there's experimental work going on. This is a live field. The figure of

merit is the dry mass yield in tons per managed acre. *Managed!* That is very important. Unmanaged collection is but a fraction of this. Managed acreage can provide 6 tons per year. Agricultural scientists think that by the year 2060, the genetic selection of trees and perhaps some chemicals, will double it.

The biomass electricity optimists who have looked at this say they can take an additional 5-1/2% of the land area in the United States and build in forests which don't now exist. So based on that, they end up with 1.2 trillion kW-hr. This requires putting it into a combustion process with 35% efficiency. And so we go next to the global number. We've assumed the same number: 5-1/2% globally. Frankly, this is a very soft guess: about 5.5 trillion kW-hr/year now and about 11 by the year 2060.

The total electric energy that we calculate we're going to try and produce with the full conservation case is 47 trillion kW-hr (Figure 14 above). We chose two cases:

1) Fossil and hydro are kept at a fixed level. Here we maintain and replace, but do not expand total coal, oil and gas, and expect no significant new hydroelectric power expansion.

2) In this case, we allow this combination to double.

We made optimistic assumptions about how much could come from the combination of solar and biomass. The remainder, if enough electricity is to be available to match the assumptions of the case, has to come from nuclear power.

For the first case nuclear would be 14 times what it is now. And for the second case, it is about ten times as much. That case lets fossil and hydro carry roughly an equal load with nuclear. This is a way of actually bounding the problem. If the electricity we project is to be there, nuclear will have to pick up a large amount. This would necessitate a very different political atmosphere than we have today.

What it says is: we need all the technical virtues that all the people of good spirit are selling. We need to improve the efficiency we use energy with, we certainly shouldn't have wasteful life-styles. We certainly should, in fact, we must, successfully develop solar and biomass. But we're going to need fossil, we're going to need hydro, and we're going to need nuclear.

And finally, we cannot say to the less developed parts of the world that they are not allowed to produce wealth to take care of all their social needs, which we somehow or other seem to take care of ourselves. And that's where I'm going to leave it.

Wilson: Goldemberg of Brazil and Williams of Princeton had an article in Annual Reviews of Energy about three years ago, and their projections of what the world was going to need in electricity were about just about your full conservation measure, and their methods were about the same in trying to figure out what was reasonable in trying to reduce electricity demand.

Zebroski: We can't really talk about projecting or predicting the future, but it seems to me that anything we project even for next year is more robust if it is consistent with a vision for the future which is in the range of feasibility. I think the fact that a number of different people coming from different directions have similar visions for the future makes the visions more robust and strengthens the credibility of what we may project.

Borg: I have problems with using the U.S. as an example of uncoupling the G.N.P. with energy use. The reason is that at just the point when you say they became decoupled was about time when the nature of the G.N.P. began to change dramatically in the U.S. That was when services became far more important than goods in the G.N.P. This has a serious implication when it comes to energy use, because while our standard of living continued to increase, we are beginning to import energy embodied in products. For example, our aluminum is smelted in Canada and our automobiles are made in Japan. The heavy energy intensive industries in the U.S. took a real nosedive in that period. The whole industrial sector was hit very hard by the increase in fuel prices. So I don't see how you can justify that decoupling into a global picture.

Starr: We did not use the U.S. numbers; we used the world numbers. I gave the energy picture in the U.S. to show that there was a big difference between the energy relationship in the U.S. and the electricity relationship. It was the electricity relationship that was a tie. We have curves for both energy and electricity. In the UK, when they discovered gas, the energy relationship dropped, but the electricity relationship did not change. In France, as well. You don't extrapolate energy use, you extrapolate electricity use.

Borg: But in the U.S., that energy drop is related to a whole number of things which have nothing to do with conservation.

Rossin: If we cannot use G.N.P. any more, what is the alternative?

Starr: When you look for large indicators, we have no substitute for G.N.P. You can get a whole lecture on why G.N.P. doesn't even measure G.N.P.! I've been given lectures by my colleague Sam Schurr on why

G.N.P. doesn't really measure true economic output. But you start looking for something else, and you have to spend your lifetime as an economist to find something.

Davis: We're talking about G.N.P. and not G.D.P. G.N.P. fails to take into account the energy we import, so they are not identical measures. Second, what does the economic activity that either index measures actually mean? You include in each a lot of things which are non-productive and do not contribute to the standard of living unless you broaden your definition a whole lot. A great amount of the G.N.P. in the U.S. in recent years has been military activity. Now, we can say that our standard of living is improved because we have a very strong military establishment, but I don't think that's what most people mean by standard of living. So the problem is more complex than it appears. I recently wrote a letter to Murray Weidenbaum and asked him if he could explain all this to me, but he said he couldn't. The confusion between standard of living and G.N.P. is really enormous.

Starr: What this paper does is scope world demand, taking the industrial growth of the developed world and the developing world as two separate parameters. In that sense it doesn't make any difference if cars come out of Japan or the U.S., they are still going to require an energy input.

And again, I have to emphasize, we are not predicting: we are scoping. There is a subtle difference. This is a framework for discussion, a framework that says this is the nature of the problem we have to deal with; these are the rough magnitudes of what we face, and these are the parameters we have to recognize are the ones we can affect. For us to say that we have the answers to what the future is going to be would be ridiculous. I have in my paper pointed out all the things I can do to destroy my projections!

Take an obvious example: the electric automobile. We have been pushing the electric automobile for over a decade at EPRI; it's now a marginal demonstration device. You've heard General Motors come out with a flashy display — they have a little sports car that can go 100 miles between charges. I think that is around the corner. But if the urban communities of the world start using electric automobiles to get rid of their smog problem — and I don't think they have any choice; I think they're going to be doing it — you'll see electricity demand go way up, but you'll see some other demand go down.

These are the kind of things which will change the whole nature of the

energy use pattern. But it's pretty clear that electricity is a basic input to economic growth and the production of electricity is absolutely essential to the productivity of these countries. That is the point which the public really has not accepted. The fact that electricity production has by-products which involve environmental issues: we know that too.

But it is scoping the nature of the problem. I'm trying to say some very simple things: Giving to the environmental movement all the concerns they feel are justified about future environmental impacts, we are not going to be able to reduce fossil fuel consumption in the foreseeable future, meaning the next 50 years. We might be able to reduce the *rate* at which their use increases. But to do that, we would need everything: solar, biomass, and nuclear, and we also need more improved use of fossil fuels.

But to go around and promise to the world that they are going to reduce the carbon dioxide content of the biosphere by imposing on the world all kinds of energy restrictions is either totally dictatorial or dreaming.

Sanchez-Sierra: I would like to give two conclusions from OLADE's energy studies which reinforce Dr. Starr's projections. 1) Even in countries where the G.N.P. has been negative, electricity growth has increased, sometimes by 5-6% per year. The explanation is the "informal economy" which is not in the national data, and 2) in Latin America during the last ten years we are consuming more energy per unit G.N.P. When we put this together, I would call Dr. Starr's projections conservative.

Fulkerson: Do you accept as a foregone conclusion that you can't increase productivity of energy use more than you have to date? China has had a very intensive energy conservation program over the last decade or so. They have found the opposite. Energy use per dollar of G.N.P. has gone down.

Sanchez-Sierra: I don't know about China. But for Latin America, this has been the "lost decade". With very low economic growth, with our energy-intensive industries working at 20% of their capacity, we are now using energy in even more inefficient ways!

SECTION 7

ELECTRICITY AND ENVIRONMENT

The public debate continues about the impacts on the environment of increased generation and use of electricity. Participants brought different views to the Seminar based on their experience, as well as their impressions of views of others with whom they interact. The "statement" occasionally mentioned by Participants became the Findings and Conclusions in Section 2.

Wilson: I think our statement should address the views of a number of other people who want to reduce the amount of electricity use. They wish, in fact, to stop any future electricity expansion. They hope to use reduced capacity as a way of caressing people into using less.

Hubbard: I'm the almost retired Executive Director of the Solar Energy Research Institute. About what people can adjust to: Saturday night I was on a railroad platform in Agra, India, and all the lights went out. My Indian friend said, "No matter. Five, ten minutes, it will all be back on." All the vendors got out their candles, lighted up, and went on cooking Indian bread. It's astounding how resilient society is. I think when we categorize things in terms of imperatives: "We must have this..." or "We must have that...." we have to be careful about that language.

When I first came to the Solar Energy Institute, I use to start out every talk I gave to the public by saying, "Look, the world is not divided into solar freaks and nuclear nuts." I just do not see those technologies in conflict one with the other. There has been a tendency for those of us who are interested in energy technology to be embattled about it, to be advocates or be defensive about it.

I was at that Sundance meeting. (A recent conference at Sundance, Utah, brought together persons with a broad spectrum of views on energy, including leaders of groups dedicated to stopping energy growth. A summary was distributed to the Seminar participants.) It's true that the Sundance meeting concluded in general that nuclear power was a terribly desirable option, and that we ought to have it — not that we must, but that we needed it in terms of an optimal energy system. But in the final statement, there was a codicil added which simply said that until the

public and until the environmental community are convinced that nuclear power technologies are safe and acceptable, it will be futile to advocate that they be re-utilized in this country.

Now I don't think it's quite that bad, but I think we have to be careful about that advocacy. Somebody already said that it is less a technical problem than it is a perceptual, social and political one. I would hope in our statement we can get out of that somewhat antagonistic posture of conflict between efficiency and environment and the need for energy development.

Going back to the meeting in India, which was the Association of Energy Economists, it was pretty clear that what we were talking about was the quality of life. If there is to be adequate quality of life that's generally acceptable in a global context, you've got to have some equitable distribution of resources and an equitable approach to economic issues. You need economic vitality, you do have to have a living environment that people are satisfied with, and you've got to have some political and social stability. I think that the issue of equity and the issue of balance are particularly important. We just cannot afford to get back into the situation where it is the technocrats against the Rousseaunian idealists.

Fulkerson: My responsibilities at ORNL include efficiency technologies, fusion, renewables and fossil energy sources, which is an interesting combination. The dilemma I would propose to the group is: If it turns out that someone must do something aggressive about moving away from fossil fuels, that we are technologically not very well prepared to do it, because the non-fossil sources are not very good, either singly or in combination. It is in that circumstance that efficiency and non-fossil sources are basically partners. You cannot get there without both. Both must be pursued very aggressively. The dilemma is decision-making under great uncertainty.

Furthermore, the decisions that are made by the developing nations in the world will be crucial in regard to this problem. The industrial world is going to have to provide a great deal of help and better technology that will be compatible with economic growth in the developing nations given their particular circumstances and situations. We are all in this together.

Starr: The word "conservation" is going to reappear over and over again, no matter how hard we try. I think it should be clarified so we all have the same idea of what it means. May I suggest my usage: both efficiency and

curtailment. I judge from the notes you supplied to us, that you are using the word in the latter sense, almost throughout. It should include efficiency. Now within the curtailment category, you have both voluntary and involuntary, the latter being the result of regulatory action. But I think we should have a consensus; it would be very helpful. With regard to the term "conservation", we must separate conservation from efficiency.

Borg: Well, they're very difficult to sort apart: the curtailment aspect - voluntary or involuntary or price-driven - from actual improvements in efficiency.

Erdmann: I just finished a study last month of the electricity demand in the service industry at the Swiss Institute of Technology in Zurich, and last year I did a similar study on the newspaper industry. The key point seems to me to be whether there will be another nuclear power plant started. (I personally believe that technically it will be different from what it was before.) Even if this decision is made only in the US, it will have a big global impact. In Switzerland you now find no young engineers who will study nuclear technology, so very soon we will reach the point of no return.

Of course, if the US stimulates a new nuclear power plant, that will have an influence in all the European countries, especially in those where public opinion is strongly against nuclear power. That would have a very big impact. I know it from Switzerland, from Germany, Italy, Sweden, and so on. In other countries in Europe, in France for example, they do not have this problem in which public opinion is against nuclear power. Nevertheless, the US will have a big effect. A decision made in industrial countries to return to nuclear power will have a big global impact in all countries, even those which do not actually use nuclear power or will not use it in the near future. So I think that whether a new nuclear plant or a new generation of nuclear plants can be installed in the future is a global question.

Larrson: Within the Federation of Swedish industries, I tried to work very hard on environmental issues. The environment is very high on the list of the public and also the politicians. We've tried to take a pro-active attitude rather than the reactive one. If we want to have a pro-active industry on the environment, we need to have electricity. We need to have growth in industry and we need to have an electric supply that is reliable.

My objectives in coming here were twofold: First, to try to explain to you what the Swedish situation is. To be quite honest with you, I sometimes have big problems understanding it myself, but I try. Secondly, to try to bring back to the Swedish debate what is happening here. My bottom line is that the environmental issue has brought us to, as you say, "a complete new ball game".

Li: Energy conservation — or the increasing productivity of energy use — is a very important issue in my country. We are not allowed to build any new power stations. What else can we do? We try to save energy. We talk about cogeneration, ice storage, whatever. But we must emphasize,and you have emphasized in one of the papers, that some people have the notion that by saving energy you do not have to build new power stations. And this is completely wrong. We should emphasize this in our action statement, because it is so misleading.

Now, about the environment. I've been thinking that our discussions have not put much emphasis on oil, gas and coal. We cannot avoid them for many years to come. Among fossil fuels some are better than others. For the environment, coal is bad. Why not gas? It is very much in my mind... In my country we are importing very large amounts of coal. And then I start to think, instead of coal, why don't we import large amounts of gas? We are importing anyway. We rely on foreign supply and gas is much cleaner than coal.

I have not made a proposal to my government. But I may suggest to change the coal stations to gas. If not, at least the new plants to be built should burn gas, not coal. I have not made this a proposal; it is very much on my mind, so I will be listening to your comments.

Lu: I agree with Mr. Li that there are great differences between developed and developing countries. However, we have many things in common. For instance, the importance of electricity, and the high rate of electricity growth compared with the rate of energy growth, and also the development of future technologies in power generation.

My impression is that environmental issues are becoming more impacting. But for the developing countries, the first priority is not the environment. Of course environment is an important problem. But our first priority is shortages: the shortage in power, the shortage in energy and the shortage in investment.

For instance, we are now involved in a study to the year 2050 for our state planning commission. From our preliminary results, our electricity

demand will increase at least ten times between now and 2050. How can we develop so many power stations in the next 60 years? Of course, 50 or 60 seems so long, but it is not so long compared with the time scale for energy development. If we turn to new technology for all of these power plants, the lead time for commercialization for any new technology will take at least 50 years.

So we must rely on existing technology. Now that means either fossil fuel-burning power plants or nuclear power plants. We have enormous resources of coal. But coal already causes us problems, not for the CO_2 in the far future, but for the transportation and the local air pollution. So we try to turn from coal to nuclear power, not only for power generation but also for district heating. We just completed a heating reactor at my institute. It is a 5 MW heating reactor following the Russian design, and it has operated very well for the last few months. So we try to turn to nuclear not for the far distant future but for the near-term demand. But unfortunately we find it is very capital-intensive, and we are short of capital. So for a big developing country like ours, the near-term priority problem is the shortage.

Haslip: I think there is a fundamental difference in the challenges of environmentalism that we see in this country today and what we saw in the late 1960's and early 70's. Then, in fact, it was a media-driven issue, and driven by a reasonably small segment of the population that were, at that time, very sensitive to issues like environmentalism. That segment of the population is now senior staff people in regulatory agencies, junior legislators and Congressmen, and in some case they are even executives of utility companies. So it is a much more fundamental issue that is deeper in our social fabric here, and a more substantive movement than it was during that earlier era. And I think that implies a different response from policymakers.

I would also like to comment on the issue of diversity that I think is presented in the draft statement, completely appropriately so. There is a corollary issue to diversity: the implementation of conservation and efficiency may be appropriate for a utility. I am intrigued by those people from developing countries regarding the problem of not having enough electricity. We should find ways to export from industrialized countries our experience about energy use. I think we've learned a lot about how to use electricity and how not to use it. I think it is appropriate to export those lessons learned to avoid mistakes that we've made in industrialized countries.

Cicognani: ENEA is the governmental body of Italy responsible for research and development in the energy field. Generally, ENEA gave a strong contribution to the new energy plan that was adopted by the government and debated by the Parliament in 1989. Environmental protection is supposed to play a major role and our energy plan was established with a specific concern about pollution of the environment, and aiming to limit as far as we can the emissions of chemicals.

We have discussed electrical energy supply with great concern. It is crucial for the country because in the last three years we had an increase in consumption of electric power of the order of 5% per year, and the tendency is even stronger for the next few years. All of our nuclear power stations are now closed. Now only the fossil stations contribute. Of course the hydro power is near to the limit in Italy. Hydro contributes about 25%, and the rest has to be made by fossil fuels. Also we face a lack of installed capacity. Our imports from the North, mostly from France, reached 15%. This is a very weak position for the country, and it is a matter of strong preoccupation for us.

Diversification of primary fuels and minimizing the emissions of chemicals, and also our effort to make nuclear energy acceptable again, are our key problems. We are working on simpler reactors with passive features and strong containments, aiming to avoid evacuating the population after a severe accident. We feel this will be a "must" if we want to gain public acceptance of nuclear energy in Italy.

McConnell: During my 30 years at Ontario Hydro I have had the opportunity to send staff to work with electric utilities in a number of countries throughout the world, including Nigeria, Ghana, Iran and Korea, India, Pakistan, Rumania and Argentina. I have participated in technical exchanges and served as Chairman of the North American Electric Reliability Council. It seems to me that insofar as electricity is concerned, there are many issues that are common to countries throughout the world, but every country has its unique problems as well.

Turning to a narrower front, electricity supply for one province in Canada, we have been engaged in an integrated demand and supply strategy for the electrical supply in Ontario. This was a very intense process that involved massive interaction with the public at large, our customers, politicians, etc. We started off with the idea of doing it in two years but it took us from 1984 to 1988, a full five years to develop a strategy that represented a position for the province having to do with electric efficiency and the role that it would play, as well as the supply

options. We did get it completed. We did reach a consensus among the various interests in the province.

In 1989, after ten years of paralysis in which we had never made a major supply decision, we've just launched a 25-year plan that we've announced. It is just about to go through a public review. It represents a very ambitious plan in terms of demand management. Our plan calls for a 5000 MW program of several billion dollars having to do with electrical efficiency, load shifting and the like. But on the other hand, we don't regard electrical efficiency as the sole solution. And the real discipline in this process was moving away from the generalities, and quantifying all of the options and taking a posture on what the contributions would be from each of the demand options and each of the supply options.

[Of all the specific actions brought to the attention of the Seminar, none won such wide acceptance as integrated resource planning. Hydro's integrated planning process is discussed in Section 9. The achievement of Ontario Hydro in developing this plan was agreed to set an excellent example. But within less than a year, new parliamentary elections brought a new Prime Minister to power in Ontario. He campaigned against the power company, and his first act was to order it to put all supply parts of the plan on hold and to call for a new examination of the issues. Once again, the public skepticism about nuclear power, and also about all big power projects, seemed to make opposition an attractive political posture.]

Zebroski: Most technical problems have their roots in management problems. It is not the technology that is bad; it is the way you use it and how you manage it. We should put what we talk about in light of an enormous historical movement, the reduction in the threat of nuclear holocaust.

Another monumental historical trend here is Peristroika. Peristroika is not just in the Eastern Bloc. It is a by-product of electricity. It is the global community of television and radio that has made the aspirations of people worldwide have a voice and have a sense of world community that was not possible in the past.

We face a global risk in the energy area. Unfortunately, the risks are getting more serious, because we are, in effect, making decisions by not making decisions. The public in any country can demand that when decisions are made about the future that they be robust decisions; decisions which five and ten years later you do not regret because you could have made a much better decision given what you knew at that time. (But you didn't know how soon or for sure!).

Our present political process does not make robust decisions. If you listen to our media today, the words "corrupt" and "pervasively contrary to the public interest" are becoming common perceptions of the way the political process works.

As an example, we should not underestimate the implications of one important polling result. If you poll people on a NIMBY (not in my backyard) question, it is 90% plus: I don't want it in my backyard. On the other hand, when people are asked do you think nuclear energy is important in our energy future, you get upwards of 70% saying that it important. I think that is the constituency that this effort needs to reach.

The basic fact is that many energy decisions, if they are to be beneficial to society and the environment, cannot be made on a political basis — on a near-term, one-issue constituency basis. They have to be robust. That means they need to withstand unexpected turns of events. They have to reflect some sort of intelligent, rational integration of global environmental, resource, economic and public factors.

In thinking back over the conversations with our colleagues, we find a trap into which all of us fall: we say that things "have to be done", that actions "must be taken", that we "can't afford to delay". But the reality is that these things which seem so obvious and so vital to scientists and technologists, who in fact do understand pretty well the problems facing societies, may not be done at all.

Experience has taught us that just because something is right and necessary does not mean that people will do it. In some cases there are other groups to whom these very actions are just what they do not want to see happen. And in others, even if understanding is there and the need is perceived, the resources to make them happen are simply not available. Things that we say "must" happen, simply do not. This increases the chances that one or more of the "downside risks" will turn into realities.

FINANCIAL MATTERS DO COUNT

Shackelford: I retired as President of PG&E in 1985, and am now on the Boards of a geothermal energy company and a gas pipeline company. My feeling is that we have to agree on what our audience is. If what we say comes out like energy experts talking in energy expert language, it's not going to be very effective. Somehow, we've got to cast our statement in terms that a well-informed person outside the energy field can understand.

I agree that we ought to try to take a global approach. We have an opportunity to have people who are our guests from other countries help us to inform the U.S. as to some of the questions, particularly about what happens if you don't have an energy supply with adequate margins. We don't have much experience in the U.S. about what happens if you don't have enough electricity. But there are places in the world that could inform us on this.

Coming from the utility background, I can tell you that at some point the question of financial risk and perceived financial risk to utilities of embarking on large energy projects in the current environment in the U.S. has to be considered. In the current financial and regulatory climate, this is not happening.

Sanchez-Sierra: During our last OLADE Ministers Meeting we tried to discuss the most important issue of the energy sector in Latin America and the Caribbean: It is the financial situation of the electric power sector. It is not in petroleum or coal, it is the electric power sector. Here, I would like to stress the following: we have a lot of experience to share. You don't know what it means when we say shortage. You don't know what rationing means.

A year ago Argentina just passed a critical situation in the power sector. They had problems with the Atucha nuclear plant, problems with the hydraulic system and at the same time with all the thermal equipment. It was a time when "willingness to pay" was demonstrated. It was five to six times the traditional rate, which they were "willing to pay!" For the financial district in Buenos Aires they had to run diesel engines and they had to pay at least six times the tariff they were paying before. And they paid! In Haiti, the tariff is very, very high. A kilowatt-hour costs three times what it costs in the U.S. But they pay it!

The issues can be different. Here, in the industrialized countries, CO_2 could be the most important one. But I can assure you that in the developing countries, the people don't know anything about the CO_2 issue. Here, — and I'll be very frank — you don't know how it is to run a utility company when the most important constraint is the national financial constraint. You haven't experienced anything like it. You have a media issue which is important, and you have a CO_2 issue.

I strongly recommend that we agree that we are not here for a short-term analysis. If we take a short view, we would assume that for the U.S. Congress right now it is not important what the situation is to the South. For the industrialized countries the most important political develop-

ment is in East-West relations. But here we have a big responsibility to take a visionary approach, 20, 30 or 50 years, and recognize that all of the problems at the global level are important. Our recommendations are not for the next 5 or 10 years.

When it comes to important decisions, if you tell us that we have to take care of the environmental issues without any commitments from the industrialized world in order to solve the problem together, you are not going to get a positive response. The world is changing too much, we all know that. But when we are talking about 30 to 50 years from now, we cannot be short-term oriented.

Davis: In my view, the basic problems we are facing, and must deal with in any kind of an action statement, are really institutional problems and not technical problems. I think this is extremely important. The technology has to be right; it has to support the decisions. But the institutions are the ones that are going to make the decisions and carry them out.

I think it is vital that we recognize the importance of economics. We tend to talk a lot about the environment and about the technology, but I think the one thing that is missing from the discussions is some real understanding of what the economic impacts are of many of the decisions that might be made. Some of the ones we are discussing would have absolutely enormous impacts on a global basis. And of course the principal one of these, which is the most confusing issue in terms of intelligent decisions on energy policy and particularly electricity policy, is the perception of the imminence of the Greenhouse Effect. This completely confuses today the whole issue of making intelligent decisions. I think that is one of the principal issues we have to struggle with.

I have been concerned over the last several years over the almost complete lack of any real leadership in energy or electricity-related matters among industry or government, nationally or internationally. We have suffered from a great lack of real leadership. I don't know how to correct it, but I don't know how to solve some of the problems unless we get some leadership with the courage to make tough decisions.

[Ken Davis served as Director of Reactor Development in the Atomic Energy Commission and Deputy Secretary of energy at the Department of Energy. In 1990, Sec. Watkins had just assumed his duties at DOE, and his National Energy Strategy document was in preparation. Issued in 1991, the NES has not yet resulted in any implementing legislation, although a number of important bills based on it (or contrary to it) have been submitted in the Congress.]

RELIABLE ELECTRICITY: IS IT A PREREQUISITE?

Rossin: How would you respond to this question: Is reliable electricity a prerequisite for economic growth and environmental quality?

Is there a possible consensus on this statement? Are there any who would have problems associating themselves with such a statement?

Wilson: I helped start the Energy and Environmental Policy Center at Harvard University. I feel very strongly that energy and the environment do belong together. In this particular question of electricity, I am constantly overwhelmed by the importance that electricity has in one's life, and also by the fact that younger people tend to forget that. They think that it just comes out of a plug in the wall. But it takes a lot of trouble actually to get it there.

Every time I've seen a study, the cost of electricity interruptions looms extraordinarily large. We can do without electricity; I have done without it. I don't like doing without it. We must be aware that one reason that people concerned about growth attack the electricity sector is because by its nature it is regulated, and therefore vulnerable to attack.

Olds: As Executive Editor for Power Engineering Magazine for 20 years, I dealt with the problem of communicating from the technical sector to the public sector. One of the many problems is the use of words. For example, the term "crisis" or "energy crisis" has been terribly overworked, and we've had one crisis after another. From the public standpoint these have all been solved. You remember 1973, 1979, high gasoline prices... Now that's all gone, so the public doesn't really see anything wrong with the world's energy situation. That's the public in the U.S., because most of the people in the U.S. believe that everybody in the world has electricity, when relatively few people actually do, and certainly not ample electricity.

Another thing: People quickly forget events that have no lingering effect on them. For example, on the East Coast there were brownouts and blackouts in 1989. Hardly anybody remembers these. The big emphasis in the papers now is that we have too much electricity in the Midwest, and we are paying dearly for the excess idle capacity.

Another problem is that we in the U.S. are called the energy hog of the world and the only nation of significance that does not have a national energy policy. We used to have one. I remember when the AEC and the utilities set national energy policy. We had a fairly well-understood energy policy that was based on Keynesian economics, and said that to

make the economic system run we must have abundant low-cost energy. So the utilities and the AEC provided for it. Since 1973 we have had a totally fragmented set of institutions talking about energy policy. In Congress you have a myriad of committees and sub-committees all exercising responsibility or oversight on the energy policy of the U.S. Everybody has a cut: the NRC, the DOE, and the Members of Congress and their staffs who try to perceive through the media what their constituents seem to want today.

Each year I speak to high school science teachers and students in Georgia. They work with a textbook that has one chapter on energy, and the teachers say they seldom get to that chapter. So their understanding about what energy is and the relationship between energy and standards of living around the world just does not exist. They are thunderstruck when I show slides of how much energy is where, who has it, and so on. So we have a big problem getting information to our young people today.

I'd like to comment on something that happened back in about 1975: the advent in this country of participatory democracy. At that time, the NRC decided to hold hearings on nuclear waste disposal. The reasoning was that there are social, environmental and economic implications and the public must have a right to vote on these matters. Now they never addressed the fact that the public needs facts in order to vote. I'll never forget a statement by Prof. Harold Green of George Washington Univ. on this subject. He said, "It is more important in this country now for decisions to be reached on a participatory basis than that the decisions be correct." In other words, decisions are to be based on the voice of the people and whether they are educated enough to make an intelligent vote is less important than they had the opportunity to vote. So this is a gloomy assessment that I have of the U.S. as the energy leader of the world.

Borg: Electricity today is a constant related with economic growth. But is it a prerequisite? Regarding CO_2, reliable electricity is not prerequisite to environmental quality if CO_2 is the factor by which you measure environmental quality.

Starr and Wildavsky said that with a higher level of electrification and industrialization, health and environmental quality are improved. So they are intimately associated.

Wilson: I certainly would agree very strongly that going for more electricity is a good idea in order to get environmental improvement. But you can go for electricity without getting environmental improvement, and you

can get environmental improvement without going for electricity. If it is written as a prerequisite, it can be counterproductive in the way it is read.

Davis: Prerequisite is a word that gives people some problems. The general concept is accepted, but prerequisite may be a problem.

Starr: Sam Schurr puts it like this: "There is not any national infrastructure that can exist without electricity supply." I think that is one you could get everybody to agree on.

Davis: Unfortunately, I think that is a wonderful way to lose an audience.

Starr: That may be. But I'm not talking about a document for an audience. I'm talking about the concept itself.

McConnell: Like others, I'd have trouble with the words here.

Borg: Instead of prerequisite, you can say historically, electricity has been associated with economic growth.

GLOBAL ISSUES - INDUSTRIALIZED AND DEVELOPING NATIONS

Davis: As we discuss the "industrialized nations" and the "developing nations" we need to have a list of concepts in our minds as we proceed with our discussions.

Starr: Are you looking for a global issue or for the U.S.?

Davis: Everybody in this room knows the answer, but each would say it differently. For our purposes, we have to approach this on a global point of view. It may be necessary to say something specific about what the U.S. or the industrialized countries or the developing countries may have to do. I think we have to start with a global point of view.

Starr: If you want to look at this as a global question, if you want to ask what the U.S. can do to assist global electrification problems, that is a question that might be pertinent to the DOE or the State Dept. It is one thing to talk about the global electricity supply in which the role of the U.S. might be very secondary. It is another thing to ask what the U.S. can do about it.

Davis: That is not the only question. What can all the industrialized nations do? What can international organizations do?

Starr: You can make the global electricity supply the issue, and then ask what the industrialized nations can do. The answer is slightly different whether you talk about the problems of the globe and the electricity supply, and the problems as to what the industrialized nations can do to assist the global electricity supply.

Davis: You seem to be saying too much in one sentence. I would say: An adequate supply of energy is necessary for economic growth. An adequate supply of electricity is necessary for economic growth in the developed countries. A healthy economy is necessary to achieve environmental quality. Those propositions should be the substance of what we are trying to say.

Starr: I agree!

Zebroski: As many of our friends have said, the U.S. has a very strong influence on what other nations do. The U.S. today does have an energy policy! It is the same energy policy it has had since the late 1970's. The energy policy is to talk about everything and to burn more gas and oil. Because of North Sea oil and gas and Russian gas, Europe has done this too. This is a policy that at least some of us feel is headed for serious economic difficulties, at least by the mid-90's. The things that are decided in 1990 can make a big difference on whether that turns into a painful crisis or one that we robustly survive.

Now at least one of the priority things we must talk about is, can we make some statement that would affect U.S. energy policy in a constructive way? You can say pious things about global issues, but if you are not taking care of your own kitchen, you are not helping the world very much.

In fact, the U.S. is a model for a decaying infrastructure. We have a rapidly decaying energy infrastructure, in which our average plant age is going to be 30 years by 1992 or 1993. And we're going to solve that problem by building cogenerators that basically burn natural gas, our most expensive, our most environmentally precious fuel, and at the highest cost!

Starr: That is one way to get attention. You start off with the fact that the U.S. is a model for a decaying infrastructure.

Zebroski: As Wildavsky said, I think we have to air our fears!

POTENTIAL FOR CONSERVATION

Davis: How much can projected electricity demand growth be moderated by conservation initiatives and improvements in efficiency? Perhaps Chauncey's talk preempts that by saying "Fine, I'll give you a very optimistic projection of what we can theoretically do, and we still have a problem."

Starr: Other studies were mentioned to me right after my talk, and they reach

the same conclusions.

Hubbard: Your numbers on biomass and solar energy potential are consistent with ours at the Solar Institute. You may argue about how much you can project, but we seem to agree that no matter how much one can reasonably do on energy efficiency and so on, it is not going to be enough to satisfy the remaining demand.

Gottlieb: That is a very important statement. It is not a long statement, but people can understand it.

Hubbard: This is precisely where the battle is going to be joined with the environmentalists. This is going to be attacked. This is what the issue really is, and we need to state it very strongly.

Fulkerson: I wouldn't latch onto just one analysis for the potential for conservation, because those vary enormously depending on the eye of the beholder. I don't think that Amory Lovins would agree with Chauncey in all details in regard to how far efficiency could help.

Wilson: If you look at Amory Lovins' projections, he suggests that India reduce its per capita energy consumption by a factor of two, and I don't think that is a moral thing for anyone to request.

Hubbard: I don't think we could be in a position where we are going to satisfy every extreme point of view.

Fulkerson: The point is we don't have to. What we need to say is that improving the efficiency of electricity services is a net good, if it is done economically.

Hubbard: Yes, if it is done economically. That is a very key provision.

Fulkerson: Absolutely, that's a key provision. I do not disagree with you at all.

Hubbard: We should not water down the statement so much that we miss the point we are trying to make.

Davis: The key to the statement is that with successful or even optimistic achievements in improved efficiency and conservation, there will still be the need for additional supply to meet the demand.

DEFINITIONS: CONSERVATION AND EFFICIENCY

Starr: We ought to settle on the word. Do you want to use conservation, or efficiency improvement?

Fulkerson: I would use efficiency improvement.

Borg: I would use them both in conjunction with each other. If you use the word conservation, it could be qualified as to what you mean. If you mean efficiency, say it. If you mean conservation as involuntary curtailment, identify it clearly.

Fulkerson: Do you mean that standards, such as Federal standards to require that cars achieve a certain average miles per gallon, that would be involuntary?

Borg: Anything regulatory is involuntary curtailment.

Davis: You have a problem here. You are going to have to have some kind of recommendation that will include energy efficiency and that we will accomplish it by somebody doing something specific in order to bring it about. You can say it is a good thing, but in the end you are going to have say how you are going to make it happen. Is a requirement that all refrigerators have a certain efficiency an improvement, or is that conservation?

Starr: What we are talking about are two basic approaches to reducing energy for any given output. One is technological improvement and the other is through life-style changes. Technology is driven by cost-benefit analysis which shows what is worth improving. This is in the hands of the manufacturers, the engineers , the technical professionals. It also is driven by imposition through regulation. Life-style changes are personal matters, but they can also be regulated; take the 55-mile speed limit as an example. So you have a choice of two parameters on conservation. One is technological improvement of efficiency in use of resources and the other is by life-style changes.

But there are also two ways of getting either one of these changes. One set of changes is in the hands of the technocrats, and there is another set that is part of the political process. One works on improving the efficiency of the technical system, and the other puts impositions on how the technical system is to perform or how you use it.

Davis: But in the end, what we are trying to say is that even if we can be very successful with these initiatives, all of them, we will still need additional supply.

Starr: My numbers were based on technology limitations. I did not impose life-style changes. However, you can impose them. It depends on how autocratic the government wants to be. If I have an argument with Amory Lovins, who has a lot of good points as well as a lot of nutty ones, it is

that he doesn't distinguish between the imposition of an autocratic government on the people and on the technology. I want to distinguish between what the technology can do and what people are willing to accept in the way of political domination.

Wilson: I think that is a tremendously important distinction. I think that is one of the reasons why I would avoid using the word "conservation", which is so vague that you would have to define it almost every time. But it is tremendously important, because a vast majority of the people who might read the document we would produce would say they would like improved fuel efficiency, even if it is not economically efficient, but very few people want the imposition of somebody else's life-styles on themselves.

[Here is the key point about Downside Risks: maybe people will accept political domination on energy use. Maybe they will accept restrictions only if there is no other choice. But what if the crisis comes and they won't accept? That would be called a political crisis. With it, the downside risks begin to become realities.]

Olds: We've been focussing on the industrialized nations where conservation or improved efficiency may have meaning. But most of the people in the world don't have anything to conserve, and these words don't really mean anything to them.

Borg: Oh, I think they do!

Gottlieb: Efficiency and demand controls are what people are talking about. We could make the additional point that in other areas in the world, it means different things.

[Here is Wilson's last point vividly demonstrated: Unless conservation is defined, it means different things to different people, even those who are talking across the same table!]

Fulkerson: If you limit yourself to efficiency improvements, they can make economic sense whether you are in Kenya or in the United States. There is example after example where improved technology on the demand side of the equation helps out the developing countries. China is a good example, we know.

Zebroski: But they are extremely capital-intensive!

Fulkerson: That's what you mean by economic. Building power plants is capital-intensive too. You've got to figure out a way to finance both, and you take the cheapest one. Isn't that right?

Zebroski: No! When you are in Poland, you build the coal plant that belches out the particulates and the SO-2 and the NOX, because you can't afford the scrubber and you can't afford the backups.

Fulkerson: OK, you are right about the externalities. They may be different in a few cases. But if you haven't sorted out the externalities, you pick the cheapest solution.

[This discussion swirled around definitions, but underlying it were basic differences in views. Some of these hinge on what people believe different things cost. What may be a good investment in an ultimate economic sense may be impossible because there isn't enough capital to do it, or to do enough of it. Or, in a particular country at this particular time, it may be politically acceptable to invest in supply but not in efficiency. In the U.S. today, it is just the reverse!]

Shackelford: We spent some time with the PRC power planners. It was interesting, because what they wanted to talk about with us was not supply-side planning, but because of their problem of being behind already in terms of meeting load, they wanted to talk about methods of load management: demand-side management. I think economic demand-side management is something we ought to do in the U.S. also, and it is being done.

[Shackelford was President of Pacific Gas and Electric Co., a utility that has taken the lead with a number of major conservation initiatives.]

Borg: In the case of the developing countries, I don't think we should forget that improved efficiencies are already part of the developed world's strategies as a normal course. So if you are going to say what conservation, specifically meaning efficiency, can do for them, you have to mean *over and above what they are going to do anyhow*.

Erdmann: Conservation means that I reduce the temperature of my house. Technical improvement means that I put in a new boiler, which produces the heat. For developing countries, reducing the temperature of the house is not possible because such a large part of the population have no home heating. The best way to do it is technical improvement, and that is the only way. There is no other. But for industrial countries we also can say conservation, meaning that we do not travel so far, or we take a trains instead of cars, or we reduce the temperature of the house, or switch off the refrigerator. I doubt whether it is feasible that people really will do

this. People do not really act like this. But we could say it may be a possible strategy, but only in industrial countries, and technical improvement can be a strategy in all countries. I know that in East Germany, for one ton of steel they use four times as much energy as they do in West Germany. So you can improve a lot in technological efficiency in the East Bloc.

Sanchez-Sierra: Even though there is a possibility to save a lot of energy through energy conservation, or as we say in Spanish "rational use of energy", that is the first part. The second part is that it is necessary to expand the capacity. And this is true all around the world. From the developing countries' point of view, we can agree on that type of position. I think that we agree on the major topics: energy conservation and the need to expand capacity.

EVOLUTION OF ELECTRICITY APPLICATIONS

Erdmann: Another point we did not talk about: Most technological innovations that are foreseeable in the future are demanding electric energy. For example, there is the possibility that in the near future there will be electric cars. In Switzerland they are discussing the introduction of electric cars as a secondary car, and that could be a very interesting measure to improve environmental quality in cities. Then when you travel downtown, you only use electric cars. So we should mention this kind of thing, because it may create such a lot of demand for electricity that we must adjust the capacity. These new technical improvements and shifts will all be in the direction of more electricity and not less electricity. Wherever you look in industry, you see that where there will be technological change in the future, and that the new technology will use electricity. This is another reason why we will have more demand.

Wilson: Yes, all environmental improvements, and all technical improvements, all of them go in the one direction of increasing electricity demand over and above what was planned.

Erdmann: Right. Whether it is planned by the Government or not, it will happen like this. I will give you an example: laser technology. Laser technology for cutting steel has a maximum efficiency of 10%. It can replace torches that burn chemicals to cut steel. The energy needs for this factory using lasers will be less to produce a certain amount of products because of using electricity instead of fossil fuels. And that will be the future!

Rossin: EPRI has extensive documentation on this. It is an extremely important example, and one that is not widely recognized. The replacement of fuels for processes with electricity is one that is happening throughout industry all over. But what does it take for developments like this to take place in the developing world? We do know that it is happening in the emerging industrialized nations, like Korea and Taiwan. But is it even practical to think that because something that has been a successful innovation in our country, it will take place in many developing economies?

Starr: There are several things which the politicians will buy, and one is the globalization of technology. Technology can be moved to any country in the world, even the most sophisticated technology. Workers can be trained everywhere to use it. So if the people who have it want to move it, they can move it. The second thing is the globalization of information, which is creating the political revolution. And the third is the globalization of the environment. That's why we are excited about the Greenhouse Effect.

So the answer for the industrial world is to develop those technologies which can then be made available to developing part of the world to use. It has to be done on a commercial basis, that's the function of the industrial world, and that's what is actually happening.

The developing part of the world will not want to buy the second-rate power plant; they want to buy the first-rate power plant. (We can't even sell military equipment that's second rate.) I have been a consultant to the Government of Taiwan, and I've seen it. The developing part of the world wants to buy the most advanced technologies, and it is the function of the industrial world to develop those technologies.

Zebroski: On a five or ten-year time scale the industrial/developing world distinction is a valid one. But on a ten-to-twenty year time-frame, I believe all countries are developing countries. I cannot see the U.S. ten years from now proceeding on the path it is has been on for the past twenty years. I can't see Eastern Europe progressing on the same path they've been on. Major developments in infrastructure and technology are absolutely required.

Starr: Are you talking about levels of maturity?

Zebroski: This is an example of the global village: transfer of information, transfer of technology, and transfer of manufacturing capability. Barriers are disappearing monumentally in Europe, possibly even in the

Eastern Bloc. The USA has been in the international manufacturing business for a long time, though it has not always been very visible. I worked for GE for many years, and people didn't recognize that even 25 years ago, a great many of our products were, at least in part, manufactured in other places. Now it is obvious to everybody that we have the global village. So in reality efficiency and conservation should transfer by example to all countries. But building new capacity is a fundamental necessity for much of the world. Our energy growth was subsidized by cheap gas and oil, for which we were able to raise the capital. To follow that pattern as a world model now would be terrible.

NEW CAPACITY: IS NUCLEAR POWER A VIABLE OPTION?

Davis: To meet remaining demand increases with adequate reserve, what options are left? If those responsible feel that new nuclear power plants are needed, will they be politically acceptable?

Sanchez-Sierra: What options are left? We need to discuss this at three levels: political, economic, and environmental. Political: it's up to the countries. If they have the uranium, if they have geothermal, if they have hydro, and if they have the political will to do it, then they are going to do what they can. From the economic point of view, each power company will make its own analysis. But for the global environmental decisions, we need to get something creative from this meeting. If we all agree that the environmental issue is a global one, we have to link industrialized countries with the developing countries.

Consider China: It is not just up to China to improve the technology and to reduce the environmental impact. I think that it is up to the whole world. When I worked with the World Bank, I found out that it is a matter of political decision at the Board of Directors level what kind of loan they are going to approve. Can we change the rules? Suppose there is pressure from the major countries to the World Bank, or the InterAmerican Bank, or the Asian Development Bank to lend money, for example, to China to build a 500 MW coal plant. Let's say that 80% of the money that is going to be spent for the conventional part of the plant is going to be loaned at the normal amortization period and rate, and the other 20% is needed for environmental protection (but here 20% can mean over $100 million!). Since we all agree there is a global problem, why don't we change the rules? Why don't we suggest a 40 year amortization period, a 3 or 4% interest rate, and a grace period of 20 years for the environmental protection components?

That kind of issue is a critical one for the future. How are we going to tackle energy development on a global basis? Three weeks ago in Europe, at a very important meeting about CO_2, the industrialized countries started to talk about a CO_2 tax to be invested in environmental protection around the world. With a little imagination it is possible to find ways to continue with rational energy development.

In Latin America, there are four countries with nuclear programs: Cuba, Mexico, Argentina, and Brazil. From an internal political point of view there is no problem in Cuba, Argentina and Brazil in order to continue with the program. The problem is an economic and financial one. So if there is interest in order to support the Brazilian nuclear power program, there is a lot of room to do it. But where are you going to get the money?

Let me give you a real example: Brazil was discussing a $500 million dollar loan for the national utility company (Electrobras) with the World Bank, and it was postponed because the nuclear company, Nuclearbras, is integrated with Electrobras. The issue at the Bank is that as long as the Brazilians include nuclear, there is a problem for this kind of a loan.

The most important global issue is energy, and the environmental problem, the global one, must be tackled properly. The others, like energy conservation, are things you can do in industrialized and developed countries.

Rossin: So here's something that would be environmentally desirable, but the World Bank's concern is that it might be a political liability if they put their money there for that purpose?

Sanchez-Sierra: From the Bank's point of view, it was no problem to lend money to Electrobras of Brazil as long as they did not include nuclear in their program. Nuclearbras exists as part of Electrobras. The World Bank will not lend money to it. But this is a very particular issue. In fact, I think it is possible to develop coal. We have the technical capability to avoid environmental impact if you are willing to spend the money you need to spend.

Borg: Doesn't Brazil have the largest national debt in Latin America right now? Does that in any way influence the decision of the World Bank not to give them additional loans?

Sanchez-Sierra: Not at all! Because the debt of Brazil is around $110 billion dollars, and a good part of that is coming from the energy sector, at least $30 billion dollars. And a good part of that is from the nuclear program, but that was not the major issue. At the end, the big part was that

Nuclearbras was an integral part of Electrobras.

Davis: I think all of you have thought about what we might say as a Finding about the need for nuclear power in the future. I thought Chauncey Starr's analysis made it perfectly clear that if you are going to "get there from here", there are going to have to be substantial increases in electric supply from nuclear power. Is that what we should say, or is there something else we should say?

Fulkerson: Only if global warming is a constraint. If global warming is not a constraint, what the hell, use coal. And by the way, we are spending half a billion dollars a year figuring out how to burn it cleanly.

Rossin: But keep in mind that's the legacy of a policy that's been in place for quite a number years.

Wilson: It is not necessarily incorrect unless one believes in global warming.

Fulkerson: That's right!

Starr: Clean coal gets rid of most of the pollutants and ends up with water vapor and CO_2, which is the perfect end point for a hydrocarbon. Clean coal technology does not get rid of the CO_2. The real issue of course, and you've raised the right question, is how serious is global warming? That hasn't been resolved, and we won't know for years down the road if it is truly big or not.

If there is a restriction due to that fear, in anticipation of global warming, then we're faced with the alternative of low or zero per-capita energy growth, as my figures show, with its limitations on the global economy, health, education and environmental protection.

Shapar: I found at the International Energy Agency that the whole world is asking the same question. What's the answer? Is it clean coal *and* nuclear? It should be diversity. We recognize that China is going to expand its use of coal two-fold before the year 2025, and India is going to triple it. They've got to use coal for much of that. Looking at it globally, the answer has to be clean coal and nuclear. Any additional hydro sites worldwide will be used as well. And of course, we need better end-use efficiency, and as we tried to define it before, conservation and change of life-style. We're talking about everything.

Rossin: Is it fair to say that whether the Greenhouse Effect turns out to be real or not, that diversity of supply is important enough that we need to use all of these options?

Fulkerson: No.

Shapar: If you are looking at the globe, there is no way that China and India are *not* going to increase their use of coal. If you are talking about the United States, you might come out with a different answer. Besides, there are two billion people in Asia that are cooking their food over open fires.

Davis: All of these clean coal technologies are less efficient than the present methods, and they actually increase the amount of fuel that needs to be burned, and thus increase the CO_2 emissions. You ve got to make a fundamental decision about how serious the Greenhouse Effect is likely to be.

Shapar: The environmentalists are attacking the Clean Coal Program of DOE. They're saying it is an excuse to sell and burn more coal.

Rossin: Dr. Lu, forgetting about CO_2 for a moment, will the program for increased burning of coal in China include pollution controls on coal-burning plants?

Lu: Presently we do not include plans for such investment. In the future, it might be so. We anticipate by the year 2000, we will be burning 1 to 2 billion tons of coal a year, and by the middle of the next century, 2 to 3 billion tons of coal, compared to 0.8 billion tons a year now in the U.S. At the same time, we have to keep in sight the costs. With such heavy dependence on coal, we must face transportation problems and local pollution problems.

Blue: If the CO_2 issue is debatable, one issue which is not is local air degradation. Those of us who have visited Eastern Europe have ample evidence of particulate pollution. The level of that pollution is severe enough to suggest that some substantial amount of cleanup will be required and needs to be funded. To accomplish that will cost money, and therefore coal will cost more to burn. But if you want to choke on coal gases, you can just visit cities in developing nations around the world today.

Other sources of energy supply may become more interesting, even nuclear fission. We should not lose sight of the fact that uranium is just another fuel. If you are looking at significant multiples of what we use today, then it is obvious that the availability of another energy source (uranium) as well as fossil fuels that we burn, will affect costs. So ultimately, the issue is an economic one. The phenomenon we perceive today is the increasing costs of fuels.

Stauffer: Since we are focussing on economics, let me raise the question whether nuclear power in the U.S. really is economic? Or do we have to assume a variety of shadow pricing effects to try to justify it?

Starr: I think we get in trouble if we don't face this honestly. New nuclear power plants in the U.S. would be uneconomic under today's rules. The cause of that uneconomic power is a different question. It is not the technology that is uneconomic.

Stauffer: Then can you go one step further? Take the French costs: Given today's oil prices, or given gas prices in the U.S., even at French construction costs, is it economic?

Starr: Well, France is able to sell power more cheaply to England than the English can generate themselves, to Switzerland, to Italy ...

Stauffer: That's not a proof that it is economic, that's a proof that the pricing is competitive.

Erdmann: Of course, the French nuclear plants are half as expensive as the ones in Switzerland and Germany. That is clear. Also, in France, one kilowatt-hour costs half as much as in Switzerland. The reason is you can build them faster. This is the reason you have cheap nuclear power in France. They are standardized, so you can build more bigger ones for lower costs. When you build one it is more expensive than if you were building ten. These are very simple reasons. Government subsidies are also involved, but the subsidy is not so big that the subsidies determine the economics.

Starr: This is a very complicated question. Every one of our energy sources is subsidized. Who pays for the black lung disease for coal miners? It is the U.S. government.

Fulkerson: You think that's a subsidy? That's not a subsidy. It's an internalization!

Starr: OK! The point is that if you look at the Electricite de France balance sheet, it is in the black. They turn a good profit for the government, and the real argument is how much they can raise rates and make more profit for the government. It's true in Japan too. Nuclear power is cheaper. If you talk about the U.S., nuclear power is out of whack and much more expensive. And until something happens to bring its costs down comparable to the best elsewhere, it's not going to make it.

Rossin: We should be talking about building new nuclear power plants to supply future capacity. That's different from saying that existing U.S.

plants are not economical. Some nuclear plants in this country are expensive. We know that. By and large, though, the ones that exist in general are more economical than alternatives. The existing plants with their sunk costs are economical, although it costs a lot to run them, and these operating costs are rising. The French are finding this out too.

Wilson: Did we get the answer to the cost of nuclear power today? Is it economic on a technical basis? I mean price, not cost. Is there acceptance that nuclear power, when done the way France or Japan does it, or the way we did it in the good old days, can be economic?

Stauffer: I think that what comes out of it today is that at present oil prices, which set a cap for coal prices, the economics of nuclear power, even for French reactors, built as cheaply as they can be built in the world is questionable. If you do the full costing, even the French reactor barely breaks even against imported oil. I'm talking about new ones, not the existing ones.

Starr: The French don't agree with that!

McConnell: I spent two months last year with extensive discussions on economic evaluations of the French situation. I just don't think oil in France is even close to nuclear power costs. Nuclear is much less -

Fulkerson: Did you hear three times as much?

McConnell: Their numbers showed that electricity from oil is 200% of the nuclear power costs.

[Electricite de France publishes operating and financial data in its environmental reports, and this information was gathered after the Seminar. However, throughout 1991 the international organization Greenpeace has been claiming that the French nuclear power program has been an economic failure, and these claims have been echoed by many other activist organizations. Citing 1989 data, Greenpeace cites the record of unplanned shutdowns, production efficiency figures and the large debt carried by EdF. In July, 1991, EdF issued a statement responding to the Greenpeace charges.]

The following statements are excerpted from an EdF press release dated July 1, 1991:

> Today EdF's nuclear power plants produce 3/4 of France's electricity needs and one-third of its primary energy. This electricity is the cheapest in Europe, with the exception of hydroelectric power in some Scandinavian countries. In 1990 France exported 12% of

its electric power production for 2.2 billion U.S. dollars.

With regard to debt: At the close of 1990, EdF's debt was $45.2 billion (226.1 billion French francs). This is $1.3 billion less than in 1989. The debt is 1.4 times the annual revenues. This ratio is common with electric utilities, regardless of whether they are using nuclear power. Nuclear power is capital intensive, which is the main reason for use of long-term financing and therefore, the existence of this debt.

The reduction of EdF's debt in 1990 was achieved simultaneously with a profit of $20 million (100 million French francs). EdF's goal, in agreement with the French government, is a reduction of electric rates of 1.5% per year in constant francs, which was achieved in 1990.

Zebroski: I keep seeing that the industrialized world, at least parts of it, can build both nuclear and clean coal plants which are environmentally desirable and can be economic, and which have the great advantage that they reduce the world pressure on oil prices and gas prices. As those prices go up, the countries which will be most disadvantaged are the Third World countries that do not have gas and oil.

I think that we should discuss the institutional obstacles that make a plant that can take 120 months in some countries that can be built in 39 months in other countries. This is the main element of cost overruns. And the same thing is happening on clean coal. Clean coal is capital intensive, it means big projects and it is a big environmental target. It is a risky proposition for many companies to tackle. They will put scrubbers on old plants because that's all they've got, but when someone says tackle this billion or two-billion dollar plant, which you may not be allowed to run, the default is to burn more oil and gas. That's the bad guy in the world energy picture and we should address it. So the institutional obstacles that can make the environmentally and economically desirable options impractical in this country are a central policy issue for us.

Hubbard: Ed, you're saying that they are environmentally desirable, and a lot of people wouldn't agree with that. So that's not an institutional issue, it's a public perception issue.

Rossin: We do have one record on this. Every licensed nuclear plant in the U.S. had an Environmental Impact Statement, and went through the whole public hearing process. The conclusion in every one of these was that it was preferable to the alternatives.

Fulkerson: Most of the NEPA work was done at the time when one did not consider Class 9 accidents.

Rossin: Class 9 accidents are scenarios that are beyond the design basis. If you are going to include such calculated scenarios you must include their associated probabilities. And then, even if Class 9 accidents are included, it doesn't make a bit of difference in the conclusions.

Fulkerson: Oh yes it does! It may not make a difference in probabilistic risk calculations, but it makes a difference to the public. We fundamentally did the environmental impact statements wrong.

Shapar: It survived legal attack on that very basis, and it has been upheld by the courts.

Erdmann: I have studied costs for nuclear plants that are planned to start construction in 1987 and be in operation in 1995. They are compared with plants that would burn black coal in Germany. These designs are for clean coal, because that is the only option for Germany. In any event, the nuclear plant option is definitely cheaper than coal.

Starr: I don't think it is wise for this group or this study to make economic comparisons or say that one is better than the other. I think that has to be decided by each country or each utility system. What we are arguing about is the options that have to be made available to the world, and about seeing that these options should be developed as effectively as possible.

Davis: No one is going to order a plant based on the price of fuels today, but rather on what one thinks the likely costs of fuels are going to be 5, 10, 15, 20 or 30 years from now. The current prices have nothing to do with it; you have a series of options and other people are going to have to make their own judgments. We really are talking about keeping options open.

Rossin: If we regard diversity of supply as important, and hope that decisions can be made among options based on economics and weighing environmental impacts, then it is all the more reason to have a wider range of options to choose from, and not anticipate that one will do it all somehow.

Stauffer: For the sake of argument, if you believe then, that nuclear power is economic, and I'm speaking of the U.S. where rate-making procedures are different from anywhere else in the world, if you believe that a nuclear plant undertaken today would be economic compared to oil, which is the way they are often tested now de facto before utility commissions, then the entire rate-making structure in this country is

institutionally designed to make it look uneconomic. If one were to build an economically effective and practical plant today, it would nonetheless raise rates.

Rate shock is not only a function of the intrinsic capital cost in this country, it is also an artifact of the rather bizarre way in which we design rates. You can show that a plant which can generate at below the average cost of power could nonetheless cause the rates to go up! Now that is a very real institutional inefficiency, and one for a variety of reasons the utility industry has not been able to address. That is a basic obstacle.

Starr: I think it is real; the only thing one can say about those issues is that if they persist, they will discourage the construction of high capital cost of any kind. They can be changed by the political will of the people to change it. It can be done. If they were to allow CWIP (inclusion of amounts representing investments in Construction Work In Progress in the rate base before the plant goes into commercial service) there would not be rate shock, the rates would go up slowly as the plant is completed, and then the price would drop.

Rossin: And that's what happened in many states until adversaries discovered that by eliminating CWIP they could discourage large, high-capital cost plants.

Stauffer: It is not only CWIP, it is more fundamental than that. The problem faced by the utilities is they have to deal with rate shock, even if they come up with a plant that could generate more cheaply.

Shapar: In a study done by OECD, comparing nuclear and oil in 1987, in most OECD countries except for the U.S. and parts of Canada, nuclear was much cheaper than oil, and also cheaper than coal. The study is being redone now with the drop in coal prices, but the prediction is that nuclear will still enjoy a cost advantage over coal. That study assumes that the plant will be built on a reasonable schedule.

Erdmann: I think the relation between international considerations and national supply concern is this: we cannot expect that France or the Soviet Union will abolish planning new nuclear power plants. In France there are 15 being planned, and I don't know how many in the USSR. But what happens in some countries like the U.S., or Switzerland or Germany if the knowledge to build nuclear power plants will be gone? We have a big problem now in Switzerland in that we have no one studying nuclear technology at the Swiss Institute! This will continue. In a few years time there will not be enough qualified people; we will have to start the whole

industry from the scratch again. We in Switzerland can buy power. But for other countries, this will be a big problem. Some countries of course will continue with nuclear: France will, even if there is a second or third Chernobyl!

IMPLICATIONS OF INADEQUATE GENERATING CAPACITY

Rossin: We spoke of inadequate capacity. What are the implications in industrialized countries that already have an infrastructure that depends heavily on electricity?

Kaprielian: I can speak to the attitude of people in California. People in California do not want to remember when their last interruption was. If there was an earthquake, or a very severe storm, the public is very understanding, so long as you don't keep it off for too long. If, however, the cause is inadequate capacity, lack of hydro because of a dry year, or an inordinate number of large units being shut down by forced outages, public tolerance as I know it approaches zero. And the public at large is going to be climbing all over everybody. The utility companies will be faulted for inadequate planning, and as a nation, we're going to start throwing money in any direction possible that will bring something on the line fast. What will be fast will be uneconomical. That's my observation based on my personal knowledge and understanding of the reaction of the public.

Starr: We had a historical case when the semiconductor industry in California made a study and tried to get reassurances on the reliability of electricity, which is absolutely essential for the reliability of their production processes. They decided that in view of the attitudes within this state (the Public Utilities Commission, the California Energy Commission) on electricity supply, they had better start looking at other states for expansion, and that's what they've done. So one of the effects of an anticipated shortage of reliability of electric supply has been to move industry out to other areas.

Fulkerson: Is that good or bad? There are people in Tennessee who would like it.

Starr: Well, that depends on your point of view. If you like industrial growth and jobs for people, it's bad to have good industry move out. You've just heard a description of what happens if you get a sudden impact on the public, but there's a gradual one where the industries anticipate an unreliable situation and shift their industrial base. Now they can shift their base anywhere in the world.

Rossin: And they have. I was at Commonwealth Edison for ten years, and for all sophisticated industries, those within the state, or planning to expand an considering doing it in Illinois, it didn't take them long to figure out what our plans were and whether we were going to have adequate capacity. It was a straightforward thing since all power plant plans are filed with the State.

Wilson: There are two aspects: Certainly 20 years ago, the demand for reliable electricity dominated all utility thinking. That went to pieces about ten years ago when all the environmental issues came up. Certainly in the Northeast, those that I know were dropping reliability out of their priorities, even though we had just had the NY blackout of 1977. The CEO of New England Electric explicitly said it was no longer one of his objectives. I think maybe we went too far on reliability in the 1960's. But we should address not only the impact of the public demand, for there are actual costs which, every time we look at them, are extraordinarily high. Since the NY blackout, the reason we no longer demand quite so high a reliability is that the hospitals in the Boston area have doubled their capabilities for emergency electricity. (They don't always work well in thunderstorms; half of them don't switch on in fact, but they are there.) The cost of unreliable electricity is well over a dollar per kilowatt-hour.

Fulkerson: Doesn't that depend on the use? Certain industrial processes are critically dependent on reliable supply. On the other hand, for the average consumer, a two-hour power failure is not catastrophic, and it is not very expensive to him either.

Rossin: And it is tolerated as long as he thinks there is a legitimate reason for it, other than poor planning.

Wilson: I'm just asking myself how much would I be prepared to pay. Actually, I just came back from five weeks in China. I never saw a power cut! Not until two hours before I landed in Boston, and it was out for two days! I would pay quite a lot to have had power during those two days. I would pay a dollar a kilowatt-hour.

Erdmann: The government can impose economically designed taxes to slow demand, as is now being discussed in Switzerland. We should discuss what are the societal costs of high electricity prices.

Starr: But it's even more fundamental. If you raise the costs of electricity, you raise the costs of all production in the total economy. You are in a competitive world. I don't know what percentage of Switzerland's products are exported, but I imagine it is a pretty big part. You are in

export competition with countries whose electricity costs might be lower, so you begin to lose market share, and to lose GNP for Switzerland. This is a slow-moving thing. It does not occur overnight. There is a big difference between visibility of an issue that occurs quickly and one that is slowly moving.

Rossin: What about countries in Eastern Europe and some developing countries that have a limited supply of electricity today? Is that the constraint? In some cases it may be a constraint on growth and on investment.

Sanchez-Sierra: There is an important experience that you can learn from us: the willingness to pay. When you don't have electricity, you know the worth of it. In Argentina in January, 1989, Florida Avenue, which is the most important avenue in Buenos Aires, was full of diesel engines producing electricity for the banks, the shopping centers, etc. And at what cost? Five or six times the cost of buying it from the electric company! How long? Almost two months!

Kaprielian: About industry's reaction: We used to make available to large industries (and we still do) interruptible rates which allowed a lower cost per kilowatt-hour, with the expectation that when you came into a peak demand situation, you could either have the customer go off automatically by action of automatic relays, or anticipate for him, and tell him there is going to be a problem tomorrow, so that he could shut down. This was received very well for a number of years, so long as there were no interruptions.

But the first time there were interruptions, our President got phone calls from chief executive officers that said, "Look, you've never done this before! Why are you doing it now?" Immediately, they would want to get on a firm rate! Right now!

Zebroski: You were too reliable! That was your problem! You weren't unreliable enough to begin with!

Kaprielian: Well, I'll buy that! But I'm addressing the point about the developed nations and the people who have gotten used to the conveniences and all the good things that electric energy brings to us. To suddenly *not* have it available by the flipping of a switch, or to be without it for a period of time, is no longer an acceptable option.

Rossin: Then that is really the flip side of what New England is being told! They are hearing that reliability is not important anymore!

Wilson: That's right! New England is still saying that. I've twice been in the business of negotiating electricity rates for my labs, at Harvard 20 years ago and recently at FermiLab. You are exactly right. We had complete confidence we were unlikely to be switched off very much. We had exactly a one-minute notice that we had to switch off from 70 megawatts down to 10 megawatts stand-by! I think it happened twice.

[People just don't believe it can happen. They have become accustomed to reliable electricity. In fact, electricity at reasonable cost is regarded as a "right" in many states. "Lifeline Rates" have been instituted for poor and disadvantaged customers. Utilities cannot refuse service, and find it very difficult to cut off service for non-payment of electric bills.]

Kaprielian: To draw on the experience of our Canadian friends to the east of Ontario Hydro, they've had typically one outage, system-wide, per year for years. And this has gotten the top political people in Quebec demanding that something be done!

Rossin: I remember our planning criterion at Commonwealth Edison back in 1972 was one outage in five years.

Sudarsono: We had that experience in the 1970's. We started an economic development plan in 1969. The political situation was unstable. We tried first for political stabilization, and then economic stabilization, because in 1965-66 we had 500-600% inflation. Our power sector started at a very low base, about 500 MW. But only 10% of the households were connected to a grid. Our industrial base is still small now, but it was smaller then; it was less than 15% of the total GDP.

We wanted to develop economically, so we invited foreign investment. There was response from the private sector, both domestic and foreign, and there was a high demand for power, from the early 1970's until now. In fact, the average growth has been 15% per year experienced by the utility, because we were starting from such a low base. The utility was unable to meet all of this demand. And now, even though we don't have exact data, 50% of the generation is captive, that is, it is done by the industrial companies that use electricity. Our government decided in the early 1970's to allow them to do this because we had no alternative. We had no capital; we had no means to install quickly the additional capacity the utility needed. So we allowed them to install their own plants and gave investment incentives. Now, of course, this is a negative, because this capacity in separate units in all these industrial plants means a waste of capital resources. They are not connected with one another. They use

small plants. They are inefficient and they use oil; they cannot substitute other fuels. So we are paying for that now.

Fortunately, Indonesia is an oil-producing country. We did have a windfall in the 1970's. When we made an assessment of the social demand for power in the late 1970's (this was before the second oil price rise) we decided we should keep away from oil-fired generation. We decided to use coal and to make additional investments in hydro power. These decisions were made on the basis of diversification. With these investments through the Economic Development Bank and the World Bank, until now the utility was able to supply the current demand, because of the independent capacity. But with the 15% growth that has been experienced since the early 1970's until today, the utility very soon will be facing a great concern, because 15% per year means a doubling of capacity every five years, and as you know, it takes longer than that to build a power plant.

Rossin: Does the utility still have the obligation to supply any new customer?

Sudarsono: Of course. They have to. The utility is State-owned, and the Government is part of it, and if the utility cannot provide the power, it is a reflection on the achievement and the performance of the Government.

[This discussion session, and the detailed discussions of electricity demand and supply issues in the industrialized and the developing nations, formed the basis for the Seminar's Findings and Conclusions in Section 2.]

SECTION 8

GLOBAL WARMING: SCIENTIFIC UNDERSTANDING ON CO_2 CONCENTRATIONS

Dr. Michael McCracken, Director,
Atmospheric and Physical Sciences Div., LLNL

One thing we know, that we really know and are certain of, is that the CO_2 concentration has been increasing from when it was first measured in 1958, from 315 ppm in Hawaii to about 350 ppm today. So the concentration has gone up. There is a network of stations around the world that confirms this.

One of the interesting things is the seasonal variation that occurs as a result of the northern hemisphere biosphere, from peak concentrations in the late winter and early spring to minimum concentrations in the early fall. This change in mass of carbon in the northern hemisphere is about 7 gigatons: 7 billion tons of carbon. You can compare that to what we are injecting as a result of fossil fuel emissions, which is about 5.5 gigatons right now, and biosphere deforestation another 1.5 gigatons. So the total of man's activities are putting about the same amount of carbon into the atmosphere every year as is being drawn out and put back in from biosphere over the whole northern hemisphere. So if you want to capture man's input and store it somewhere, it is equivalent to an awful lot of twigs and grass.

Now the reason that the concentration does not go up by 7 billion tons a year is that half of it gets mixed with the Southern hemisphere, where concentrations are also going up; and we believe that the ocean is taking up about half the carbon that is emitted. I say "believe", because there is a new paper that suggests that it is actually growth of the mid-latitude biosphere that is managing a way to store more carbon in the soils. We're not quite sure where it is going; it is likely a lot of it is going in the ocean.

If you want to stabilize the composition of the atmosphere, have the CO_2 concentration not go up [illegible] any more in the future, you would have to cut this emission number by 80% or so. You have a system that consists of an atmosphere and an ocean. The atmosphere and the upper ocean are in

equilibrium, but what is not in equilibrium with them is the deep ocean. We haven't cycled the carbon down to the deep ocean. Sediment removal is a pretty slow process. The amount you can add to the atmosphere without that concentration going up is what you can store in the deep ocean. That number is only one or two gigatons per year.

Fulkerson: I've heard numbers down to 50%, compared to the 80% you cite. If that is the case, that means that the fossil fuel ratio is extremely small.

McCracken: That's right. If what you are going to do is stabilize the composition of the atmosphere, and not use the atmosphere to store some of your wastes, which is what you do for every other medium that exists, you must cut emissions drastically.

Fulkerson: If you could remodel it and get 50%, I could sure use the extra carbon emissions for energy production!

McCracken: And it also depends on the amount of net deforestation. It is fine to cut down trees to build buildings that last a long time and store carbon in buildings, but when you destroy the forests by burning them and putting the carbon into the atmosphere and don't allow that regrowth, then you have a net deforestation and more carbon is going into the atmosphere. So if you want to stabilize the composition of the atmosphere and don't do anything about deforestation, you would have to go all the way, virtually to zero, on the fossil fuels. It is a coupled problem.

A lot of what is driving this is the rapid population growth that has gone on since World War II. If we are going to stabilize things, we are going to have to do something about population. If you recall Sen. Wirth's energy bill in 1988, a large fraction of the money was for population control. That is an interesting role for an energy bill.

Where is the carbon coming from? In 1950 we were emitting about 1.6 billion tons of carbon, mostly from the industrialized world. Not much from the developing world. In the next 30 years, the total amount nearly tripled. It was the industrialized part that almost tripled. Meanwhile, the developing world part increased by a huge fraction.

Consider a hypothetical case: If you take the year 2000 population, roughly 6 billion people, and you say that every person uses 5 kw per person, which is more or less the amount of energy demand in Europe today (the United States is about double that), and you assume that all the developing world is aspiring to that, and we've stabilized population, we would be putting out,

keeping the same fuel mix, about 20 billion tons of carbon, four times what we're putting out today. There's a real question, of course, if we could ever get there because of availability of fuel and generating capacity, but if you keep the energy mix the same, you're going to increase dramatically the amount of CO_2 going into the atmosphere.

The 20% reduction in CO_2 emissions from the industrialized countries talked about at all international conferences this year would reduce it by one gigaton. Even if you reduced it to zero, but if the rest of the world develops the way the industrialized world has developed, you are going to have tremendous emissions, and what is done in the industrialized world will make little difference. So the challenge is to find some way to provide clean energy for the developing world. (Figure 8.1)

Depending on what you do, the CO_2 concentration could go up from its value of 350 ppm today to double the pre-industrialized value, 600 ppm, sometime in the middle of the next century. It's now growing at about 1 to 2% per year, so 600 ppm would be reached about 2060.

The atmosphere holds about 750 gigatons of carbon now; the living biosphere above the ground about 560 gigatons. So if you were to totally destroy all trees and add this to the atmosphere (remember that half of it goes into the ocean) you're not going to double the atmospheric CO_2 concentration. (Figure 8.2) If you burn all the available oil and gas and add the carbon to the atmosphere, and half goes into the ocean, you're not going to double the CO_2 concentration in the atmosphere. The problem comes when you start using coal and oil shale. Then you can easily double the carbon concentration.

It is often pointed out that global warming is not entirely a CO_2 problem. CO_2 is about half the problem. There is a range of gases, methane, NO, and the chlorofluorocarbons, that have quite small concentrations, of the order of ppm and reasonable growth rates. Some of them have direct effects on the radiative balance; that is, they directly trap radiation. Others have chemical effects. They change the ozone concentration, and that increases the global warming effect.

Olds: Do these gases reach an equilibrium distribution in the atmosphere?

McCracken: Most of the important ones are distributed pretty uniformly. Methane has a lifetime in the atmosphere of about ten years. It is pretty uniform around the globe. One of the most interesting things is that it has a 20 - 25% effect on enhancement of the Greenhouse Effect. With its ten year lifetime, if you were to do something dramatic about reducing the

The Relative Contribution of the Developing World to CO_2 Emissions is Growing Rapidly and Could Become Dominant

Figure 8.1

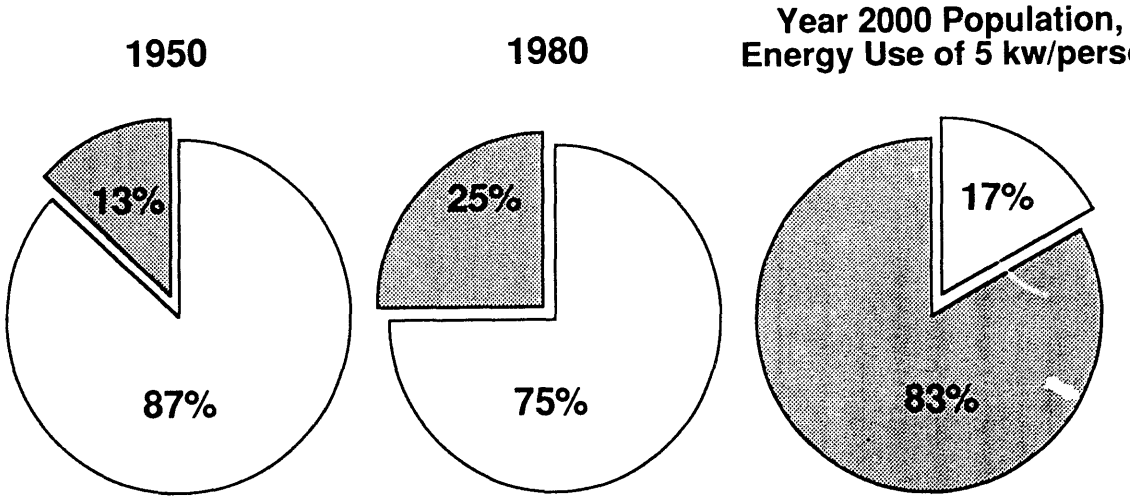
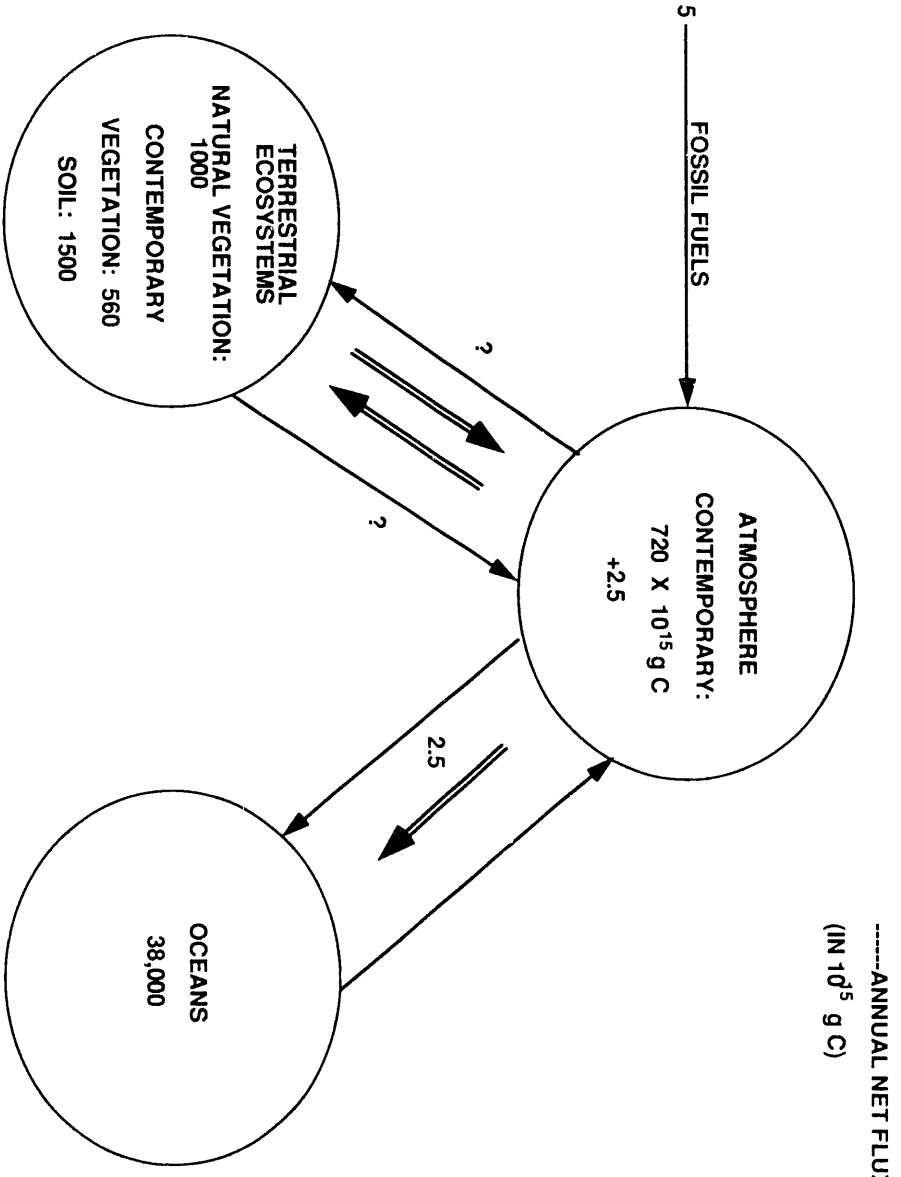


Figure 8.2


5
FOSSIL FUELS
TERRESTRIAL ECOSYSTEMS
NATURAL VEGETATION: 1000
CONTEMPORARY
VEGETATION: 560
SOIL: 1500
?
?
ATMOSPHERE
CONTEMPORARY:
720 X 10^15 g C
+2.5
2.5
OCEANS
38,000
-----ANNUAL NET FLUXES
(IN 10^15 g C)

methane emissions from rice or farm animals or leaking natural gas lines, perhaps by 25%, the excess methane concentration will start going down. That will tend to counterbalance the radiative effect of CO_2 increasing. So you can think about trying to manage the composition of the atmosphere. Methane concentration is now about double its pre-industrial level.

The fluorocarbons have lifetimes of the order of 100 years. Now we are trying to replace them with new compounds that have a lifetime of 10 to 15 years. In terms of their infrared capacity, the new compounds turn out to have roughly comparable effects, but because they have shorter lifetimes, they do not build up in the atmosphere. It is important to distinguish between merely reducing mass and reducing numbers of molecules, as the newer compounds are lighter. If you do it on an equal mass basis, you get a Greenhouse Effect that is not too much lower than what you are expecting from the longer lived ones, because the Greenhouse Effect is based on molecules. I haven't seen a very good analysis of this on a molecular basis. When you consider solvents, is it molecules or is it mass? Or foam insulation: is it on a molecule basis or on a mass basis? I think it is really on a molecule basis, but everybody is assuming in most of the calculations that it is on a mass basis. That's something that needs to be cleared up!

In one of the most interesting efforts to understand CO_2 in the last decade, the Soviets drilled an ice core in the Antarctic, and measured the concentration of CO_2 in bubbles in the ice. We have some sense of the temperature in the ice from isotopic data, going back about 160,000 years. The last ice age, about 18 - 20,000 years ago was about 10 degrees colder at this location, and this glacial climate prevailed back to 110,000 years ago. The last time it was as warm as now is a rather brief period about 125,000 years ago, and before that there was another glacial cycle.

What's interesting is that the CO_2 curve has a very similar pattern: peaking at about 280 ppm, which is sort of the pre-industrialized level. The data points span 2000-years. There is a real question as to whether the CO_2 caused the ice age, or contributed to it, or there was a feedback process. The resolution isn't really good enough to do leads and lags very well. But it seems to be related. The French feel that the two factors that contributed are CO_2 and methane, and variations in the Earth's orbit, and that the two may be about equal. So they would say that about half the temperature change is due to CO_2 and methane — about the same as the models we are using.

Fulkerson: Do you think that gives us a clue as to how much natural Greenhouse gas could occur due to temperature changes?

McCracken: We wish we knew. It was natural, not man-made. There are possibilities that warming would lead to melting of the permafrost, which would release methane, and that would be a large source of methane.

Now if our models were ten times less sensitive, they would not match these data, but our current best models do explain the data fairly well, within a degree or two. Actually, the climate hasn't changed as much as the models indicate it should, and we don't know why. The ocean lag can be a factor of two. That cuts the prediction down to 1 to 1-1/2 degrees warming, and that's what the models suggest we should be seeing. Actually, we're seeing half a degree, and we don't know why.

Fulkerson: We're not even sure we see half a degree, are we?

McCracken: Well, there's a lot of argument about that. The consensus in the Intergovernmental Panel on Climate Change is about a half a degree.

Erdmann: What created the recent rise in CO_2 in the last 20,000 years?

McCracken: We don't know. It is hard to explain such a long period. There are plans to drill another hole, maybe on Greenland. With its higher precipitation rates, you can get better resolution.

MODELS

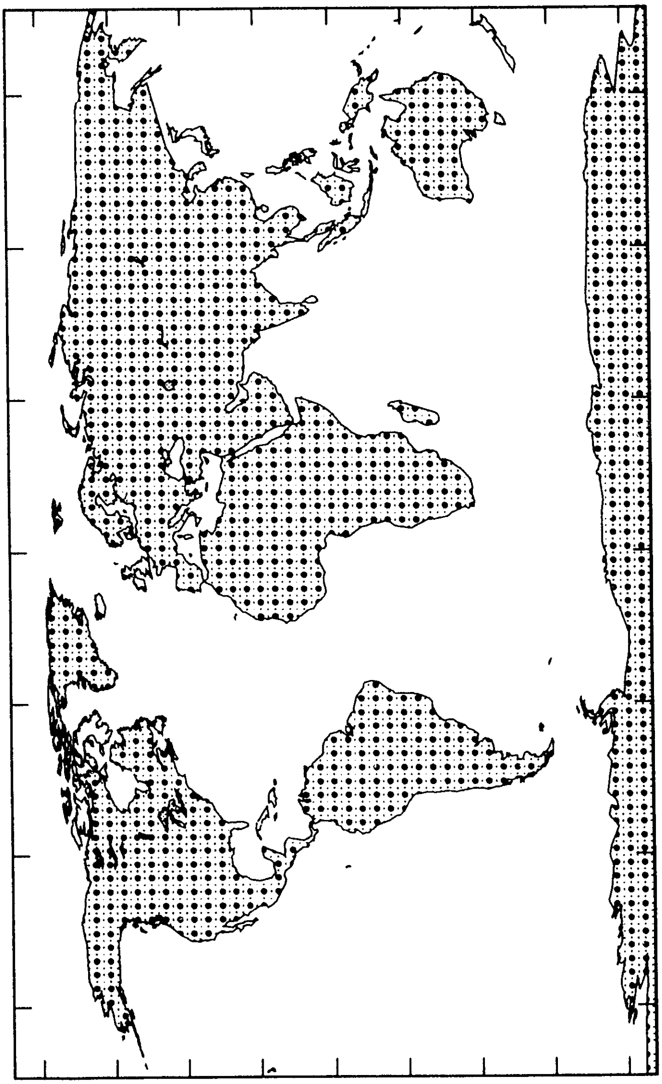
We wish we didn't have to use models. We wish we could go into the laboratory and do experiments or use past analogs. But the system just doesn't work that way. We're forced to use climate models instead. They are theoretical, so one does have to worry about confirming how they work. You make a lot of assumptions, because we have to represent a lot of complex processes, like cloud cover, which has received a lot of attention lately, about surface hydrology, about oceans, and so forth. So you ought to be skeptical of GCM's (General Circulation Models) and you certainly should be skeptical of the details of them. GCM is jargon for the most comprehensive of the models that exist.

The models divide the world into grids and boxes. (Figure 8.3) I've shaded in the center of a box on the finest resolution model used in the United States. The Europeans and Canadians have some recent results with a slightly finer grid. You can see that one grid point is about the size of the state of Colorado. That means every place in Colorado: Denver, Grand Junction, Steamboat Springs, Vail, has one value of temperature, one value of wind, one value of precipitation.

So the first problem is to decide what the temperature of Colorado is. There's

Figure 8.3

Gridpoint Locations Over Land for 4° x 5° Grid



not much resolution. We will not get any local results. Here at Berkeley our grid point extends from the Pacific Ocean, across the Bay, the Berkeley Hills, the Central Valley, the Sierra and into Nevada. Again, the model has one point of information for all that. So these models are clearly approximations. You are not going to get regional detail out of the present version of them, and that's a serious limitation, because people want to do impact studies. For example, the Canadians want to know in one particular specific place how the snow changes. Very difficult!

Well, we try to test these models to the best of our ability, against a lot of things. We can test some individual processes: radiation in the laboratory, advanced weather forecasting. You might say, "Well gee, that must mean everything's terrible, given how bad weather is." But weather is the instantaneous state, climate is the statistical state. The question is, can we get the same sort of statistics. We test against the seasonal cycle. We test against El Nino, when it comes. We test against some of the glacial data, if we can. But there is a real sparsity of information that is precise enough over the past 100 years that you might use to look ahead 100 years.

Consider the four GCM's used in the United States. (Figure 8.4) I've compared their predictions for wintertime temperatures across the country. The models don't agree well on details amongst themselves. And they are better at predicting winter temperatures than summer temperatures.

So what do models do well, and what do they do poorly? We think they do reasonably well on the global average temperature, on the north-south temperature gradient, on the change from season to season, and on wintertime temperature. They do relatively poorly on regional detail, or summer temperatures, hydrology or extreme events. The problem is if you are doing impact studies, this is the information one really wants. But if it gets a few degrees warmer in the summer in the Midwest, that could be a real problem.

We use these models nonetheless. For example, we double the CO_2 concentration and make a simulation. The modelers say that when you double the CO_2 and come to a new equilibrium, you get a temperature change of from 3 to 5 degrees for these conditions for the global average: larger at high latitudes, less at low latitudes. If however, you examine a sequence of papers over the years, you see that their predictions varied. The one that's gotten a lot of attention over the past year, the study from the UK Meteorological Office, took the very same model but changed how they treated clouds a little, by changing the optical properties as they got warmer. This gave a dramatic change in temperature for a doubling of the CO_2.

FOUR GCMs HAVE BEEN USED IN U.S. TO ESTIMATE SENSITIVITY TO CO_2 DOUBLING

GROUP	GRID	VERTICAL LAYERS	DIURNAL CYCLE	OCEAN CURRENTS	SOLUTION METHOD FOR DYNAMICS
NCAR (Washington and Meehl)	4.5°x7.5°	9	No	No	Spectral
GFDL (Manabe and Wetherald)	4.5°x7.5°	9	No	Adjusted solar flux	Spectral
GISS (Hansen et al.)	8.0°x10° (some 4°x5°)	9	Yes	Implicit at present values	Grid
Oregon State Univ. (Schlesinger and Zhao)	4°x5° 1°≈100 Km	2	Yes	No	Grid

ALL MODELS HAVE: "realistic" geography and orography
interactive, variable cloudiness
interactive soil moisture and hydrology
interactive sea ice and snow cover

Figure 8.4

This is why the NAS and the others say "Well, we are not sure what it is, but let's take a range from 1-1/2 to 4-1/2 degrees, because we think it's in that band." You have to be very cautious. But it's a very important difference! If you're a farmer in Nebraska, and it's only going to go up 1-1/2 degrees in the next 100 years, you're going to adapt your agriculture very slowly. If it's going to go up 4 degrees, and there's an amplification in the continental interior due to drying that makes it 6 to 8 degrees, so that it is 1-1/2 degrees in the next twenty years, that's going to be much more important. Right now, we can't tell you the difference.

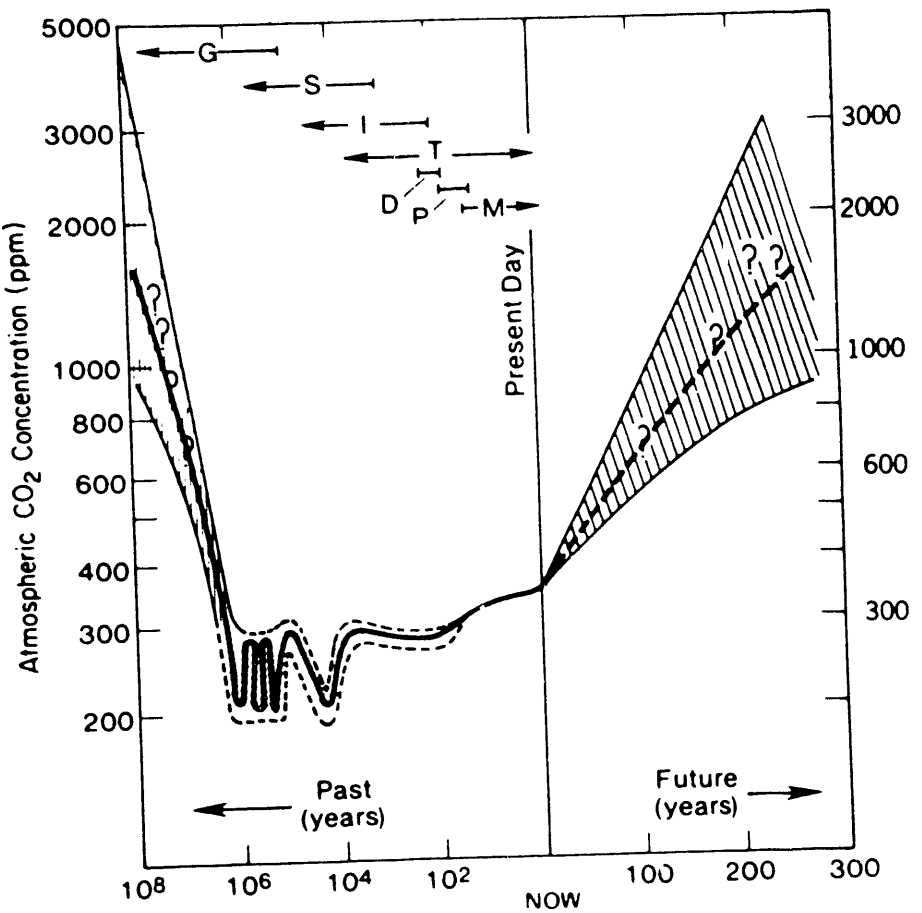
Most of the differences between models seem to be related to how they handled the clouds. There is a lot of uncertainty about what the models are showing. But I would argue that the temperature response to a doubling of CO_2 is a few degrees. It is not tenths of a degree. If it is that low we would have real trouble representing the past climate change and the seasonal cycle. And it's not ten degrees. If it were ten degrees, the climate would be changing all over the place. But, as I've commented elsewhere, I didn't say if it was Centigrade or Fahrenheit. It is certainly a factor of two, and "few" means anything from two to four. There's a fair amount of uncertainty in what's happening.

GROWTH SCENARIOS

Now these are equilibrium calculations. What's really happening is that we are slowly increasing the CO_2 concentration, and you want to know when you'll get out of the band of natural fluctuations around the present climate by a half a degree or so, and start rising into the warmer state to come. There have been a very few calculations of this. This is one from Jim Hansen that has received a lot of publicity. He starts in the late 1950's and runs into the future with three scenarios, A, B, and C. (Figure 8.5) Each represents a different amount of Greenhouse gases put into the atmosphere: corresponding roughly to unrestricted growth, moderate growth, and lower growth. The temperature starts rising maybe by about 1/2 to 1 degree into the early part of the next century. The shaded area is believed to be in the warm period 5000 to 6000 years ago that you remember from your high-school history books, when the climate of the Middle East was quite different.

125,000 years ago the sea level was maybe 5 meters higher than it is now. If we got equilibrium in this condition, we would expect the sea level to be higher. He sees this slow, steady warming well into the next century. It isn't as if it suddenly is going to be upon us and there's some great jump. He is

Figure 8.5


5000
3000
2000
1000
800
600
400
300
200
Atmospheric CO_2 Concentration (ppm)
G
S
I
T
D
P
M
Present Day
Past
(years)
Future
(years)
10^8
10^6
10^4
10^2
NOW
100
200
300
3000
2000
1000
600
300

saying that in a statistically significant way it would be different from the 19th century.

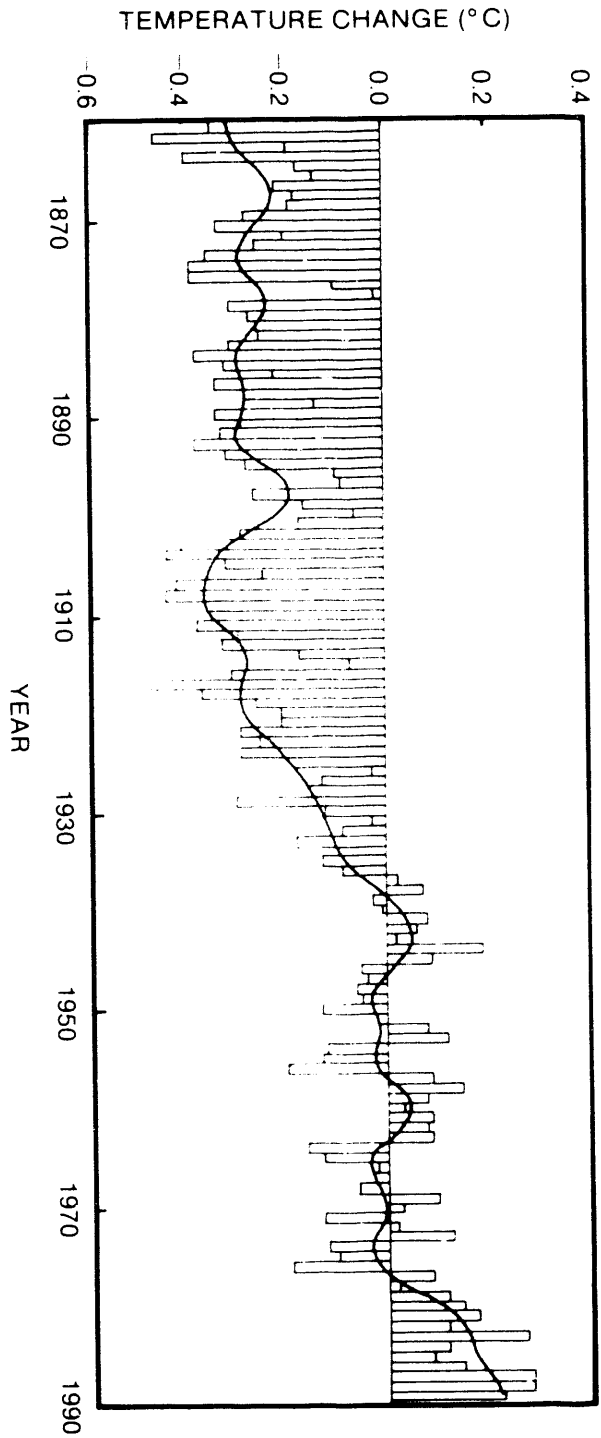
What do we think we know? It is reasonably well established that the globe's going to warm. We argue a little bit about how much. We think we understand the mechanisms, at least the amplification in the polar regions because of snow cover and ice melt-back. Certainly if you get to warmer conditions you are going to get increased evaporation and also increased global precipitation. For a number of reasons, ultimately, we think we'll get rising sea level out of it, although there are arguments about what happens to the polar ice cap, and whether you'll initially put more snow or less, and whether the melt water off of Greenland will initially reach the ocean or will seep down into the glacier and make it more dense for a while. The warming will be a little less at lower latitudes, because it takes more energy to evaporate moisture at higher temperatures. You are likely to get increased summer drying of the continental interiors, mainly because you get increasing evaporation rates. Although precipitation goes up, most of that's in the winter, and as a result you will get more frequent hot summer days.

There are a number of things that are possible that we really don't understand, mainly precipitation changes. They are likely to change, but we don't know how.

Dr. Borg asked about our reconstruction of the temperature measurements over the last hundred years. There's a lot of problems. You have to go back to the days of sailing ships to get ocean temperatures. They threw canvas buckets over the side and pulled them up on the ship, as they cooled in the wind, to get ocean temperatures. You have to adjust for a lot of different things. Those adjustments on individual measurements turn out to be as large as the kind of change we are looking at. So, one does have a problem!

But one sees some reasonably steady warming on a global basis (Figure 8.6). It is a little bit steadier in the Southern hemisphere than in the Northern. The cooling period around the beginning of the century isn't understood at all. It has been suggested recently that it could have been due to increased sulfur oxide emissions in the Eastern United States and the industrialized countries, which create sulfate particles that become cloud condensation nucleii, so that the number of droplets in clouds changes, and if you increase the number of droplets it makes the clouds brighter, and that tends to reflect away solar energy. So there are some suggestions that this can be due to man, but these are only suggestions, and we have a lot more work to do to see if that's true.

Figure 8.6


TEMPERATURE CHANGE (°C)
-0.6
-0.4
-0.2
0.0
0.2
0.4
1870
1890
1910
1930
1950
1970
1990
YEAR

GLOBAL ENVIRONMENT AND ENERGY

If you are going to do something about the environment that affects energy, you have to look for large effects. These are the kinds of categories where you might look for large effects. If you have a big effect on human health, everybody might want to do something. If you merely have more frequent hot days, you decide how you want to deal with that. In the tropics it is harder than in the high latitudes. There are suggestions that pests and tropical diseases will be more prevalent, but then you have to make a prediction about how medicine evolves. Certainly, food and fiber resources are an important issue. CO_2 enhances the growth of many plants. It also enhances the growth of many weeds. You'll have longer growing seasons, so farmers will benefit and grow more crops. You do have to worry about earlier summer drying, so you have to manage your moisture more carefully.

One of the things you have to worry about is the fresh water resource. In California, for example, if you raise the snow line, and keep precipitation the same, the maximum runoff may be higher, because more of the precipitation will be coming down as rain than snow. As a consequence, you have to lower your reservoir levels to protect against the 100-year flood. But if that storm does not come that you've protected against, then you have less snow in the mountains to run off in the Spring to fill your reservoirs for the Summer, so you will end up with less water available for agriculture. If you get increased precipitation, you have to lower your reservoirs even further. So water resources will be a serious issue.

The other issue is the potential for rising sea level. Estimates have been coming down since EPA's rather outlandish estimate of 1 to 3 meters by 2100 a few years ago.

The other night I watched an NBC special on the Greenhouse Effect? Well, it was very interesting. Steve Schneider said you have to be very careful; the press always takes extreme views, and he kept warning about caution. And the rest of the show was all extreme! The whole world is going to die! They had a picture of Washington, DC, awash in water! And they talked about not going to extremes!

In the last 1100 years sea level has gone up maybe 10 to 15 centimeters, probably from thermal expansion and melting of some mountain glaciers. The rising component comes from the flow of ice into the ocean, which many think won't happen for a few centuries, if at all. The negative component comes from more snow on the Antarctic as it gets warmer, but still below freezing. So the "central guesstimate" is still 50 to 150 centimeters by the year 2100, but I think people are leaning toward the lower number

in recent years. Even so, in coastal states, like California, rising ocean water would mean more salt water pushing up into river deltas, which could mean even more water problems.

POLICY

Cutting back Greenhouse emissions is going to be difficult, because it affects energy, it affects food and it affects health. My view is that the CFC problem is a 1% problem: you adjust costs over some scale by about 1% to deal with it. Acid rain, if you spread the cost around, is a 10% problem. Greenhouse gases are more like a 100% problem. You have to think about changing technologies. If you hope to scrub CO_2 you have to have another power plant and that takes twice the amount of energy. EPA has put out a chart on where these gases come from. About 20% comes from the United States, with 6% of the world's population. We take a lot of criticism for producing Greenhouse gases. My sense is that you have to be careful in saying that, because there are a lot of developing countries that would love to have the standard of living that we have, and that means they aspire to have the emission rate that we have.

You have to be careful about land area too. The California Energy Commission estimated how much CO_2 is produced per person in California by taking the total combustion in California and dividing by the number of people. The average number in the United States is five tons of CO_2 per person per year. Anybody want to take a guess on whether California is higher or lower?

(Guesses: "Higher!")

Higher? Actually, it's only three! The reason is the way they do their accounting. The power we get from Arizona which is generated by burning coal counts against Arizona. The energy used to make the cars we drive that come in from Japan is counted against Japan, not California. We do, however, count the energy to grow the food in California that we export. One way to help correct the United States' problem is to stop growing food and exporting carbon! That hurts the nutrition of the world, but it would reduce our carbon emissions, because we wouldn't have to use all that diesel energy.

There certainly are limitations in the models, in space, in time, and in observations. In fact, we don't have a very good baseline climate model to compare with to understand natural variability. We have problems reconciling models and observations. The models seem to be maybe two or three times more sensitive than the observations are indicating. We don't know why. And the regional changes in the observations aren't matching the

models well, so we have work to do there. There are other factors that can affect climate: solar variability, volcanoes, and on longer time scales, orbital drift and continental drift. There is also the question: Is the climate predictable at all?

Well, I guess I would say it is more predictable than a lot of people might think. Certainly winter-to-summer changes are not chaos. That's very regular. A lot of the variability occurs from natural oscillations: sloshing modes, diurnal tides that are results of natural oscillations that are excited by forces in the system. These are important for our ultimate understanding, but they are not on the scale of change we are talking about.

What do all these uncertainties mean as far as presenting the scientific results? Scientists have a hard time putting the uncertainties up front. What does that mean for policy making?

I would summarize by saying that we are going to see potentially large climate changes, and they are going to keep happening. It is a cumulative effect. We need to understand better the vulnerabilities and sensitivities. And it is going to take all of us working together to figure out what to do about it.

QUESTIONS

Zebroski: Is the gain in arable land likely to offset the loss of coastline? Say you gain arable land in Siberia but you lose coastline.

McCracken: I think any change is a problem. You can postulate that the world we are moving toward will be better, if we can adapt to it. If change occurs rapidly it will be hard to adapt, and it will be a negative impact. If we can make the change occur slowly enough so that we're technologically adapting to it, that will be a lot easier. The issue is probably not stabilizing the composition of the atmosphere, which is very difficult, but slowing the rate of change as much as you can, and bringing some balance between the impacts of these changes and the costs of getting to those new energy technologies.

Starr: The big concern is the time. What would you guess for the doubling? 20 years? 50 years? 100 years?

McCracken: We've seen of the order of half a degree over the past 100 - 150 years, about half-way to a CO_2 doubling. What we're going to see over the next 30 - 40 years, maybe because of all of the trace gases, is that we go up to the full equivalent of a doubling due to the methane and fluorocarbons. So you might see the same temperature change over the

next 30 years that you saw over the last hundred, and maybe a little more depending on the how much the oceans contribute.

Sanchez-Sierra: Can you estimate the contribution from the power sector?

McCracken: I think that the CO_2 emissions from the United States electric power is about 30%, transportation a little over 30%, commercial about 15 to 20% and direct residential use about 10 - 15%. That's putting all the credit for residential power use in the power sector.

Rossin: What about breathing? That makes CO_2.

McCracken: That's recycled. There is recycling through the plants and the food chain. The net exchange with the biosphere is about 60 million tons a year, and the variations are only a few million tons.

Rossin: Are you saying that there is a big inventory out there almost at equilibrium, and we are only talking about little wiggles on it?

McCracken: Yes. If we follow a carbon molecule, its exchange time with the biosphere is on the order of ten years. But if you add a carbon molecule to the system, the time before it gets removed from the atmosphere-ocean system is of the order of 500 to 1000 years. The exchange processes are much more rapid than the net processes.

McConnell: I just want to ask, how radical a solution would you look for?

McCracken: Well, my strategy is to do all that you reasonably can to slow the rate of the change. We are using other components of the system: the ocean, the land and other places to store the wastes of mankind. You want to reduce them as much as you can. Are you going to say we can no longer use the atmosphere? How do you balance out worrying about sea-level rise and the people in Bangladesh who may be flooded versus the 100 million people in central China who need electric power to raise their standard of living. I don't know how you strike that balance. It's difficult. So far, we've heard a lot from the industrialized countries. It's going to be interesting when the developing world starts coming into this discussion.

Comment from someone: Stick around for this afternoon!

SECTION 9

THE INDUSTRIALIZED NATIONS

Every nation has its own unique characteristics and history. And so it is with regard to energy and electricity. No single nation's story is representative of many others, but each has its story, and there are lessons to be learned from them. With many participants from the United States, it was agreed that we should not ask someone to prepare a summary paper. Categories like "industrialized nations" identify a broad class. Within that class, our participants from Sweden, Italy and Canada each agreed to discuss their particular electricity issues to help focus our discussions.

Sweden' situation is truly unique: a democracy faced with the consequences of its own political decisions. Lars-Gunnar Larsson, of the Federation of Swedish Industries warned:

"The energy policy is supposed to result in a sufficient supply of energy for households, hospitals, schools, and industries while three decisions by Parliament are respected: to start the nuclear phase-out in the middle of the 1990's, not to increase the releases of carbon dioxide, and not to use the remaining untouched rivers for new hydro power. It is evident that there are serious conflicts between these decisions.

"...The most electricity consuming industries will not be able to satisfy their need for electricity. ... It is extremely difficult to predict to what extent the increased prices of electricity will force industries to close their operations. ... Natural gas cannot be the long term replacement for nuclear power."

"... The Social Democrats feel that a future nuclear accident will happen. They feel that they cannot face such a situation without remaining committed to the nuclear shut-down. Some call it 'a vaccination for new accidents.' The politicians can say, We started to phase it out. We were wise.

"... It is frequently claimed that Sweden has solved the problem of the nuclear phaseout. That is not true. That is a lie. We are having a problem because we are not allowed to build anything anymore for

power production. ... Ironically, a limited energy supply is the greatest environmental threat.

"... Prof. Thomas Johanssen says that major efficiency improvements can make up the deficit. But the incentives are already there, and it has not happened. He says it will take education and government intervention, and admits that it could only happen 'if we in Sweden have the political will.'

"... We do not so much have a problem with public acceptance of nuclear power, we have a problem of political acceptance. In a democracy, there can only for a short time be a difference between public acceptance and political acceptance. We do not see it as possible to avoid a very difficult situation of forced choice in which most likely one or more of the Parliament's decisions will have to be revoked."

In Italy, public opposition to nuclear power, particularly after Chernobyl, led to a government decision to shut down all nuclear power. Ironically, Italy now depends on French nuclear power plants for more than 15% of its electricity. Its economy is growing faster than some other nations, but as GianFranco Cicognani reports, its balance of payments problems are growing, and the people do not yet feel the impact.

Canada's largest utility, Ontario Hydro, just completed a 25-year integrated plan. Based on four years of research, polls, interviews and computer modeling, it appears to be an excellent example for utilities to follow. [Elections in 1990 brought new leadership to the fore, and shortly thereafter, before the public hearings on the integrated plan were completed, the Government put the nuclear part of the integrated plan on indefinite hold.] Lorne McConnell, who directed the preparation of the plan, describes how it was developed and its recommendations.

SWEDEN

Lars-Gunnar Larsson: I will try to tell you a little bit about what is happening in my country. Usually, coming from a small country like Sweden to an international meeting like this, I should be flattered that there is such a great interest in my country. Here I think, Sweden may be used as a bad example rather than a good example. But nevertheless I will try to explain what is going on.

We used last year about 140 terawatt-hours (TW-hr) in Sweden. Of that, nuclear produced 47%; hydro 48%; and the rest, 5%, was fossil. It's a good

system. We have nuclear for baseload and we regulate with hydro, and we use fossil fuel for peak load power.

Industry in Sweden used 51 TW-hr, which is about 36% of the electricity use in Sweden. And about 2/3 of that is used by the electricity-intensive industry: paper and pulp, iron and chemical industries. Also, we are very dependent on the international market. We export half of our industrial production.

The referendum system is only advisory. The decisions can only be taken by the Parliament. In 1955 we had a referendum on which side we should drive. At that time we were driving on the left side of the road, as Britain still does. The result was that with a majority of two to one we rejected the idea of driving on the right side. We wanted to continue to drive on the left side. In 1967 we changed to driving on the right side anyhow. Why? Simply because the opinion had changed and Parliament took the decision.

In 1976 we had a change in government for the first time in 42 years. The Social Democratic government had to resign because of the election in 1976. They resigned because there was a major win by a party called the Center Party, which had an anti-nuclear platform. It is generally conceded that the reason why the Social Democratic party lost was because of their pro-nuclear position.

It is frequently claimed that Sweden has solved the problem of the nuclear phaseout. That is not true. That is a lie. We are having a problem because we are not allowed to build anything anymore for power production.

The Parliament stopped construction of any new hydro production in the mid-1970's, because why should we use our last rivers when we had nuclear? Then we had the nuclear phase-out decision by the Parliament. And in 1988, the Parliament took the decision that the release of carbon dioxide shall not be increased in Sweden.

That means that we are facing an impossible situation. We in the industry claim that we need to enlarge our industry; we need industrial growth, and that also means that we will need more electricity.

That energy policy we have now has no credibility with Swedish industry. As a result, there is today no plan for any investment in any electricity-intensive industry. I've been with the Federation of Swedish Industry for four years, and there have always been some big projects going on. Today there are no plans at all. Though no plants have been shut down yet, the mere uncertainty that the present policy gives to industry creates a problem.

The referendum that was held in 1980 concerned the safety of nuclear power, and also the question of welfare and employment. I will read to you what was said on the ballot, on those two paragraphs that won by a 2/3 majority in the referendum:

> "Nuclear power shall be phased out at the pace that is feasible with regard to the need for electric power for the maintenance of employment and welfare. In order to reduce the country's oil dependence, pending the availability of renewable sources of energy, no more than the twelve nuclear power reactors that are currently in operation, finished or under construction shall be used. There shall be no new construction of nuclear power facilities. Safety aspects shall determine the sequence in which the reactors shall be taken out of service."

Now, was the outcome of that referendum pro-nuclear or anti-nuclear? I think you could say it was both. It was pro-nuclear because it said we can operate the twelve plants that were planned at that time, but it was anti-nuclear to the extent that we are not allowed to build any more.

> [It is important to remember the emotion of the 1980 referendum campaign. In coffee-break discussions Larsson explained that the wording itself was a compromise, because some groups were demanding an immediate shutdown of all nuclear plants.]

After that referendum, Parliament decided that all nuclear power should be phased out by the year 2010. But it is important to remember that the year 2010 was not on the referendum ballot. After 1980, there was no real discussion of nuclear power in Sweden. The public sort of said that they had enough of the discussion. Then we had the Chernobyl accident, which as you know, was first discovered in Sweden.

We had a committee to look at Chernobyl and what consequences it should have for Sweden, and I sat on that committee. We gave two conclusions: 1) that the Chernobyl reactor was of such a type that it could never get a license to operate in Sweden because of its instability problems, and 2) the view of the safety of the Swedish nuclear power plants has not changed because of Chernobyl. So the results should be no change in policy because of the accident.

But the Social Democratic party, still the largest party in Sweden with about 40% of the votes, was split. On the one side they had the women and youth organizations: anti-nuclear, and on the other the labor unions: pro-nuclear. There were discussions within the party about what to do. As a result, there was a compromise: to start phasing out nuclear power in Sweden by shutting

down two reactors, one in 1995 and one in 1996. And also, we should have what the politicians call a "check point" in 1990.

Why did they do that? To understand it, one can take an analogy. The Social Democratic party had strong problems after the TMI accident and after the Chernobyl accident. The decision to phase out two reactors six years into the future is thought to be a "vaccination" for new accidents. The politicians want to say if we have new accidents, "Isn't it wise that we started to phase nuclear power out in Sweden?."

But Autumn of 1989 there was much heated debate. The labor unions, which are closely identified with the Social Democratic party, has stated several times that they are in opposition with the Government's policy. In an article published in Sweden's largest morning newspaper, four major labor leaders strongly attacked the Parliament's decision to start the nuclear phase-out in 1995-96. Their arguments are that it would change the industrial structure in Sweden, which would result in lower industrial investment and higher unemployment.

On the next day, a Social Democratic party working group, which had been assigned the task of formulating the policy of the party for the coming decade, published their report. And on the energy matters, the group stated that there were serious conflicts between the three mentioned decisions in the Parliament on the rivers, nuclear power, and carbon dioxide. There was an admission that one or more of the Parliament decisions may have to be re-evaluated. But both our Energy Minister and our Prime Minister immediately denied that the conclusions made by the policy group were against the energy policy of the government. It is, however, quite clear from the public debate that the Social Democratic party is deeply divided on the nuclear issue, and that the hot debate which has started within the party will go on for quite some time.

Several expert groups are now working on all the problems involved in carrying out the government's energy policy and they will all report to the government before Spring of 1990, and energy policy within the party will be discussed at the party congress in September of 1990.

After that debate the Prime Minister wanted a close up on the lines, and he decided that he would chair a four-member committee to review the nuclear issue and the energy issue in Sweden. That means that there will be some changes made in the energy policy of the government. What those changes will be however, is today impossible to say. I'm quite sure that there will be a postponement of the 1995-96 decision, but whether it will go further, we really don't know at this time.

It's also interesting to know that there has been a major change in public opinion in Sweden on nuclear power. The last Gallop poll in Sweden indicated the majority of Swedes think that it was good that Sweden started with nuclear power, and in May of this year 51% said that they did *not* believe in phaseout of nuclear power by the year 2010. In November of this year, 77% of the Swedes said they did *not* believe in phaseout by the year 2010. That means if you look at the polls, this is exactly the situation where we were in 1985, before the Chernobyl accident.

However, if you look at the Parliament you'll see that a majority - 66% - believe that nuclear power *will* be phased out by the year 2010. So we have a situation where 77% of the constituency believes nuclear power should not be phased out, but 66% of the Parliamentarians think it should be phased out!

Borg: Is the question "Do you believe it will happen?" or "Do you *want* it to happen?"

Larsson: The question is designed to ask whether they *believe* it will happen, and we have asked the same question to those who design the polls: if they say that people are answering the questions in the same way as what they believe will happen.

Borg: So it may not be their personal preference?

Larsson: Yes, it is their personal preference. That's the way the people who are doing these polls indicate that respondents are giving the answers. I'm not familiar with the way they are phrasing the question. That's a science in itself, but it's a valid question.

To clarify this confusing result: what the poll showed was that 66% of the Parliament believes that nuclear power will be phased out by the year 2000, and 77% of the people believe it will not be phased out by the year 2000. So we have a little strange situation in Sweden. Nuclear power may be generally accepted by the public but it's not accepted by the politicians!

Perhaps we might not have a public acceptance problem in Sweden, but more probably, we have a political acceptance problem!

Fowler: Could you explain that shift from 51 to 77% in so short a time?

Larsson: Yes, I think that there are two things that happened. First of all the labor union movement started to criticize the position of the government, which was a major thing. And also, it has to do with the environmental problem; it has to do with the Greenhouse Effect. That's new. If you look at the ballot when we had the referendum in 1980, nothing was said about

environment. The word "environment" did not go on the ballot. But I think that if you had a referendum in Sweden today on any issue, the politicians would certainly try to put environment on there, but at that time it was not there. Now, when people start really thinking about the phasing out of nuclear power and look at what are the alternatives, you find that the alternatives are not better, they're worse from an environmental point of view, and then they start to do some rethinking.

[An update on the political situation in Sweden with regard to energy policy follows at the end of this Section.]

Shackelford: Is anybody in Sweden putting together any kind of a forecast for the next 10 or 20 years?

Larsson: Yes, actually right now we are preparing to launch a study of what we think will happen - some sort of a forecast or market analysis of just that.

Shackelford: Any idea of what that's going to show?

Larsson: Yes, it's going to show a steady increase in the use of electricity. But the problem is, what could be the price? Because if we have to phase out nuclear power in Sweden, that means that the price of electricity will about double. That means that we will not have the basic industries, paper and pulp, and iron and steel, and we will have deep problems in Sweden. That means that we will not have growth in those industries.

So there are two parameters here. First, the price of electricity, and also the use of electricity. But we see that in the residential sector, the use of electricity is gradually increasing as well.

Shackelford: The way you describe the political situation, it sounds as though Parliament has said you can not build any kind of power plant. So what kind of a power plant do they propose under those circumstances?

Larsson: What we are showing is that we need more capacity. That's what we have to demonstrate to the politicians so they will give us a "go" on new projects.

Shackelford: So again, what kind of new plants are they proposing?

Larsson: Well, to back up a little bit, we have had plans to build a coal project and that has been denied by the politicians. We're thinking about importing natural gas, maybe from Norway, maybe also from the Soviet Union, but those negotiations are in limbo right now. There is a coal gasification project, a demonstration project, that a private company wanted to start in the south part of Sweden, but it was denied by the

politicians. So the situation is that right now, we don't have any plans for new plants.

Zebroski: How much independent generation do you have?

Larsson: You mean cogeneration, by factories, in large complexes, and things like that? Not very much. You have to use fossil fuel there too, and with a ban on fossil fuel, you cannot use that.

Erdmann: But did the government actually forbid individual companies to use fossil fuel?

Larsson: Well, it's more complicated than that, because we have a local veto in the communities and it's the communities that say no to these kinds of projects.

Fulkerson: I've been reading this book from a conference in Sweden this past summer, and the last chapter of that book is Johanssen's view of how to deal with these problems. His view is that the need will be met with biomass (biomass in Sweden seems to be kind of crazy, but I don't know) coupled with a very, very strong conservation program (which also seems to me to be kind of strange, because you think about Sweden as being very efficient already). But this study says, "No, there's a lot more that can be done there". So they do these scenarios which show less electricity and more electricity services, with biomass replacing nuclear power, if I recall correctly, and less CO_2 emissions. Would you care to comment?

Larsson: Sure. I think it's very important to realize that what's discussed in "Challenges of Choices", which is the name of the report, is a number of scenarios that *could* happen *if* a lot a things were to happen in particular ways. For instance, you'd have to have a lot stronger central government. The individual interests will not be able to make their own choices about where they're willing to put their investments, whether they should put it into market investments, whether they should put it in energy investments or other things. Because that study believes that the industry, for instance, only makes investments in the energy sector, so to me these are not realistic. It's the kind of scenarios that could happen. If you, for instance, invest only in new technology, which of course in most cases are more efficient than old technology — well, we've had that situation for decades. And the situation in Swedish industry is that we're using more electricity than the increase in production, because electricity has other values than just the energy factor. It has to do with productivity, cleanliness, environmental quality and things like that.

Conn: Could the situation cause the Swedish industry to start to build plants outside of Sweden?

Larsson: Yes. It has already started with the electricity-intensive industries which are not having any plants inside Sweden. The expansion plans for that part of the industry are outside Sweden today.

Li: Are you planning to buy electricity from neighboring countries as Italy is doing?

Larsson: The problem there is that we have a very good exchange of power between the Scandinavian countries, but one of the base requirements is that each country should take care of its own base load. So what we are doing between the Scandinavian countries is that sometimes we import, and sometimes we export, but we can't base our electricity use on large imports from other countries, because that's simply not viable after the agreement between the countries. Each country should be responsible for its own base.

Erdmann: May it be possible that this agreement could be changed?

Larsson: Some feel that maybe we can solve our mutual problem by importing from other countries, and clearly, that's not a viable solution.

Erdmann: In Continental Europe it is now possible to import a large amount of electricity from France.

Larsson: The situation in all Scandinavian countries is basically the same: new power plants are blocked. The most interesting situation from that point of view comes from Finland, I think, who are discussing their fifth nuclear power plant. But they will wait for those decisions until after elections in 1991.

McConnell: Do you have have programs or plans that have to do with electrical efficiency improvements in Sweden?

Larsson: Yes, If I may first talk from the industry point of view, we have a situation where 2/3 of the use of electricity in industry is by electric-intensive industry. That means that they're using so much electricity that even though electricity is quite cheap per kilowatt-hour, they're using so many kilowatt-hours that it's a substantial amount of the cost for those industries. I think that electricity is being used very efficiently in Sweden. If you look at the last decade, what has happened is that we are today using about 30% of the amount of oil that we used 15 years ago in 1975. Only 30% of the oil that we used in the mid '70s! But we use much more electricity. If you take the electricity use and look at the production,

those follow very, very close in Sweden. So if you want more production in Sweden, we need to have more electricity in Sweden. So I would say that we are much more energy efficient in Sweden than we used to be, but we are using more electricity.

Borg: What's the average age of your nuclear plants?

Larsson: The first plant started in 1972 and the last one in 1985, so the average age is about 10 years.

Rossin: Let's follow through on Lorne's question a little bit more. Are there any government initiatives which include subsidies or regulatory requirements on energy conservation? You mentioned the large industries; are there any requirements that the government has placed on them? And then, what about small industry?

Larsson: There are grants that some industries can get to help on their investment in energy conservation and electricity use. But the hope is that the utilities will get involved, and look at not only how they're selling electricity, but also at how that electricity is used. All major utilities in Sweden are now having big programs on energy services, as that is called. If you take the major consumers, however, their electric bills are so large that they have already instituted those measures that are effective from an economical point of view.

Rossin: I heard Johanssen speak at the World Energy Conference and if you listen to what he said, his point was that largely through improved conservation - and I didn't even hear that much about biomass - that substantial savings in electricity use could be made. And I'm not talking about a few percent.

Fulkerson: That's right. That's what he claimed.

Larsson: It's just not credible. Because if you look at the input that he gave, there are a lot of "This could happen if you have a lot of education...if you have government interfering, if you have ...." So there are lots of "ifs" in those scenarios. I was in a debate with Thomas Johanssen about a month ago where he finally proclaimed that his report could not be used as planning for what we're going to do with electricity in Sweden. He claimed that it was a political document to show the politicians what they could do if they had the will. But if you read it carefully you'll see that there are so many "ifs" in his scenarios that to us in the industry, it simply is not credible.

Kaprielian: To what extent do you have domestic steam heat as a utility supply in Sweden? Whatever the answer is, the next question is: Is it

possible that there might be a shift towards allowing electric generation with district heating using this by-product?

Larsson: We have quite a good program of cogeneration in Sweden but the situation is such that we have used all the economic opportunities now available. This is because you have to have a grouping of houses that should be quite dense. We have district heating in those areas where it can be used economically. We cannot use it where we have lots of villas or housing that is spread out.

Kaprielian: And the source of that energy is what - oil?

Larsson: Some places we have oil, some places we have coal, but we also in some cases use electricity for district heating systems. That is, in the part of the year when we have lots of electricity because of the hydro. We have to spill it out anyway, so then we like to use it for heating instead.

Li: Could you do more with energy storage? Could you use pumped hydro for storage of electricity?

Larsson: We have that ban on further development of hydro. Four of our main rivers are still untouched. And people generally said, "Shouldn't we leave these rivers the way they used to be since we have this wonderful energy source called nuclear power?" The problem is that first we had the decision in 1970 with hydro, we had the decision in 1980 with nuclear, and then we had the decision in 1988 with fossil fuels. There is no one in the Parliament who has looked at those sources at the same time and weighed between them. It's one decision that's followed by another. The production of hydro in Sweden today is a little bit more than 60 terawatt-hours. If we harnessed our four additional rivers, that would be an addition of 15 terawatt-hours. So even if we take all the potential hydro power we have remaining in Sweden, it's only the equivalent of three nuclear power plants.

Sanchez-Sierra: Could we say that Sweden is a kind of extreme case? Among the major industrialized nations, aren't you having the same problems? Problems with a coal plant in Florida? A hydro project in Canada? A new nuclear site in Japan? To me, the lesson is that Sweden is an important case, but still kind of an extreme case in the industrialized world.

Larsson: I would like to challenge that a little bit. I don't think we are all that extreme. As I said in the beginning, in a way I'm glad that Sweden is of such great interest here, but the difference is that Sweden is a small country. Only eight million people; everybody knows each other. We

have close links between decision-makers. We have a small moment of inertia, I think. That means from the time an issue crops up until an issue is decided upon, it takes quite a short time. And I think from that point of view it is interesting to look at Sweden because we have a small moment of inertia. Things move very fast in Sweden.

We take on a lot of views from other countries, but we implen .t them very, very fast. The anti-nuclear movement came from this country, was very fast coming to Sweden and was implemented first in Sweden. Now I see a sort of comeback for nuclear. We still have a long ways to go, but I think there are some changes. The politicians are not so sure anymore. A year ago they were very sure: Yes, nuclear power should be phased out. Now they are not so sure anymore. Now they are thinking also about the Greenhouse Effect. Maybe we should take a second look. And from that point of view I think that Sweden is of some interest. I'm not saying that we're a model country, but I think from that point of view it is an interesting phenomenon.

Sanchez-Sierra: Maybe you didn't understand me. I think that what is happening in Sweden is extremely interesting. But can we extrapolate from Sweden to the rest of the industrialized countries? If so, fine, but if not, do we need to study every country in similar detail in order to reach any conclusions?

Borg: I think what Lars is giving us is an indication of the volatility of public opinion there and whether it be Sweden, a large country or a small country, I think we all are pretty much aware of the fact that there is that same trend or undercurrent throughout the industrialized world.

Starr: But I think there is a point which the description of Sweden illustrates, which is fundamental for all the industrialized countries, and it is a fundamental point. The time constant for the political machine to come to certain conclusions politically is very short compared to the time constant for either technological change in industrial systems or for information development about the environmental issues that are involved. And so what you have is an instability in the democratic process. The instability is that the political operation goes rapidly relative to the other things that it's trying to manage, and I think that Sweden is a good example of this.

Wolfe: Let me argue just the opposite. Let me argue that I don't think there's a heck of a lot of difference between Sweden and the U.S. in the sense that in the U.S. you can't put up any large energy facility either — coal,

nuclear, dams, even geothermal — the chances are essentially not there. And I think the issue, the reason that it happens both in Sweden and the U.S., and in Italy for that matter, is that there hasn't been a need. If you look at the U.S. in the past 17 years since the Arab oil boycott, we've had a surplus of capacity. So you could be against everything. You could point out all the bad things about dams and about coal and nuclear, and therefore on each individual issue say they're bad. We didn't build them, and it didn't matter.

I think what we're facing now is a change in that environment. We're beginning for the first time in 17 years to find energy shortages in the U.S. In Sweden, I gather from what Lars says, they're beginning to face up to industrial problems with lack of power. So I think we're entering a new regime, and the issue is, how are we going to solve the new energy requirements that are developing in the 90's, which I think are quite different from the surplus situation we had in the past two decades.

Olds: I think in the U.S. there's an interesting parallel in the political instability with regard to energy matters. We heard Dr. Seaborg talk (Section 11) about his advice to President Nixon on nuclear power, and Nixon made nuclear power a high priority. The breeder reactor was our Number One energy priority development target as a follow-on to light water reactors. Then, Mr. Carter was elected, and nuclear power became the energy option of last resort, and there was no breeder, other than a continuing study, no reprocessing, and the emphasis was all on biomass and renewables.

As I recall, at Alvin Weinberg's Gatlinburg Energy Conference Number 2, Stuart Eisenstadt, who was advisor to President Carter, said they made this decision without really knowing anything about nuclear power. Now that was a monumental political shift in terms of its impact on the world as well as what happened in the U.S. But as you say, we didn't really need it at that time, so it didn't really matter that much. But now we're beginning to feel the consequences of those decisions. So I think there is a distinct parallel between Sweden and the U.S., but you in Sweden are a better laboratory on a smaller scale.

Hubbard: Furthermore, there was a reversal again in 1980 and '81, which as a matter of fact came down heavily on the renewable alternatives, but at the same time it did not bring a constructive nuclear program back into being.

Olds: The decision of the Reagan administration was that it was up to the industry to do it and it's not the government's business.

Blue: The question here is: What is the actual situation now? There is no new hydro, no fossil, no nuclear. They are at a point of crisis. What is the corresponding information in the other industrialized nations?

Starr: We're at different stages of the disease.

Blue: Are we terminal yet?

Starr: But that's the answer. It's not terminal. Let's run a scenario on Sweden. Eventually it's going to have to get changed. That is obvious for lots of reasons. But when it gets changed, by that time, if it doesn't get changed soon, there will be a shift in the industrial pattern of Sweden. Many Swedish industries will move out to other countries, and the big companies I know in Sweden have already established relationships in Western Europe and elsewhere, and they'll shift their big energy absorbing technologies into other countries. There will be less employment, a lower GNP, and so on, depending on how this gets done and the rate at which this occurs. Sweden has tremendous numbers of public services for the individual and a lot of that will have to get cut down. So it's a question of when the cure begins to work. It's a natural result. And one of the things you hope to do in the other countries is somehow to call the attention of the decisionmaking bodies to the course of this disease, in order to prevent it from coming to a head in every other country of the world. That's the problem.

Gottlieb: All right, say I have a picture of the Swedish situation. Now, if we go over other individual industrial countries, how critical is the problem in each of their cases?

Starr: Well, you've heard about the U.S. from Bert Wolfe. The likelihood of being able to get approval for any big station in the U.S. is very small and for nuclear particularly small, and it'll take legislation and administrative changes to really open up the door for any decision making. In the UK you have in effect a de facto moratorium on new nuclear stations as a result of the Thatcher reorganization and privatization program, so they'll complete what they've got but the likelihood of new ones being authorized is quite small. In Germany there's a big battle going on about everything, and how its going to go is uncertain. France is the only one that has laid out a policy that they plan to continue. In Italy it's been practically dead on everything. Japan is continuing, but Japan is getting

the first symptoms of an infection in terms of public opinion. If you call it a disease, there's various stages of this occurring in all the major industrial countries.

Eibenschutz: Are you talking only nuclear?

Fulkerson: He's only talking nuclear.

Starr: Coal and nuclear.

Eibenschutz: There's one important question that I've been meaning to ask Lars from the beginning. When do you expect shortages — actual shortages? The demand keeps growing....

Larsson: If you look at the demand curve and the supply curve, they'll meet sometime around the mid-1990's. We've also had plenty of rain the last few years, which means we've got a lot of hydro. And statistically we'll have a couple of years now with good summers, which means we'll have not very much rain. So of course it depends on the statistics, but sometime in the 1996 - '97 time, we see the supply and demand curves crossing each other.

Fulkerson: Is it too early to ask, Lars, if public opinion and ultimately political opinion continues to grow toward accepting more nuclear power, and you may again be considering new nuclear plants, are you at the point yet where you've thought about what kind of plants?

Larsson: No, that's too far ahead for us. Let me give you two scenarios which are in the Swedish thinking. One is that we'll not have any more Three Mile Islands or Chernobyls anywhere. The other situation would be the reverse. There's no doubt in my mind that if we have some sort of an accident or major incident, then all the politicians will jump on the bandwagon and say, yes, we have to get rid of nuclear power. So, its very crucial for us that things do not happen, neither in Sweden nor anywhere else. That's the reason why the Social Democratic party changed and had this premature phasing out in 1995 and '96. That is their vaccination for new accidents.

Shapar: I was waiting for you to say what the extreme case was in Europe. Probably Austria, with a completed plant just shut down and closed.

Sanchez-Sierra: Or Italy, where they shut down their plants that were in operation.

Hubbard: Lars, another point of information on the Swedish situation: What's being done in Sweden now and by whom, to inform the people, the politicians, whoever, of the implications of the situation that you see

yourself getting into? You said your crossover point will appear in the mid '90's - that means you should be building something now, or deciding to build something now. What's being done to inform the public?

Larsson: We have, in the Federation of Swedish Industries, started a program to inform the people who work in the industry of this, and I think it may also have an effect on public opinion on nuclear power. So we are starting an information program for our own people in the industry and also we are writing articles, talking at radio and television stations and things like that. I think we're gradually seeing a change in attitude. It's slow, but it's positive.

Rossin: I think if there's anything that drove my thinking as to what the key issues were for us, its perhaps the last discussion that we've had. Because it comes back to lead time. Energy facilities take a number of years, the public doesn't feel the pain at the time those decisions have to be made, and the question is how can you inform a public that there are problems that are a few years ahead and yet they don't feel anything right now. How do you get them concerned enough to get them to take a forward looking attitude - the kind of attitude that industrial leaders have to take, that utility leaders have had to take in this country, but that is not a very palatable position for politicians.

Zebroski: My favorite book of recent years is "The March to Folly" by Barbara Tuchman, in which she holds forth on how countries can follow policies which are to their own detriment for long periods of time. I think in this country we have a difficulty in that many of these decisions are never explicit. It's like "the death of a thousand cuts." The public does not really understand that last process. We talked about the expense of nuclear power. It's expensive because of this very process. The Japanese are building a plant in 39 months and the French still do it in 60 or 70 months, so the high cost in this country, which is the real negative, is a consequence of that process. We seem to have found a way to make policy decisions where the damage is many years later, and those who make them are far out of the picture.

Erdmann: Perhaps we could discuss new evolutions in Europe involving the opening of the East, because this will create a need to adjust existing strategies and scenarios. Look at the Federal Republic of Germany. All these energy scenarios which were made in the last ten years expect a constant energy demand — no growth anymore. Perhaps more electric-

ity, less oil, but overall energy demands were stable. Also, the assumed population is stable or even declining. But when you add the people which are coming every day to the West, then it adds up to about one million people during the last two years! So now is the first time in 20 years that the population in Germany is growing! And of course, all these scenarios about energy demands must be thrown away. They are not valid when you have one million people more. They will obviously ask for more electricity.

Starr: The statement was made by Mr. Larsson that if there isn't another TMI or another Chernobyl, things are going to go pretty good. I think the Western world can control its nuclear plants so that there won't be another TMI. I'm willing to accept that as an extremely low probability. On the Soviet RBMK (the Chernobyl design), however, we have yet to see any solid evidence that the USSR has done anything tangible that reduces the possibility of another RBMK failure. In spite of all the literature, all the talk and all the reorganization, the information I have seen in the professional press suggests that the actions that have actually been taken are minimal. They've reorganized the players, but not the machine. I think that the RBMK reactor as a machine is in a completely different category than the Western world power plants, and that one should not face the future of nuclear power planning in the Western world based on the hope that they're not going to have another RBMK reactor accident.

The second point involves the people who are staying in the East. They are counting on the Western countries helping them in building up their infrastructure, and the only way to do this very fast is to deliver to them electricity. So East Germany, Czechoslovakia, Hungary are all waiting for deliveries of electricity, especially in the winter, in order to avoid pollution, in order to avoid the shortages which exist in East Germany, and indeed, in the whole East bloc.

Kaprielian: I'd like to make one observation, and that is that everything we've said today in commenting on the Swedish situation seems to center around current technologies. It seems to me as we think about our final statement, and I'm putting myself in the position of a reader, there could very well be the criticism that these guys gathered around and just talked about what everybody knows about already, and nothing was suggested about whether some energy storage capability could be developed with the surplus of hydro you have in Sweden. Does it fit into the mix in any way? Is any consideration being given to compressed air,

batteries, fly wheels, these other technologies which we have looked at and talked about over that last 15-20 years? Are we eliminating these possibilities in these discussions? Lars, does storage figure in Sweden?

Larsson: We have been trying to do a lot with storage, but we have not come out with anything that you don't have. In our statement we should make clear that we do believe in future technologies, there's no doubt about that.

ITALY

GianFranco Cicognani: Italians know they must cut back on their heavy dependence on imported oil. But, little hydro potential remains, there is strong opposition to coal and there already are very stringent limits on emissions because of concerns about acid rain. This means that in the near future, natural gas is going to play a significant role in the production of electricity. A pipeline from North Africa will provide large, stable supplies of natural gas.

Electricity use in Italy has increased about 5% per year for the past three years. There is very strong dependence on imported oil and gas for electricity production. Hydro sources make up 25% of domestic supply and there is a very limited contribution from geothermal energy. Hydro sources are being used to their full capacity. There is also an effort to modernize older fossil-fueled plants.

Over the past few years, imports of electricity from foreign countries, mainly France, have increased to the level of 15% of all electricity in 1989. Integration with Europe will mean compromises between national necessities and European necessities. In the context of a unified European energy market, Italy could play an important role in the natural gas sector, thanks to its interconnections with the producing countries, particularly in North Africa.

As far as nuclear energy is concerned, even though all of the existing nuclear energy plants have been shut down, Italy has decided to retain a research and development effort in order to arrive at solutions characterized by a very high degree of safety and reduced environmental impact. It is planned that this endeavor should be carried out in strict collaboration with similar programs in Europe and the United States.

McConnell: With the description of the situations in Italy and Sweden as industrialized countries, we've asked you, Lars, is Sweden an extreme case? I think that the general response that we've heard around the table

is, perhaps not. Perhaps its just helped to characterize the situation that many industrialized nations are facing in different degrees: a situation where there is indeed a very complex set of issues that have to do with politics, and also with technical options, and with emerging environmental issues that are making the world seem very complex. We don't want to "cry wolf", and say that we're about to have power shortages, but it's quite clear that as time proceeds, that day of reckoning is getting closer.

This poses for all the industrialized nations a question of how one deals with that problem on a timely basis. What can we do by way of leadership to put forward a position that will either resolve energy supply impasses, and prevent major consequences, or at least mitigate them? What Lars has outlined this morning has at least put the problem in a little clearer perspective!

Borg: It occurs to me that is there a common denominator in all the industrialized world and perhaps descending into the less developed countries as well, that has to do with surpluses that allow the country the luxury of banning the use of fossil fuels, banning nuclear plants, large base load plants. Is that basically a threat that runs throughout? And conversely, where there are shortages, those sorts of bans and considerations, don't the people affected have a voice? Germany seems to be on the fence, but you suggest that it's going to turn around too as their demand goes up. Is that basically what all our problems have been...that we've had the luxury of surplus capacity?

Starr: There's a quick answer to that one. It's the definition of what you mean by surplus. Every electric utility system, if given the freedom and if it can raise the money to expand, expands enough to meet some reliability criterion. This means that it has in reserve a certain amount of power producing equipment (in the US 20% is considered comfortable as a rough number) to take care of the unanticipated failure of equipment. And so the customer never feels this. If everything runs very, very well, that reserve can always be used for additional load purposes.

What has happened in the U.S. is that in many of the major utility systems, that reserve capacity has been been gradually drawn on for normal load purposes and the reliability then is on the edge of failure. Then the risk of brownouts and blackouts becomes greater. So there is a variable called reserve, and you can play around with the delays, inadequate planning for the future and so on, but you might pay for it at the expense of reducing the reliability of the system.

Wolfe: Let me answer a little differently. I think what happened in a large number of industrial countries after the Arab oil boycott and the price of oil and energy in general doubled, is that the electricity use growth rate went down. In this country it still grew, but it went from 7% a year to 4% a year. At the time of the Arab oil boycott in 1973, we were planning on a 7% per year growth, so there was a lot of capacity that was in the pipeline. Even though we cancelled a hundred nuclear plants in this country, we had, instead of the 20% normal excess capacity that was mentioned, a national average of 33% until recently. I think that was in general the situation in the industrialized countries. One difference was France, where as a result of the Arab oil boycott, they concluded that they had no indigenous resources. They just decided they were going to switch to nuclear. But in most other countries, people saw they had a surplus and therefore it wasn't necessary to do anything.

Borg: Well, by surplus I mean adequate margins.

Wolfe: You mean more than adequate margins!

Starr: But the point is that commitments to build those power stations for the future had been made in the early seventies, so when the economy stopped growing so fast in the seventies, these plants had already been built. So what would have been a normal 20% reserve came out to be a 30% reserve. And now that reserve is now being used up.

CANADA—INTEGRATED RESOURCE PLANNING

Lorne McConnell: What I'd like to do is take a few minutes of your time to talk about a case example that applies in Canada, in the Province of Ontario, where I've been responsible for the planning and for designing the process.

The Ontario Hydro 25-Year Integrated Plan was the result of a commitment my company made. We came to the conclusion that our traditional way of planning for meeting projected demand and reserve requirements by doing our own planning and then presenting our decisions to the Provincial Government as "the way to do it" would no longer be successful. So we combined our planning into a process that involved the public. For three years, we conducted public meetings as our plan was being developed. We interviewed thousands of persons, did in-depth polling, and analyzed popular attitudes on the options we had under consideration. We committed to do all we could that would be responsible and cost-effective on the demand side, and only then to determine the capacity necessary to meet the

resulting demand. We analyzed more than 100 scenarios. Our investment plan, its major components of demand management and energy supply is summarized below:

Total New Requirements	21,600 MWe	
Demand-Reducing Options		5,900 MWe
Renewable and High-Efficiency Supply Options		4,200 MWe
New Base-Load Supply (Nuclear)		7,100 MWe
New Peak-Load Supply (Gas-fired)		4,300 MWe

Yesterday we got into a discussion about when we use various words and what we mean by them. Sometimes, even when we think alike, we don't always put the same value on words. In terms of starting with the obvious, I think all of us would agree, if we're talking about energy in the most elementary sense, it is vital to the wellbeing of all of the industrialized nations. There's a loop between the word *energy* and the word *people* — ultimately, that's the loop, as I see it — that we have to close.

The second word I'd like to talk about is the word *need*. In our company we've found that we've enhanced our communication with the public by clearly separating between the word *needs* and the word *requirements*. In an elementary sense, we talk about it being dark out at night, and we want some light to help us to see. We're meeting a need. If we're talking about it being cold outside and we want some energy that will keep us warm and comfortable, we're meeting a need. One can go on with thousands of examples - whether we want to provide some cooling in order to make us more comfortable in the heat of summer, or whether we want a machine that will preserve our food, a refrigerator or freezer, or whether we want to make the utensils that we eat from more sanitary by washing them with hot water. We've got a whole range of needs.

Now when we want to bridge the gap between needs and requirements, without denying the needs of industrialized nations, we can do things that will reduce the amount of energy that is needed. That, of course, falls into doing things more efficiently or doing them differently. If we're substituting a microwave for a regular oven, we may very well be reducing the amount of energy that is *required* and we're performing the cooking of the food with less energy. So we can reduce the requirement of energy while meeting the need. Now in an industrialized nation, is it our intent to try to change the needs? In the intensive public review that we've had in our province we've been told, "Now look, we're living in a free society - don't try to change my needs. I don't mind if you intervene in terms of trying to reduce the requirements."

With a few rare exceptions, the process that we're following is if you're going to provide energy to meet people's *needs*, that's *supply*. And if you're going to influence the amount of energy that is required to meet the needs, that's demand management. And there is a question: Will demand management provide all of our needs from now into the future? That becomes a quantitative question in which you address opportunities for reducing the requirements while meeting the needs.

Fulkerson: That's not a play on words, that's a very clear definition. That's very important.

Starr: Lorne, this is something I know you know, but on demand management, there are two sectors: demand management which is under control of the utility, and demand management which is under control of the user.

McConnell: You're a good straight man. Chauncey has already said it, and I can repeat it here. We conducted 10,000 interviews: 4-hour interviews with men and their wives, in their home settings on Saturday mornings. We talked to them about their values, and when we came to the question of whether or not it was socially acceptable for their electric utility to be trying to influence the amount of electric requirements, it came through loud and clear, they want to make their own decisions. How the electricity is supplied is the utility's job, but how it is to be used is not.

But if, in fact, there's going to be anything mandatory, such as saying that all refrigerators have to be built to a higher standard, that's a job for the government. As a utility, we quickly got our act together and differentiated the role of government, that would influence requirements for that arm of demand management that would be done on a compulsory basis and said that it's the people that are going to get elected that have to stand up and tell people that there is going to be an imposed standard. And I think in our province that will happen and it is happening. The compulsory component that will come about through standards will be imposed by governments; the amount that can be influenced by the utilities is done on a voluntary basis.

Rossin: Where do government subsidized incentives come in?

McConnell: You mean will you raise the price? I can't speak for the rest of the world, but in the province in which I live, we went out and asked is it acceptable that we bring about a reduction for the demand of energy by raising the price of electricity above what it costs? And the answer was a resounding "No!" It quickly became quite clear that the Chairman of

our company would not remain the Chairman if he tried to raise electricity prices above cost.

Fulkerson: Does that preclude price changes that reflect low production costs, like time-of-use rates?

McConnell: No, that does not influence time-of-use because time-of-use is related to cost.

Fulkerson: As long as it matches costs — that's OK. But you're not talking about marginal cost now, you're talking about average cost, right? I mean, is the tradition in your province that you charge an average price for electricity or a marginal price for electricity?

McConnell: The average customer pays the average price, but on the other hand, we do have time-of-use rates and so on.

Fulkerson: So the average customer doesn't pay what economists would call the correct price for electricity, which is the marginal cost.

(Many voices: No! No!)

McConnell: That gets into a deep philosophical argument.

Fulkerson: No it doesn't! That's one of the things that's wrong.

Starr: The average customer does not pay the marginal cost.

Fulkerson: He should!

Starr: I know, but what he pays is the average cost because that's what he's billed.

Fulkerson: That's right, but what he should pay is the marginal cost.

Starr: Perhaps, but the economists have argued this out with the ratemakers for decades now. The answer to the question is, the customer pays the average cost and the last customer, who ought to pay the marginal cost, does not pay marginal cost.

Erdmann: In Europe there is now a very strong discussion about this point. I think that in Switzerland we are going in the direction of marginal cost electricity pricing. And what does marginal cost mean? It means the cost of the next power plant you build! *But it is not built!* It's not really "marginal cost" that the economists normally talk about. They say that it is marginal cost, but I say it is *additional build-up cost.* The problem is that it means that these marginal electricity prices will rise about 50%. It will be enough to stop electricity demand growth for ten years! I would like to ask the question of what is going on in other countries, because this is the major issue in Switzerland.

McConnell: Another question we asked in these interviews is, what do you think of strategic conservation? The answer was, I don't like it.

(Several voices interrupt: What is it?)

McConnell: And the second question they were asked was, what do you think it means, and they said, "I don't know." Many people said "It sounds an awfully lot to us like you're asking us to do without." And, "My neighbor has an air conditioner and I'm bloody well looking forward to getting one, and when I can afford it I want one and I don't want you telling me to do without." So, by and large, ...

Fulkerson: But what is strategic conservation?

McConnell: That's what we asked the public.

Fulkerson: I know, but what do *you* mean by it?

McConnell: I'd rather ask you that!

Fulkerson: What the hell are you talking about?

McConnell: Well, the bottom line is, we took the words "strategic conservation" out of our vocabulary.

Blue: Good! That sounds sensible.

Wolfe: Since you can't define it, you did a good thing!

McConnell: Basically, what we talk about to our public now is the components of demand management.

Hubbard: What did it mean when it was in your vocabulary?

McConnell: What it meant when it was in our vocabulary was a synonym for electrical efficiency improvement. We were using it, but we're simply not using it at all anymore. In our vocabulary we've divided electrical efficiency improvement into two components - one that has to do with improving the efficiency of the physical facilities, and the second has to do with the human aspect or the behavioral aspect of how efficiently those facilities are being used. And those are both components in what we define as electrical efficiency improvement.

Of course, in demand management there was the question of not only reducing demand through efficiency, but there was the question if one could reduce the peaks by load shifting, by valley filling, and so on. The challenge that we found was that we had to quantify all the different opportunities associated with electrical apparatus to try to get it to the same kind of mathematical accuracy as the components of building a power plant. And believe me, that is a major challenge: to stop talking superficially and start to quantify all of the components.

For example, in the Province of Ontario 38% of the electricity consumption is in the industrial sector. And in that industrial sector, 73% of it is for electric motors. When we analyzed the electrical motors in use and determined technically what is the real opportunity to improve the efficiency of the electric motors, and examined the motors that are actually available in the marketplace, for the large industrial motors, there was an opportunity to improve the efficiency by 1%. We found there was an opportunity on small motors to improve the efficiency by 12%, and in some instances even higher. But in any event, we could identify what the opportunity would be over time. That gets complicated, because one cannot achieve overnight penetration.

I think the analysis that Chauncey Starr took us through (Chapter 6), in which he took a time horizon of 2060, indicated that this was not a total solution in terms of meeting the requirements of mankind, in terms of the increasing population, and the desires for the have-nots to become the haves. In our particular instance, having gone through a fairly rigorous analysis of all these components, all I could do is reinforce the conclusion that Chauncey put forth yesterday.

The bottom line is that we're going to have to work awfully hard with a 4 billion dollar program to achieve a reduction of about 3000 megawatts by the year 2000 in a system today which is 24,000 megawatts. When we take the system size that we project for the year 2000 (30,000 megawatts) that's approximately a 10% reduction by the year 2000.

Fulkerson: Do you have an aggressive demand side program using least cost planning, where a dollar is invested on the demand side if it has a greater return than a dollar on the supply side?

McConnell: Yes, I should've said that our whole premise is economic demand management, where in fact, there is a net worth to our customers. This is within the concept of least-cost planning.

Fulkerson: And you're able to recover a fair rate of return on demand side investments as well as supply side investments?

McConnell: There are two kinds of tests. We had to go through a public review on this. One test is what is classically called the "no losers" test, in which the rates for our customers do not go up. And the other is the more liberal, social test, which has to do with the concept of total customer cost, and that's the case in which all the rates for all customers do go up, but there's a net benefit to society as a whole, as a result of the reduced kilowatt-hours that have to be provided. We use the latter: the total customer cost.

Fulkerson: The size of your system is 24,000 megawatts right now. What is the size of your system that you're projecting in 2000?

McConnell: Our planning is being done on the basis of a bandwidth concept. Our plans are to fill that envelope regardless of what happens, but nominally it would be around 30,000, and in the year 2014 we're talking about it being roughly 40,000 megawatts.

Fulkerson: But the 30,000 megawatts in 2000 assumes that it would have been 33,000 if you hadn't had demand side management. So you have a net growth in 10 or 11 years which is substantial, despite the fact that you're doing aggressive demand side management.

Borg: Now wait a minute. Does that 30,000 really assume that you've already saved 3000?

McConnell: The demand would be a bit over 30,000 without the reduction, but with our aggressive demand-side management program, we project it will be 27,000 megawatts in 2000.

Fulkerson: Okay, I think that's a very important point. It shows roughly what I think industrialized countries are going to be able to do. They're not going to able to totally stop electric demand by demand side management, but they're going to able to slow it down. That's basically what's going to happen.

McConnell: It's my contention that in industrialized countries, in order to make the public and the politicians come to grips with reality, there has to be an integrated demand/supply discussion.

Fulkerson: Absolutely! Absolutely!

McConnell: And that any piecemeal discussion in which people say we don't want hydro one day, and then another day say we don't want nuclear, and then oppose another one ... it just doesn't work. If we're going to come to grips with the issues we're talking about, we have to somehow or other bring about the instruments in our society that will force integrated demand/supply planning and integrated supply and demand discussions.

Olds: What fraction of your energy is from hydro?

McConnell: The energy contribution of hydro in our province is 25%. The contribution of fossil is 25%. The contribution of nuclear is 50%.

Sanchez-Sierra: What is the situation right now? Can you build hydro or nuclear or fossil?

McConnell: The simple answer is, I don't know, but we're proposing the construction in our integrated plan.

Starr: Lorne, before you leave demand-side management, I want to mention experimental work that's been done for the past decade by some of the U.S. utilities. Empirically, they've been able to find they can get about a 5% reduction in peak power demand by demand-side management techniques, such as time-of-day, turning off on request certain users for a short period of time, and there's a whole series of techniques that are being practiced, but the number comes out about 5%.

Kaprielian: Chauncey, is that energy or is that capacity?

Starr: That's peak demand — peak shaving.

McConnell: I think one thing that it's fair to say is that in our situation, which is similar to Sweden and perhaps the U.S. and other countries, that we have been paralyzed since 1978. We have not committed to a major generating station since 1978. And that when we ask ourselves the question, if there is a shortage in the future who is at fault, the answer came through very loud and clear. The utility will be blamed.

And so we said, if the utility is going to be blamed, and we are responsible to provide electricity to meet the future needs, we're bloody well going to file a plan, come hell or high water, that lays out clearly an integrated demand/supply basis for the future. We filed that plan in December, 1989. It accommodates the uncertainty in terms of what the loads will be; it accommodates the uncertainties of what the yields will be from demand management; it accommodates the uncertainties that are associated with all the cost estimates that we've done with all the options, and so on.

But in any event, we've said it will be clear on the record that if this province goes without power that it wasn't because of a failure of the utility to get off its fanny and to take a position and to stand up and be counted, and to quantify everything, including all the demand management components. Behind our supporting document, which is about 400 pages long, is another pile of documents that detail all the individual components.

Kaprielian: May I ask the question of how soon that will be revised?

McConnell: Well, the document itself clearly identifies that if you're laying down a 25-year plan, you must adjust your plans annually, in accordance with the reality of the way the world unfolds. Nevertheless, if you in fact have done a 25-year analysis, that lays out a picture of the future from

which you make some decisions having to do with the next five years. And that document makes a formal application for approval to build power plants. I'm not saying how its going to end up. I'm just identifying the action that's been taken.

Kaprielian: What will be the review process then?

McConnell: The review process for that is a formal review by an environmental panel, under the Environmental Assessment Act of the Province, and that will take place during the next 18 months.

Shapar: Was there a press response when you released the plan?

McConnell: Yes. Interestingly, we had a premonition that most special interest groups would say: Your demand management targets are too low. We felt they would say that. We felt that special interest groups that were opposed to nuclear power would say that, and so on. And we felt that the political opposition parties would criticize the plan automatically, because they would be trying to get at the current government. And in a sense, we weren't disappointed. All those criticisms tended to come in. But they were relatively minor! We were extremely pleased with the general response that we got from the media and the public, because the crunch was starting to come on. We had, in fact, during the course of last winter found it necessary on occasion to cut interruptible power.

Shapar: Were your motives attacked?

McConnell: By some special interest groups, yes, our motives were attacked. We continued to be called a "monster out of control" by the usual parties that like to call us a monster out of control. Yes, it wasn't without criticism. But generally it was well received.

Kaprielian: The point is you tried to quantify all these things, and on the demand management side you had stated you were taking into account social costs as well. The question is how do you do that? How do you quantify that?

McConnell: It's a very complex question. Basically, we have a process which we call "Internalization of Environmental and Social Costs" and another process that's called "Externalization" and the process that we followed and described in our document has to do with internalization of costs. For example, in our province, if you took, for example, a social requirement that we have to limit our acid gas emissions to 214 million kilograms per annum by the year 1994 and thereafter, our plan has all the costs in it that guarantee that we'll never exceed 214 from now until the year 2014. So, by and large, all the costs are internalized in our plan. Now

there are acknowledged costs that one does not include in all of the options, and we attempt to describe those where they have not been quantified.

Borg: If you were o build a base load plant in the next ten years, what do you expect would be the options you'd use?

McConnell: Our plan identifies the options we propose to use to use. After having adjusted for the demand reductions on demand management which I've described, our strategy calls for top priority being given to hydroelectric. We have a hydro program which calls for 2800 megawatts between now and 2014, which yields about 7 terawatt-hours. We have a high priority for any non-utility generator that can sell us power by developing small hydro or burning municipal waste or wood, and we have that in our plan.

Dave: What about natural gas? Can you do it with gas?

McConnell: In terms of the economics, we are proposing to meet our new base load requirements, after we've allowed for all these other components, with nuclear units. In the case of the median forecast, that corresponds to a commitment of another 10 nuclear units, which is what we proposed.

Borg: CANDU's?

McConnell: All CANDU's, yes.

Borg: When was the last one that was built ? A long time ago?

McConnell: We've got four under construction now. They'll be finished by 1992, and then we're proposing to start the program in 1993 for the construction of the next one. We are proposing to meet our intermediate requirements, from 20% to 40%, by retrofitting our coal-fired plants with scrubbers to meet the acid gas requirements. All our new fossil options that we studied are with full acid gas requirements. And then we propose to meet our peaking requirements with gas-fired combustion turbines.

I really want to bring out a principle. And that is, that in the period from 1900 to 1945 at the end of World War II, our system load grew to 2,000 megawatts; today it is 24,000. The bottom line is that 92% of our system has been built since 1945, which has meant that up to now, with regard to our fossil and nuclear, we have not engaged in any heavy replacement program.

But when we analyzed the next 25-year period, it was very clear that even if we get 40 years out of our nuclear and fossil plants, we have to replace 8,000 megawatts in the next 25 years, and that's a very major part of our

plan. It's 50% of the supply requirement! I think that's a principle that all industrialized nations have to recognize now: we're just beginning to enter an era that, with the very heavy growth that occurred between 1950 and now, those plants are going to be coming of age to be replaced in the early part of the next century. So there's going to be a massive requirement, and when we did our analysis, it indicated that when we take replacement into account plus a very modest growth rate, in fact, our capacity requirements for the future were greater than anything we've every experienced in the past.

Fulkerson: Lorne, you had an increase in 12 years of 15% in your overall capacity, and it looks like that rate looks goes for another 25 years, leading to a 30% increase in capacity. What's the population increase in Ontario that drives that, and what's the economic growth rate in Ontario that drives that? That puts in some of the perspective that Chauncey was bringing in yesterday for an industrialized situation.

McConnell: Our median load growth that we're forecasting, excluding demand management, is 2.2% per year.

Fulkerson: And you bring that down to about one-point-something?

McConnell: That's the median; the lower value is about 1.7% per year and for the upper it's about 2.7%. We did an analysis of our population projections, and an analysis of the productivity per person. We're reaching a situation in our society where the baby boom era is already fully entered. In our society we haven't fully reached maturity on women entering the work force. That isn't a driver in this, but that's still going on. So we are projecting a somewhat different forecast from the year 1990 to 2000 than we are thereafter. It's tailing off for a time. So there's no simple answer to your question.

Fulkerson: I think its very interesting, because you've got your overall capacity growth rates down to of the order of 1 to 1 1/2%, and I bet you that your economy and your population together are growing of the order of — I would guess of the order of 3% — so that's quite an accomplishment, I would say.

McConnell: But our economy is certainly not growing at 3%, our capacity is not growing at all, and our reserve margins are getting tighter. We've only put forward a plan. We don't yet have it fully approved. There are a number of components in that plan that don't require approval, things like demand management, the purchase of non-utility generation and those kind of things, and they're going ahead full steam. The demand management program that I described is underway.

Now, I'm a Canadian, and you might be interested in the Canadian view of demand management in the U.S. There were no documents available to us that summarized demand management targets in the U.S. We looked everywhere. So we hired a U.S. company to work for us, to do an evaluation of the demand management targets that exist in the U.S. Are you interested in what we learned?

Zebroski: There is a whole host of documents at EPRI.

McConnell: Yes, we've got EPRI documents by the hundreds, but I'm talking about what the bottom line targets are. What we did in this study was to ask two things. We said we want to know, for the top 50 U.S. utilities in size, what their demand management targets were. And secondly, we wanted to know what the targets were for the most ambitious utilities in the U.S., whether they were large or small. Of the 51 large U.S. utilities that we studied, there were just under 30 that had a program.

Borg: All in California?

McConnell: No, no, all over. And the number that I identified for Ontario Hydro for the year 2000: 3000 megawatts, which is 10% of our system at that time, is the second highest number in North America. That gives you some kind of feel for the number that I gave you, in terms of the formal programs that exist in the U.S.

Fulkerson: Your approach, though, sounds very much like California's, and much like the Northwest Power Planning Council, which takes exactly the same kind of approach.

McConnell: At any rate, the bottom line that I would put here is that I think it's inevitable that all Western countries, and all industrialized countries, West or East, are going to continue to face very complex and rapidly evolving environmental requirements. The thing that I would encourage is saying that it doesn't matter how uncertain the future is, it's going to require aggressive action on the part of each nation and each utility to come forward with a plan, and force the public to come to grips with an integrated demand/supply approach.

Borg: Well, I'm curious. With these companies that you identified that have programs to control demand management, how many of them did this voluntarily the way you did it? And how many were required by their public utility commissions or energy commissions to have these programs? You did it voluntarily apparently. Is that typical?

Fulkerson: Did you do it voluntarily? You went through this as part of a regulatory process, didn't you?

McConnell: No, it had nothing to do with a regulatory process. This was our own initiative. We started this process, and it took us five years to get the strategy in place, and then one year to develop the damn plan. (Q: You beat 'em to it?) Oh, we've got our regulatory agency just like everybody else.

Borg: You didn't answer my question. How much of it was voluntary in the U.S.?

Starr: There's a general answer to that question. For the U.S. utilities, it is a mixed bag. Demand side management has been going on for a long time. Time-of-day pricing, for example, is an experiment that's been going on for decades, where there are two different sets of rates for the consumers; interruptible power pricing is demand-side management. So on a small scale, many utilities have practiced this to reduce their peak demand.

An aggressive program to do this, like getting more efficient air conditioners, was a result of a combination of things, undertaken by most utilities on a voluntary basis. The utilities actually decided they wanted to run some experiments on whether they could subsidize more efficient air conditioners to reduce peak demand during air conditioning periods, and they had to get approval from their utility commissions, which gave approval on an experimental basis. And some of those things worked. And as years went on, about five years ago, I guess, some of the big utilities tried to organize major programs. EPRI was involved in laying out the program that helped them get the data. That's why I say the results of the past few years have shown that they can reduce the peak by about 5% by aggressive demand-side management.

Fulkerson: We're talking about much more than peak power reduction in the demand-side programs. Demand-side programs that Lorne's talking about are across the board. I mean it is to improve the overall efficiency of electrical energy use, and by that, he's going to reduce his system capacity growth rate by about half by the year 2000, of what it would have been if they didn't do that. Isn't that right? And that's a very, very significant thing. That's not a 5% effect, it's a lot bigger than a 5% effect. And the Northwest Power Planning Council and the State of California are finding the same thing.

Starr: What do you mean "finding the same thing"? You mean proposing the same thing. There is no track record yet.

Fulkerson: *Doing* the same kind of thing! That is, spending a dollar on the demand side if its cheaper than spending a dollar on the supply side. It

doesn't mean you won't need more supply, you do need new supply. One thing this Seminar should come out with, it seems to me, is that this integrated demand-supply side planning is the key to sensible decisionmaking in the electric utilities. If you can buy services cheaper by making things more efficient, then by God, do it! And set up the institution so that you can make money by investing in that efficiency improvement.

Starr: I don't think any utility would argue with that. But you have to distinguish between base load capacity and peak capacity. It's the peak capacity where the biggest variable comes in. There's some small variable on the base load from demand-side programs, but that's very hard to do and takes a long time to do, because it's a capital intensive purchase on the part of the consumer.

Fulkerson: Absolutely, and you make it easy for the consumer to buy that.

Starr: But that's a very slow process. On the peak side you can do more and it's that side where most of the experimental work is being done.

Gottlieb: I think it's time to make a statement. What are we searching for? We're searching for a statement we can make about future growth, future needs for generating capacity, are we not? That's what we're searching for. What we need is statements about what judgments we can make about the growth of demand, about control of the growth of demand, the limitations on this, and about the time scale at which this will become an urgent problem.

I don't know for certain, but I suspect that one could make a statement that perhaps, with the exception of Japan and France, it appears that within the next decade that we will reach a severe supply problems in the industrialized nations. There are a limited number of things one can do about this of course. Demand control is one of them. But it's also clear that you're going to have to rely largely on existing types of generating devices. You're not going to get it out of R&D on any of these long-range solutions that many of us are talking about. They're not going to solve that supply problem within this decade. Even for the next decade, you've got to choose from existing kinds of options. That sets a kind of time scale. There's another time scale, which is a longer range time scale in which you have a different, augmented set of options, provided of course you take steps to create those options.

Li: With the creation of this 25-year plan, and then hearings, and review by the government, it sounds to me very much like government planning. In communist systems, this is generally done by the government.

McConnell: Well, in North America it's generally not done by the government.

Li: But in Communist countries, they do.

McConnell: Yes, in Communist countries, they do, or at least they used to!

Li: Do you think there is some advantage for the government to do the planning?

McConnell: I wasn't suggesting that.

Li: Of course you can't suggest that! I was just asking.

McConnell: No, if you want my opinion, I think the people who should do the planning should be people who know something about what the plan involves.

Shackelford: What you just said is important, I think, and goes to the question that I asked earlier as to the review process of that plan. In California you have an Energy Commission and a Public Utilities Commission. The Public Utilities Commission regulates the investor-owned utilities and the Energy Commission regulates the non-investor-owned utilities that the Utilities Commission doesn't regulate. All other plans have to go before both of these commissions. Only the Energy Commission has the authority in this state to rule on electric capacity generation plans.

There ought to be integrated demand-side and supply-side planning, and that planning ought to be open and subject to public review and comment. And that's what will ultimately bring these plans to a point of public credibility, because it's much more difficult to attack the plan once that's been done.

Kaprielian: One more ingredient that I haven't heard mentioned as we've discussed the plan and various resource options is the whole matter of transmission. You can have the best energy sources, but until you can build the transmission line to where the load is, you haven't accomplished very much except for expending the dollars. It seems to me it wasn't a very long while back that Ontario Hydro was faced with precisely this kind of a situation in which you had major generating stations which were ready to run and you had, at least for awhile, the inability to get the public and perhaps even governmental acceptance for the routing of those lines and the need for those lines. Now in your 25- year plan, what assumptions are being made with respect to transmission?

McConnell: That's true. In the 25-year plan the formal application includes the request for the generating station together with the necessary integrating transmission.

Kaprielian: Is public acceptance changing from what it has been in the past?

McConnell: It will continue to be, in our situation, touch and go. It will have to do with NIMBY (not in my back yard)—the local impact. On the other hand, with our process we're trying to separate the debate into two parts. One is the provincial need for the common good, and the other is the reasonable impact that we have on the local communities. At any rate, we don't have any pat answer to that question. It'll be a tough one.

Kaprielian: A follow up question. That part of the world has an almost unlimited source of hydro-electric power potential.

McConnell: Where?

Kaprielian: Just to the north and east of Ontario: James Bay.

McConnell: No. The cost of hydroelectric power in Quebec, which is adjacent to Ontario, we expect, will be higher than the nuclear option.

Fulkerson: Electricity costs in 1988 dollars? How does that change over your 25-year planning period?

McConnell: For each cost estimate, we've done an 80% confidence bandwidth analysis. As you appreciate, with the uncertainty of new environmental requirements, there has to be a significant bandwidth because of the uncertain requirements that have to be met. We expect that the bottom line costs to Ontario customers in constant cents per kilowatt-hour will be, with this plan, somewhere between plus 15% and minus 10% over what it is today. Now, interestingly, between 1950 and 1990 the rates in constant dollars are about the same.

Fulkerson: So what you're saying is, you accomplish all this and the price of electricity to consumers is going to be roughly constant!

McConnell: Actually, a significant part of that uncertainty is our cost allowances for fossil-fired plants, considering scrubbers and all the new requirements that exist now. They've raised our cost for fossil about 25% for the quarter of our energy we generate with fossil fuel.

Fulkerson: This is amazing because you're assuming you're going to build ten new nuclear plants and the cost of those is not going to drive up power costs.

McConnell: The cost of our nuclear plants corrected for inflation has not changed between 1957 and 1990.

Fulkerson: That's amazing!

Rossin: You've built them on schedule.

McConnell: We have a fairly standardized design, and we know how to build them.

Fulkerson: Maybe you should build a couple thousand nukes up in Canada and send the electricity down here!

McConnell: Actually, New Brunswick has proposed to do that with one!

Rossin: I think this indicates the depth of the discussion we could get into if we had unlimited time.

UPDATE ON SWEDEN

A year after the Seminar, Lars-Gunnar Larsson and Carl-Erik Wikdahl of the Swedish utility RSK provided the following update:

In a country like Sweden, with half of the electricity being nuclear, the nuclear program cannot be phased out without a heavy burden on the population. This is a fact which has now been understood by a clear majority in Sweden.

The Social-Democratic party, now forming a minority government, arranges its Party Congress every third year, always in September, one year before scheduled general elections. The decisions by the Congress are looked upon as commitments for the party until the next Congress.

The leaders of the trade unions, closely connected to the Social-Democratic party, have acted very determined for more than a year to change the decision of an early phase out. The result was that nuclear power became a major issue at the Party Congress in September 1990.

In the autumn of 1989 there was a very open and frank debate in the press between the two groups of the Social-Democratic party. Prime Minister Ingvar Carlsson then decided to form a group of four for an internal preparation of a new energy policy. The group consisted of Mr. Ingvar Carlsson (chairman), Mrs. Birgitta Dahl (then Minister for Environment and Energy), Mr. Stig Malm (Chairman of the Swedish Confederation of Trade Unions) and Mr. Rune Molin (then Vice-Chairman of the Confederation of Trade Unions).

In January 1990, Mr. Molin was appointed Minister for Industry, with responsibility also for energy matters. Mrs. Birgitta Dahl remained in government as Minister for Environment.

The report from the group was presented in March 1990. Its main conclusion was that three main decisions on energy matters taken by Parliament were in contradiction to the party's main goals to maintain welfare and high employment. The decisions were:

- no more major hydro power plants should be built,
- the nuclear phaseout should start in 1995,
- no increase of carbon dioxide releases above the 1988 level.

The group concluded that one or more of these decisions should be changed.

In June the Prime Minister made it clear that he was aiming at a compromise with two of the three non-socialistic parties in Parliament, the Center Party (anti-nuclear) and the Liberal Party (neutral). He said that only in this way would it be possible to come to a decision which could stand for many years.

At the Party Congress the Prime Minister asked for a mandate to start negotiations with the two other parties without being bound to the old decision of starting the phaseout in 1995. On the other hand, there was no doubt that the party did not want to change the decision about a final phaseout in 2010.

There was a vivid debate at the Congress, the leaders of the Women's, the Youth's and the Christians's associations arguing against the proposal from the party leadership. In the end, however, there was, as expected, a clear decision to give the Prime Minister the mandate he had asked for.

The leaders of the Center and Liberal parties have now agreed to start the negotiations about a new energy policy. The first meeting was on October 10 and the second on October 22.

After the second meeting it was announced that more studies are needed and that an agreement was expected in the beginning of December. After that the government will finalize a new energy bill, which was expected to be presented to Parliament in February 1991. The formal decisionwas expected to be taken by Parliament in April.

In September 1991 there is a general election. If the nuclear controversy is not solved before that, nuclear power might once again be a major theme in an election campaign. That is something which no party except the Green party would enjoy.

Now, is this a significant step in favor of nuclear power in Sweden or not? It is obvious for almost all political commentators in Sweden that the Social-Democratic party now has changed its nuclear policy. Few, if any, do believe that the nuclear power phaseout can start in 1995. That would be too costly for the country and for the political parties (counting votes in the 1991 election) behind such a decision.

Opinion polls now show clearly that there is a great majority against an early phaseout. This is also for those who say that they would vote for the Center party. There is also a majority for using the 12 nuclear units in Sweden as long as it is safe and economical to do so, even after 2010.

In opinion polls the following question has been asked:

What is your personal attitude to using nuclear power? The results:

	Nov 1989	Feb 1990	May 1990	Aug 1990
Stop nuclear now	7%	6%	5%	
Phase out faster than 2010	14%	11%	12%	
Phase out to 2010	21%	24%	21%	
Total Anti-Nuclear	**42%**	**41%**	**38%**	**37%**
Phaseout, but not as early as 2010	28%	30%	33%	
Use nuclear power, don't phase out	25%	27%	26%	
Total Pro-Nuclear	**53%**	**57%**	**59%**	**59%**
Don't know	**5%**	**2%**	**3%**	**4%**

The decision to be taken by Parliament next spring will almost certainly not contain any starting year for the phaseout and will not change the Parliamentary decision of 1980 to end nuclear power operation in 2010. It might take the political system another five years before that decision can be changed.

New nuclear plants are not permitted in Sweden according to a law adopted in 1986. A new referendum might be needed before Parliament would be ready for a change of that law. There are, however, now voices both from industry and political parties advocating new reactors to be built in Sweden in the future. That sort of talk has been a "forbidden area" in the public debate since 1986. It is obvious that the thaw at last has arrived to our cold country in Northern Europe.

Mid-January 1991 the Social Democrats, the Liberals and the Center party in Sweden agreed on a new energy policy. According to the agreement there will be no start of the phaseout of nuclear power in 1995 as decided by Parliament two years ago. No new starting date of the phaseout was mentioned.

The agreement does not mention any time limit for the operation of the twelve nuclear power units (10,000 MW) connected to the grid. The Social Democrats and the Center party have, however, announced they believe that the new energy policy will make it possible to phase out nuclear power by 2010. The Liberals said that there might be economical reasons to continue operation after 2010.

In the agreement, the three parties say that they will start a five-year program for the development of renewable energy sources (mainly bioenergy and wind) and of conservation techniques. The total cost is estimated to be 3.6 billion Swedish Crowns (700 million dollars). If this program would be successful, i.e., with the above-mentioned conditions fulfilled, then the planning for closing down nuclear power plants could start. Otherwise the operation of the existing nuclear facilities may continue, according to the agreement.

Government is planning to publish an energy bill. It is expected that the main parts of this agreement will be included. Parliament is then expected to confirm the decisions.

The Social-Democratic party now forms a minority government. The next general election will be held in September 1991. The three parties behind the agreement represent more than 65% of the votes. They will almost certainly represent a clear majority also after the election. Therefore, there now exist good conditions for a stable energy policy in the Swedish Parliament for the first time since 1976. Thus the energy policy will be a minor issue in the election campaign.

There is no need for new major power plants in Sweden before the year 2000. The next main decision on energy policies could therefore wait until after 1995.

The Swedish industry looks upon the agreement with relief. The immediate threat against a sound industrial development has been taken away. There are many signs showing that the agreement is just a first step, and that more steps will follow in the same direction.

SECTION 10

THE DEVELOPING NATIONS

This section of the Seminar is made up of three presentations plus our discussions on Latin America, China, and a study of electricity growth in a set of Asian and Latin American nations. Experience with demand-side management is limited thus far, but is part of the picture. Discussions focussed on electric supply capacity, and on financial barriers to its expansion, such as capital shortages, deteriorating infrastructure, and high financial risks. It is dangerous to generalize, but certain problems are evident to some extent in most of the developing world,

LATIN AMERICA

Gabriel Sanchez-Sierra is Executive Secretary of the Latin America Energy Organization (OLADE) made up of 26 member countries. He introduced his presentation with these comments:

Sanchez-Sierra: Few of the power utilities in Latin America and the Caribbean countries can service their debts or even meet their operating costs.

Actual energy losses are between 12 and 40 percent, including transmission, distribution and what we call non-technical losses. The "users" of non-technical losses, the main ones that is, are not the low income groups, but they are from the industrial sector and high income groups. They can afford to pay to fix the kilowatt-hour meter! Some actually bypass it! Last year we completed a report on non-technical losses in the power sector. It was very impressive to know that in some countries 40% of electricity is lost. Part of this is stolen and part is technical losses, but most of it is stolen. And in some nations, politicians try to solve the unemployment problem through the power company.

Some countries in the region have up to 40% surplus generating capacity, but they have coverage of less than 50% of the country. They paid a disproportionate share of attention to the supply side, and not enough to transmission and distribution.

We share concerns of the industrialized nations about energy and the environment. We regret this has not been a concern of yours since the industrial revolution. We're ready to work together to restore the equilibrium between energy and environment. But the industrialized countries need to realize that we should share the costs in proportion to the damage that has been caused. We want to cooperate. We don't want a confrontation. But if we care about energy and environment, we have to find ways to improve it in good cooperation between South and North."

Sanchez-Sierra presented the following talk which he titled: "The Financial Alternatives for the Power Sector of Latin America and the Caribbean."

Dr. Gabriel Sanchez-Sierra:

What I would like to do is present the results of a series of what have to be called "erratic" policies at the national level in Latin America, and also in our relations with the exogenous elements that we have to live with. I do not pretend to generalize many of the points that I am going to make here for all of the developing countries. Of course, there are many differences. But something that is true for Latin America and the Caribbean, for most of the 26 OLADE member countries, is also true in many other developing regions and countries.

This presentation is based on what was approved during our last Ministers Meeting in Lima, Peru, in November of 1989. This is the official position of the Ministers of Energy and Mines of Latin America in regard to the most critical issue of the energy sector, which for us is the financial situation in the power sector. But don't think that the financial situation of the power sector is something abstract. It is the result of many things at the management level, the operational level, the planning level, etc.

So, with that kind of framework, maybe we can extrapolate to some conclusions supported by a lot of data and two years worth of analysis.

The power sector in Latin America and the Caribbean countries is experiencing a difficult financial situation which shows no prospects for improvement. Most of the power utilities in the region are finding it difficult to service their debts and even to meet their operating costs. This seriously constrains their ability to make the investment needed to meet the growth in demand.

I will try to draw some kind of relationship between our experience and things that you are thinking are going to happen in the future if you don't pay

enough attention to the expansion of the power sector. Some of the dangers were discussed here. The fact is that we are already passing through those kinds of difficult situations.

We have identified three very important reasons why we got where we are. The first are our own responsibility. We call them indigenous problems. Second, we have problems that come from each national economy. Third, we have problems associated with changes in the international economy.

First — and this is crucial for us, the Latin American people, to understand — is that we are the main ones responsible for our situation. And, of course, we now must be the first ones to try to solve it.

Let me try to summarize the financial situation of the power sector in most Latin American countries. The first is poor planning. We have to face it. In most of our countries, planning was isolated from the rest of the economy. We didn't pay enough attention to financial constraints. It was a kind of wishful planning sometimes.

Also, we forgot some important risks. I know that countries like the United States and many of the industrialized countries right now have already developed a lot of hydro. Hydro potential is important, but in the developing countries, with a lot of geological risk, we have to pay more attention to that risk. There are many cases in Latin America where the original estimated costs in dollars per kilowatt doubled, and sometimes tripled, during construction.

Second, we have a problem of insufficient internal cash generation. There are many ways to explain why, but this is a fact of life.

Third, as a consequence of insufficient internal cash generation, we borrowed a lot of money. Especially during the 70's, when there were a lot of petrodollars coming in following the oil price shock, utilities had a lot of access to new loans, especially from private banks. So these utilities grew heavily dependent on external sources. Many people didn't think that they'd have to pay it back one day. We just worked along as if this was a free source of resources, but it was not true.

Another problem of our own making is institutional. Maybe in some industrialized countries you have it too. In Latin America especially, we have a complicated institutional framework for the power sector in many of our countries. In some cases it is like a very rich company, a good company from the financial point of view, serving a good market, the industrial market. But we don't have any way to transfer financial resources to other parts of the countries' economies.

Then we have effects of national economic policies. These are another major factor in why our power utilities are in a very difficult financial situation.

Economic recession has been the history of Latin America at least during the last decade. Economic recession means a lower demand for power, and of course, less income to the public utilities. It has been especially difficult for our hydro development. It is highly intensive of capital. But we didn't get the expected demand in order to get the expected revenue.

Also, there has been the effect of massive devaluations. Most of the investments of the power companies — at least 70 or 80 percent — has to be done in hard currencies: German marks, US dollars etc. But because of the very, very massive devaluations in our currencies, the income for the company is lower in hard currency terms and the debt is going to be much more difficult to pay back.

Another factor is accelerated inflation. At the same time that we have massive devaluation we have accelerated inflation.

At the same time, the tariffs, electric rates, were not raised. So there has been erosion, less income of course for the utilities, and that attacks their financial condition.

Another important point is financial deterioration in state oil companies. What happened in many Latin American countries was that a healthy state oil company was subsidizing and transferring money to the power company for development. Power companies would include in their budgets at least $100,000,000 a year, all coming from the oil sector. But that kind of situation changed radically during the 1980's and now, I would say, the transfers from the oil companies to the power sector are very, very rare.

Some of the problems are associated with changes with the international economy. There has been a severe deterioration in conditions for external financing. Data in most of the Latin American countries demonstrate that amortization periods for loans from the private banks and from multinational organizations have been reduced during the past 12 years. Previously, average amortization period was 15 years. But it has been reduced. Along with interest rate increases, they have had an adverse impact on the financial situation of the power utilities.

Because of the fluctuations of the dollar on international currency markets, for the Latin American region, between 1982 and 1987, the impact of the devaluation of the dollar vis-a-vis all other hard currencies, was 62% for the region as a whole. There are some countries like Venezuela where the impact of the devaluation was more than 100%. It was 124%. In Chile, the impact of this devaluation was about 70%.

There has also been a severe reduction in flows of external financing. Private banks especially are very reluctant to continue lending money to Latin America and the Caribbean. They would like to reduce their exposure. That's their main objective. With that kind of objective, external capital flows to the region have been cut almost to zero. In 1987 and 1988 and 1989, the net flow of resources has actually been negative. It means the whole region has been exporting capital to the industrialized countries. This is a situation which we don't think is going to change in the near future.

Given that the situation is very difficult, what are we going to do? We're not going to say let's close the doors and forget it. We're trying to find ways to tackle the issue. What are the prospects? What is going to happen to the traditional sources of funding?

Concerning government contributions and transfers from the oil sector, being realistic, we do not expect too much. Why? The economic situation in the region is one reason. Also the government has to pay more attention to social sectors, like health, education, housing etc. Finally, getting money from the oil sector is no longer realistic.

Concerning internal financing, there is a possibility. There are some countries that are trying to set up a kind of a power fund. It's working. But really, we're talking of an amount of money that is needed for power development of between 20 and 30 billion dollars per year. We're talking about a lot of money which is not easy to recapture from internal savings. So, it can help, but it's not enough to be a solution.

External financing from commercial banks, I would say, is unrealistic. In 1989, the only country which, in Latin America — and this is incredible — obtained an important loan from private banks was Columbia. Columbia is the only country in the region for which they didn't restructure the debt. But, even for Columbia it is very difficult to get fresh sources of funds. Countries like Chile didn't get any important private loans last year.

What about credit from bilateral and multilateral organizations? They can play a role. We are optimistic about that. We hope that the World Bank and the International Development Bank will continue lending money to the region, but according to their own estimates, it would be no more than 20% of requirements of the power sector.

So, let's talk about strategies for financing the power sector. As I said before, we are responsible. We are the main actors in what was happening and we have to be the main actors for the solution.

The first point is to increase internal cash generation. It's difficult from the political point of view, but it is the only tool that is in our hands. How?

1) We need to reorient tariff policies. We think in OLADE, and it was approved by our ministers, we need, in some countries, to pay attention to low income groups. But it is possible to have cross subsidies. But what we cannot continue to do is to subsidize medium and high income groups.

2) Recover portfolio and control losses. And here I'm talking about the most important issues in the power sector. What I mean by recover portfolio losses, is that there are many state companies, public companies which don't pay their arrears to the power company. This is an important issue. If the water company doesn't pay it's power bill to the power company, how can you manage a power company? It's difficult from a political point of view, but we have to clarify this kind of flow of money.

3) Control tangible losses: This is another important issue in Latin America. Losses in the power sector in Latin America are between 12 and 40 percent and the average is around 22-23%. With that kind of losses, how can you operate a power company efficiently? These include transmission, distribution and what we call non-technical losses. It's important to say that the "users" of non-technical losses, the main ones, are not the low income groups. There is a lot of this coming from the industrial sector and high income groups. They can afford to pay to fix the kilowatt-hour meter! Some actually by-pass it!

4) Reduce real operating costs. This has a political message. In many public utilities in the region we have a lot of political interference and political decisions. They try sometimes to solve the unemployment problem with the power company. If we want to subsidize that kind of unemployment we have to do it in a more direct and a more efficient way; not just to hire people in the power company.

5) Another possibility which we have to tackle is to rationalize investment and to improve sectoral planning. Planning which properly includes financial constraints, risk, changes in demand, and priority in grants to the rehabilitation of existing plants. This is very important. Let me give you the example of Argentina a year ago. They had, in quotation marks, an overcapacity of between 30 and 40%. When demand was high, they could not meet it. But what had happened? Most of the thermal part of their capacity was simply not operational. With a small amount of investment, rehabilitating the thermal plants in Argentina could have solved the problem much better a year ago. But we have been very supply oriented — to build new plants and to build new transmission lines.

Achieving a suitable balance of investment in generation, transmission and distribution would help. For many different reasons we have been

oriented to build new plants and transmission lines, but made very little investment in local distribution systems. There are countries in the region where they have an overcapacity of more than 40%. They have coverage of less than 50% of the country and they don't have the distribution lines to serve these areas. They paid too much attention to the supply side of building a plant, and the other part was not balanced.

6) Adjust project size. This is very important also, to adjust project size to the subsector's financing capacity. We have been very eager to build huge 2000, 3000, 10,000 megawatt dams or power station complexes to meet national or even regional long-term needs. But in the kind of situation we live in, can we accept that kind of thing? We need to change. We need to be realistic; maybe we don't have to go to the least cost economic program. Even if economies of scale would be huge, we can't finance huge projects.

Now, let's talk about national economic policy. What can we do? One possibility is to capitalize on using some contribution to the public enterprises. So let's say you're in a very bad situation, we're going to help you. But, we in OLADE think that this is a very risky measure. Because two years from now, they can say once again, "Well, the financial situation is horrible, we need more money from the government." So, even though there is a possibility, we have to be very careful with that kind of alternative.

Maybe what we need is to do what is possible from the financial point of view. Let me give you some examples. In Bolivia, the least-cost economic program can call for a hydro plant of 200 megawatts. But can they do it with the financial and economic situation that they have? The answer is no! What they can do, and this is exactly what they are doing, is to build a gas plant of 50 megawatts and go with the kind of approach that they can manage. Oil would be possible for small plants, but oil is unrealistic, and depending on oil can complicate the financial situation for the power sector even more.

Now, let's talk about national economic policy. What can we do?

First, a possibility is to rely on some governmental contributions to public utility enterprises. We in OLADE think that this is a very risky measure. Because two years from now, they can say once again, "Well, the financial situation is horrible, we need more money from the government." So, even though there is a possibility, we have to be very careful with that kind of alternative.

Second, establish a specialized national financial organization for investing in or loaning to the power sub-sector. This is a possibility. There are some

countries in which they have this kind of experience. This is not going to solve the problem; it's just one measure which can help.

Third, establish more suitable tariff structures and mechanisms to protect utility finances against exchange rate risk. This is a question of national economic policy and a political decision. In most of the power companies the managers would like to have more realistic tariffs, but they have to get agreement from the political side. This is a topic which is very hot. Some pressure comes from this country, especially with the Agency for International Development, which has been trying to promote reorganization in some Latin American countries and other parts of the world.

Now I would like to make some personal comments. We're not against privatization, but we need to be very realistic. The kind of investment that we need in the power sector in the region is between $20 and $30 billion a year. For a medium-sized country, that could mean $800 million a year. If private investors are going to invest hard currency, say dollars, they want to get a return in dollars. But we have very high inflation. A very moderate rate of inflation in Latin America right now is 200% per year. In 1989, it was about 5000% in Brazil, 3000% in Argentina... on the order of 2500% in Peru, and a very low one could be in the area of 26%!

Also you have to include political risk. The power company is not going to decide what the tariff is going to be. The tariff is going to be set by the national board of tariffs or whatever. So these are the kind of questions from our side. With that kind of situation, are private investors ready to go and invest that kind of money?

One country which is often called a good example of privatization is Chile. But what happened in Chile? We discussed it with the Chileans. They concluded that they could not privatize the power sector if they were not going to privatize the rest of the economy. In Chile they did it and it worked out. That is called a macro-economic policy.

You cannot say that the people in the power sector are going to have this kind of exchange rate, but in the agricultural sector they are going to have a different one, as if the inflation for the power sector in relation to tariffs is going to be X and in the rest of the economy it is going to be Y! You cannot manage a country with that kind of exception. You have to be realistic. If there is not a macro-economic policy, you can't privatize a single sector. Some say that partial privatization is an option, but it is not the solution for this big financial mess that we have.

Let's move to policy for external financing.

First: International organizations like the World Bank or the InterAmerican Development Bank (and this is crucial for us) must make net transfers positive. We cannot continue being net exporters of capital. We cannot continue reducing our possibilities for development. Even though this is difficult to discuss with the banks, and to be accepted by the banks, it's our position.

This means that at least we have to balance our payments of capital and interest against fresh funds from the multilateral organization. That builds our debt, but it is a lesser of evils in our view.

Second: Allow longer amortization and grace periods. Let me give you an example. We are building hydro plants for which the planned life is about 40 years. Yet we have to pay off hydro plants in no more that 12 years. Even using marginal cost analysis it doesn't work from the financial point of view.

So, what is happening? All the debt with the multilateral banks are guaranteed by the countries. If the utility company doesn't have the money, who's going to pay it? The country! And how is the country is going to pay?

One way is printing money, but that does not produce hard currency. The other way is getting money from the social sector; that is what is happening. So we have to make a political decision.

Third: Share exchange risks. At the end of 1989, for instance, the American dollar was positive for us. But if the dollar is devaluated against a basket of currencies, our countries have to pay for that. What we're saying here is, share the benefits and share the losses.

In relation to commercial banks, there is a possibility of restructuring debts over longer periods at lower interest rates. Also there are other possibilities, like schemes for regional cooperation. We have some very good examples in the region, like Santo Grande between Uruguay and Brazil. And there are very good possibilities to strengthen the interconnections between power systems.

What is important as a conclusion to all of these possibilities is that there is not a single measure to take in order to solve the problems of the power sector in Latin America. We have to improve the management, we have to improve tariffs, we have to reduce losses. There are many, many measures that have to be taken. But, I would summarize it by saying that the most important one is to improve the management of our public utilities.

And finally, I would like to say something on energy and the environment which is an important issue here at this Seminar, and also is an important

issue for us. I'm going to say what I said at the World Energy Conference in Montreal.

We share your concerns: the concern of the industrialized countries for the environment. We regret this has not been the preoccupation for you since the industrial revolution. However, we're ready to work together to restore the equilibrium between energy and environment. But also, especially the industrialized countries need to realize that we should share the costs in proportion to the damage that has been caused. This is a position which was discussed in OLADE, and I think it is going to be a dominant position. I don't want to speak for all the developing countries, but at least from the Latin American region. We want to cooperate. We don't want a confrontation. But if we care about energy and environment, we can find ways to improve it in good cooperation between South and North.

DISCUSSION

Fulkerson: There's an initiative, which I think is beginning in Costa Rica, to do something like we heard with regard to Ontario Hydro, a least-cost approach to power sector planning. One of the problems is the difficulty of financing on the demand side of the equation as well as on the supply side of the equation. I noticed in your very comprehensive and interesting coverage of the problems and solutions that this question of integrated supply/demand side planning didn't come through clearly to me. Was that part of your strategy also?

Sanchez-Sierra: Yes, it's a part. Working in that way, we got some funds from the EEC in order to have a pilot program for demand management in the power sector. In that sense we feel exactly the way you think, that it is a very important source of electricity. And maybe we can conserve even in the expansion programs in order to use energy in a more rational way.

We have a program in OLADE which we call optimizing the operation of the power sector. But it doesn't mean we have sophisticated computer quality. What we call optimizing the operation of the power sector means trying to reduce losses at the plant level, at the transmission level and the distribution level, and at the end-users level. What we have is a very successful program of loss reduction.

Last year we completed a report on non-technical losses in the power sector. It was very impressive to know that in some countries 40% of electricity is lost. Part of this is stolen and part is technical losses, but most of it is stolen.

You have that kind of situation in countries like the Dominican Republic, where they have rationing during more than 8 or 10 hours a day. And at the same time you have users complaining. They go to the power company and they say, "I'm not going to pay the bill," and the power company people say "Why not?", and they say, "Well, with this kind of turn-on/turn-off service, I got my refrigerator broken. Who's going to pay for that? My TV has been damaged."

So with that kind of very low quality of service, you start to have some additional problems. And let me give you another example: I'm going to tell you about tariffs at the residential, commercial and industrial level in all of the Latin American countries. In a country like Haiti, the residential tariff is 17%. But the company from the financial point of view is not in a sound situation. So it is not just a matter of tariffs. We have to combine it with good planning, but basically we need good management.

Stauffer: In your assessment of the power sector in Latin America, is there anything optimistic? I think I'll summarize in just a few words the perceptions of the donors of the countries who've been reviewing the power loans to Latin America, the countries who would be expected to put up any new money if any new money were to come. The obstacles are frightening.

The power sector in South America has absorbed almost a third of all foreign lending to the region, and the assessment of the donor countries over the last couple of years can be summarized as follows: With one minor exception, not a single one of those loans is not in technical default. One or more of all loan covenants have been violated. In general, the rates cover a return on capital which might be positive or might not be. The accounts submitted to the banks, the lending institutions, are so poor that it's hard to know from the financial statements whether the company is making money or not. It's next to impossible to know what it has invested. And these are the companies that are coming in asking for more money. The reaction on the part of the U.S. Treasury and the British government as well has scarcely been hospitable to these kinds of requests.

Moreover, a further problem, which transcends that of the power sector but hinges very immediately upon perceptions in the US as to any new lending to the power sector in Latin America, is the fact that in many instances we could trace the money that was lent to Latin America right

back into our own banks. For example, in the specific case of Venezuela, with which I am most recently familiar, one can show that the known deposits of Venezuelan citizens in the Miami area exceed the total known debt. So, it becomes extremely difficult to go to the Congress and get approval for funds, or to get transfers or guarantees out of the Federal financing banks under these circumstances. And the public doesn't particularly care one way or another. But the obstacles that are very real for this sector are these kinds of questions raised by the half-dozen donor countries, other than Japan, who have lost sympathy. And I don't quite know what the Latin American utilities are going to be able to do to get themselves out of this. Because for example, once a Congressman asked a very practical question: Can you believe that a company manages its investments properly if it's unable to present a set of accounts which permits one to know if it's making a profit? That's a very hard question even for a well-intentioned loan officer to answer. So your eloquent statement is almost too optimistic. The donors are beginning to lose patience.

Eibenschutz: Well, the use of the word donor in this context makes me mad. You cannot forget that most of the loans are commercial loans, and bankers are supposed to make money. The fact that there is a great deal of corruption in many Latin American countries makes these transactions particularly difficult. But you have to remember that those banks in Miami are not exempt from corruption. The banks are lending money and somehow the money finds its way back to the U.S., because in this country you also have people who benefit from that and who are not supporting the essential needs of the developing countries. I think we have to try to be as objective as possible in this confrontation between the north and the south. The simplistic answer that the immoral and corrupt are only in the south is definitely false. It is a two way street.

But I think you have to be careful of how you assess this, because ultimately, because of this nearsighted diagnosis of the situation, the whole world is going to get into a very messy situation.

Stauffer: First of all: "donors". That is the term of art used for the international lending institutions. And the donors have a great deal of trouble now justifying further lending under these kinds of conditions. I'm simply reporting the assessment made at the board of directors level of major institutions over the last 2 years. The Japanese government doesn't seem to care terribly much, but the European governments do, and have been giving more attention, particularly with the prodding from

the U.S. Treasury, to these questions. So, I'm simply noting for the record here that the attitude is much less indulgent than it was five years ago, particularly in regard to multilateral official lending.

Now as Gabriel pointed out, in the last analysis, this tends to be a political decision made irrespective of the economic merits of the projects in question, because you can always use the project loan as a transparent guise for the balance of payments. But the problems are coming from the political sources within the donor countries as well, given the budget stringency in most of them. So there's a new concern and a new reluctance. And as others have said, this is going to be worsened by the opening of the East.

Sanchez-Sierra: I would say that I totally support Juan's position because the World Bank and the IDB, they are not donors. I used to work for the Bank. And the Bank is a bank! They have been very successful lending money to developing countries. And I'll explain why. They don't care if the project is not sound from a financial point of view because at the end they know that the country is going to pay. They don't care if the money in order to pay for the power loan is going to be coming from the health sector, the education sector or whatever. And I strongly support Juan's position, because you can't call that kind of assistance "donors". It's a good business for the bank. In 1986, for example, loans just to developing countries totalled over 1 billion dollars.

But in your assessment on capital flight in Latin America, and that's why Juan is totally right, we have to be careful what we are talking about. I would say that even the loans for power projects in Latin America, from the technical point of view, are sound; they are working. We don't have the kind of mistakes like the industrialized countries had in Austria. We heard it this morning. All of hydro plants which have been financed by the IDB and the World Bank, all of them are working. Look, be very clear. From the very beginning of the negotiations, you know as a banker that the project is not sound from a financial point of view: who is responsible for that? Both parties. The country and the bank also.

The banker doesn't care because he knows that he is going to get his money. And the country doesn't care because they need the money. And that's why we try to be realistic. If from the financial point of view we find out that with a 15 year period of amortization it doesn't work, maybe what we need is a 20 year period of amortization. So we say let's try to balance this kind of financial situation of the power utilities; let's try to

have sound financial utilities in the region so you don't have to go to the government to get your loans.

When you were talking about capital flight, most of that was coming from private banks and most of that money wasn't going to the energy sector, and less to the power sector. You're talking about a period where a lot of money went to the financial sectors in Latin America, but to extrapolate that to the power sector, I think that is not fair.

Fulkerson: Why don't the Japanese care?

Sanchez-Sierra: Let me tell you something about the Japanese. The Japanese were ready to put 10 billion dollars into the IDB. Then they got a position from the U.S. government. Here we're talking about high politics. And why? Because the U.S. wants to maintain its control of the IDB. And what happened during the last meeting in Amsterdam? They were opposed to the recapitalization of the IDB. It was a success because the EEC countries and especially the president of the central bank of Holland where the meeting was held, in Amsterdam, was very strong in order to get some kind of positive response from the industrial countries to the IDB.

Here maybe we're going to talk about high politics! But you know, when you are going to talk about the U.S. Congress, you're talking about just that! Even though we respect this country very much, and we know that it is the most dynamic and most important economy in the world, we cannot accept that we have to be managed by some politicians in this country. The other thing is that you need to realize ... and that's why I was very realistic: I don't want to be optimistic, negative, or whatever ... I wanted to show you here what the situation in the region really is.

I know yesterday we had a very good presentation in which it was pointed out that the most important energy problems in the near future, in the next 10 years, will come from the demand in developing countries. So this is not an isolated problem for us. That's why I think that this is an important meeting, so we can discuss and look for ways to solve it.

Our first point was that we are the main actors in this picture. Let's improve internal net fund generation. We're not expecting more than 20% of our investment requirements from the multilateral banks. We're not saying that the solution has to come from any one in particular. We are the main actors.

CHINA

Prof. Yingzhong Lu directed centralized energy planning in China. He was on a sabbatical at Stanford and the Lawrence Berkeley Laboratory. He said,

"All energy planning in China must begin with assumptions and projections about population. Population controls everything. Scenarios with fertility rates of less than two children per family are used, but the current rate is not that low, and the future reality may not be either." [Although the Group discussed population growth and its impact, it was not featured in the Findings. Several people who sent comments criticized our failure to deal with it.]

Prof. Lu's paper on energy supply and environmental impact in China is reproduced in Appendix 1. Here is how he introduced his discussion of China's future energy picture:

Prof. Yingzhong Lu:

We are increasing what's going on in the Chinese power sector, and in the energy sector as a whole. China has adopted a centrally planned economic system since 1949. Of course, such an economic system has some defects, but it has some merits also. In particular, in the energy sector because of the long lead time and the large amount of investment needed, I see that in many countries, even capitalist countries, most of the utilities belong to the state, they are partially or wholly state-owned. In China we are an exclusively state-owned enterprise in the power sector.

Our power sector has developed very, very fast. Table 10.1 shows the growth of national income in the PRC. We have annual statistics of it so as a rule we use national income instead of GNP as a relative measure. The 1952 figure, for the first year of the first five-year plan, is taken as 100 percent. The growth is shown through 1987. In just 35 years, the national income increased just ten times: 985.9%.

Table 10.2 shows the gross energy production and consumption. Energy production increased from 100% to 1873.6%; production and consumption by 15 times to 1588.3%. The difference between production and consumption comes from crude oil exports and small amount of coal exports.

Zebroski: How is electricity counted? Is it in terms of primary energy in the fuel used to produce it?

Lu: Yes, and that includes hydro power. We have a conversion factor for hydro power.

China's electricity growth is shown in Table 10.3. It shows the growth of electricity consumption in terawatt-hours (TWh) per year. From the year 1949 at 4.3 TWh to 1987, 496 TWh it increased more than 100 times. To compare this figure with total energy growth above, from 1952 to 1987, electricity use increased by a factor of 68.

Table 10.1 Growth of National Income in PRC

(Incomes in current prices; percentages in constant prices)

Year	Aggregated National Income		Per capita National Income	
	10^9 Yuan	%	Yuan	%
1952	58.9	100.0	104	100.0
1957	90.8	153.0	142	135.5
1962	92.4	130.9	139	111.5
1965	138.7	197.4	194	156.7
1970	192.6	294.6	235	203.6
1975	250.3	384.7	273	237.6
1980	368.8	516.3	376	298.1
1985	703.1	826.6	673	448.1
1987	932.1	985.9	868	520.0

Table 10.2 Energy Growth (Ref. 20, Appx. 1)

Year	Energy production		Energy Consumption	
	10^6 tce	%	10^6 tce	%
1952	48.71	100.0	54.11	100.0
1957	98.61	202.4	96.44	178.2
1962	171.85	352.8	165.40	305.7
1965	188.24	386.5	189.01	349.3
1970	309.90	636.2	292.91	541.3
1975	487.54	1000.9	454.25	839.5
1980	637.35	1308.5	602.75	1113.9
1985	855.46	1756.2	770.20	1423.4
1987	912.65	1873.6	859.43	1588.3

Table 10.3 Growth of Electricity Consumption in PRC (Ref. 21, Appx. 1)

(terawatt-hours/year)

Year	Electricity Cons.	Year	Electricity Cons.
1949	4.3	1969	94.0
1950	4.6	1970	115.9
1951	5.8	1971	138.4
1952	7.3	1972	150.0
1953	9.2	1973	164.0
1954	11.0	1974	165.9
1955	12.3	1975	192.2
1956	16.6	1976	199.6
1957	19.3	1977	218.8
1958	27.5	1978	251.1
1959	44.3	1979	275.0
1960	59.4	1980	300.6
1961	48.1	1981	309.3
1962	45.8	1982	327.7
1963	49.0	1983	351.4
1964	56.0	1984	377.0
1965	67.6	1985	410.7
1966	82.5	1986	449.6
1967	77.4	1987	496.0
1968	71.6		

* Source: The Statistics Year Book of the PRC, various volumes.

The ratio of electricity growth to national income growth over these 35 years averaged 1.27. But there are two distinct periods: before 1980, before the economic reform, the ratio averaged 1.48. Then, after 1980 and up to '87, the ratio dropped abruptly to 0.544. Beginning in 1980 we adopted a series of measures and formulated integrated policies for energy conservation. We see real success after the implementation of these policies.

But at the same time, we encountered a serious energy shortage. This was because the centrally planned economies put emphasis, much more emphasis, on heavy industry. Obviously, this is very energy intensive. So consequently, in nearly every region we encountered serious energy shortages, in particular, electric power shortages.

If you visited China in recent years you will find that every city has some rules for blackouts. Many factories, even in Beijing, stop work one day per week to share the electricity with the other factories. And each factory gets a quota of power supply. If you use any power exceeding your quota, you'll be fined 5 or 10 times the tariff.

For each family we have only 70 kilowatt-hours per month. If you exceed the quota you'll be fined five times the tariff. I've got a European refrigerator. Unfortunately, they consume 2 kilowatt-hours per day, so I'll be fined! So we prefer to get a Japanese refrigerator. It consumes on the average of 1 kilowatt-hour per day, so we can afford it. And in the winter, we stop the refrigerator and put the food outside the door.

Hubbard: Is it a smaller refrigerator?

Lu: Similar capacity but more efficient.

Hubbard: More expensive?

Lu: Not quite so much more. The Europeans don't care about the electricity consumption of their refrigerator. It's just a small amount of their overall expense.

We are involved in the long term forecast for our State Planning Commission from the year 1985 to the year 2050. The major result of the forecast is shown in Table 10.4. We use a sector analysis approach, and analyze each sector very carefully. Our target is set by the government. The government has a very ambitious development target: by the year 2050 we must approach the lower limit of the developed countries today. We take the energy use per capita level of Spain and Italy as the target for the year 2050.

According to such a target, the total energy consumption in the year 2000 will be 1500 million tons of coal-equivalent (TCE), or 1.5 billion TCE; in

2020 that is 2.4 billion TCE, and in 2050 it is 5.2 billion TCE. The average growth rate from 2020 to 2050 is about 4% per year. The planned economic growth rate is 5.6% per year, so the ratio of the growth rate of energy consumption divided by growth rate of the economy I used above is less than 1. It is around 0.6, which means we have considered and are counting on many energy conservation measures.

To supply such a tremendous amount of primary energy we will still rely primarily on our own resources, because we don't anticipate any imported energy resource that could meet such a huge demand. Today 40% of all industrial activity in China is involved with coal: mining, transporting and burning coal.

Our oil resources are not enough for that development. As the table shows, oil starts from 200 million tons in the year 2000 and goes up to 250 million tons by 2020. It drops to 116 million tons by 2050 because of depletion of our oil resource.

Natural gas: our reserves and resource base is rather poor, so it does not contribute a very high percentage. But it still increases somewhat, and it exceeds oil use by 2% by the year 2050. However, it is still only 5% of the total supply.

Hydropower: we have plenty of hydropower, but it will be fully exploited by the year 2050, up to 263 gigawatts installed and 900 TWh per year production. It consists of just 6% of the total primary energy consumption, corresponding to 16% of our electric power supply. And some of our new energy - for instance, solar and wind and geothermal, and so forth, will not be so much, we estimate.

So a major part of our energy supply must rely on coal or nuclear or both.

The energy resources of our country are summarized in Table 10.5: The proven reserves and the potential resource, just by estimating of course. Coal - the total proven reserve by the year '87 as 769 billion tons, or gigatons, and per capita that is 710 tons, a sizable amount. The potential is even larger. Per capita, a resource of 3010 tons could be used for centuries.

But oil, with the total proven reserve of 5 gigatons, represents just 5 tons per capita. It is very small compared to our population. The potential resource is estimated at 68 gigatons, so the per capita resource of just 56 tons is so very little.

We have not found much natural gas.

Hydro: the per capita amount is equivalent to 1700 kw-hours per year. That is not so much when compared to consumption by the year 2050.

Table 10.4 Scenarios for the Structure of Primary Energy

Item	Unit	2000	2020	2050		
				Case A	Case B	Case C
Total	Mtce	1500	2400	5200		
Oil	Mt	200	250	116		
	Mtce	286	358	166		
	%	19.1	14.9	3.2		
Nat. Gas	Gm^3	40	100	200		
	Mtce	53	133	266		
	%	3.5	5.5	5.1		
Hydro	GWe	83	174	263		
	TWh	291	609	921		
	Mtce	100	210	320		
	%	6.7	8.8	6.2		
New Energy	Mtce	0	10	250		
	%	0.0	0.4	4.8		
Coal	Mt	1470	2280	5100	4370	3640
	Mtce	1051	1626	3640	3120	2600
	%	70.1	67.8	70.0	60.0	50.0
Nuclear	GWe	5	30	291	563	835
	TWh	30	180	1750	3378	5008
	Mtce	10	63	558	1078	1598
	%	0.7	2.6	10.7	20.7	30.7

Table 10.5 Energy Resources of the PRC

Resource	Proven Reserve		Potential Resource	
	Total	Per Capita*	Total	Per Capita*
Coal	769.2 Gton	719 ton	>3200 Gton	2994 ton
Oil	5.5 Gton	5.2 ton	60 Gton	56 ton
N. Gas	1000 Gm^3	936 m^3	33000 Gm^3	30882 m^3
Hydro	--	--	19 TWh/yr	1778kWh/yr
Uranium**	10 kton	0.01 kg	--	--

* Based on 1987 population value.

** Based on official published figure of uranium supply available for 15 GWe nuclear power plants.

Table 10.6 Chinese Share of Global CO_2 Emissions

Item	Unit	2000	2025	2050			
Global:							
Carbon	10^9ton	7.2	10.3	14.5			
China:							
Population	%	19.17	20.91	19.92			
				Case0	CaseA	CaseB	CaseC
Carbon	10^9ton	1.131	1.717	3.952	3.455	2.991	2.627
Share	%	15.71	16.67	27.26	23.83	20.63	17.43

Back on Table 10.4, we take three cases for the development of nuclear power. A is a low nuclear power option. Nuclear power will constitute a 10% of the total primary energy. Even so, by 2050, 291 gigawatts of nuclear power stations would be installed. If we take high nuclear option, then we have to install 800 gigawatts of capacity. That's almost impossible.

Now, to estimate the CO_2 emitted from the Peoples' Republic in the next century, we use Table 10.6. We can see in the last line of the table what our share of the global emissions will be.

If we do not adopt nuclear energy, the result is Case Zero (0). Our share consists of 27% of the total global emissions because we use extensively coal. If we take the low nuclear option, our share of carbon emissions will drop by 4% to 23.8%. If we take the high nuclear option, our share will drop to 17%, and by that time our share of the world's population is 19%. So if we do not adopt much nuclear energy, our carbon emission share will exceed our population share in the world by the year 2050.

That's an overall view of the energy future in China. The electric power forecast is summarized in Table 10.7. You can see that total energy increases from 1.5 to 5.2 billion TCE, and the share of electricity increases from 29% in the year 2000 to 50% by the year 2050. The electricity demand increased from 1200 TWh to 8150 TWh per year, and the installed capacity is enormous. It goes from 240 gigawatts to 1630 gigawatts. Hydropower supplies just 16%, and coal plus nuclear the rest: 84%. If we adopt the low case (A) of nuclear power coal furnishes 66% of all electric power generation and nuclear 18%. If we take high nuclear option then coal generates 32% and nuclear 52%.

So from these figures, our energy future should rely heavily on nuclear power, and there is no other option; our coal means not only pollution, but also the supply will be very difficult. For instance, presently we have to transport 100 million tons of coal from Yangzhee Province to the seaport and then use ships to transport such a large amount of coal to the south and the east of China. By the year 2000 we will have to transport 400 million tons of coal from Yangzhee and Inner Mongolia. And by the year 2050, if we do not use nuclear energy we have to transport 4 billion tons from the region. It's impossible, because we have not so many seaports to load the coal to the ships and to unload the coal to the south and east of China. So it's mostly impossible.

Now that's the energy future. Recently the political climate changed a little bit! The developing growth rate has slowed down, but for the long run for such a big country like China, and we have all the resources for development,

Table 10.7 Forecast of Electricity Production for the PRC

Year		2000	2020	2050		
Item	Unit			Case 1	Case 2	Case 3
Total Energy	10^9 tce	1.50	2.40	5.20	5.20	5.20
Share of Electricity	%	29.0	40.0	50.0	50.0	50.0
Electricity Product.	TWh	1200	3008	8150	8150	8150
Installed Capacity	GWe	240	600	1630	1630	1630
Among which:						
Hydropower	GWe	83	174	263	263	263
Coal	GWe	152	396	1076	804	532
Nuclear	GWe	5	30	291	563	835

* Source: Wu Z. et al, The Energy Demand of the PRC by 2050, Inst. of Nuclear Energy Technology, Beijing, China, December, 1988, p.126.

the overall growth rate will not be slowed very much. Only, to attain this goal by the year 2050 or 2070, 20 or 30 years earlier or later, eventually China will burn so much fuel and emit so much CO_2.

Starr: It seems to me you are shortchanging your coal future. As the transportation load for coal goes up the relative cost of high voltage transmission lines becomes very attractive. A mine-mouth plant now can send electricity 2000 miles on high voltage DC with maybe a 15% power loss. So it would seem to me that somewhere along the line, instead of building more railroad cars and more ships, you will go in for a high voltage DC grid and use your coal resources much more fully.

Gottlieb: There's a water availability problem in that province.

Lu: You're right. We considered mine-mouth generating stations, but cooling water is a serious problem. We considered dry cooling even, very large dry cooling towers now exist in the world. But even high voltage power lines to transmit such a large amount of electricity are also very difficult. So we must combine all these measures together.

Fulkerson: So the place for us to sell nuclear plants is China, right? Let me ask that question a little bit differently. What kind of nuclear power plants do you see being used in China?

Lu: Our nuclear policy has been debated over two decades, and we started our first plant in 1983. We adopted the PWR as a first generation nuclear power plant, but are developing the fast breeder very soon, because our

uranium resources are not so plentiful for the full development of nuclear power. Of course, currently we can import uranium because the world has some surplus. But in the future, maybe not. And besides, we consider nuclear for district heating as well as nuclear electricity, because 80% of our primary energy is consumed as heat. In the future, even by the year 2020, even until 2050, still, 50% will be used as heat. So we are also considering development of a high temperature reactor for the cogeneration of heat and power.

Erdmann: What was the population growth rate that you used?

Lu: Our population will grow at the rate of about 1.4 to 1.5% per year into the middle of the next century and then drop. The maximum population will be about 1.5 billion, and then drop slowly.

Erdmann: Well, but for your 2050 projection of energy needs, which population growth did you use?

Lu: It's a medium growth scenario. I will explain:

The current population of China has already exceeded one billion people. Even though rather effective population control was implemented in the late 1970's, the population will probably continue to increase over the next several decades. Four scenarios of population growth have been suggested by researchers for analysis of government policy.

1. The average fertility of Chinese females will decrease steadily from 2.63% (the 1982 rate) to 1.7% by 1990 and 1.5% by 1995, and then it will stay at 1.5% from then on.

2. The same as above before 2001, but return to 2.0% after 2001. This is the "two-child each family" policy for the next century.

3. The average fertility decreases slowly from 2.63% to 2.0% by 1990, and holds steady thereafter.

4. The average fertility holds at the 1984 level of 2.4% indefinitely.

The numbers for these scenarios are shown in Table 10.8.

Scenarios 1 and 2 were preferred by the authors of the energy policy study, and recommended to the Government for planning. In Scenario 1 the total population peaks by 2019 at 1.23 billion, and Scenario 2 in 2031 at about the same level. However, actual developments reveal that these are unrealistic, and the third scenario is more likely, and is being used. Its maximum is reached in 2037 at 1.44 billion, and declines slowly, but stays above 1.3 billion people.

Table 10.8 Scenarios of Population Growth for the PRC

(in millions of people)

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1983	1022.07	1022.07	1022.07	1022.07
1989	1095.56	1095.56	1100.10	1101.63
1995	1147.99	1147.99	1179.35	1207.88
2001	1191.21	1191.21	1254.04	1307.73
2007	1218.68	1247.35	1309.60	1385.78
2013	1233.57	1288.35	1353.35	1454.25
2019	1234.37	1312.92	1392.14	1530.74
2025	1221.10	1323.77	1424.52	1609.14
2031	1192.55	1328.81	1441.57	1672.32
2037	1148.47	1324.11	1441.58	1718.55
2043	1091.68	1306.09	1431.36	1761.73
2049	1026.19	1278.07	1416.53	1809.33
2055	956.37	1248.54	1397.58	1855.70
2061	887.64	1223.79	1376.16	1898.15
2067	823.27	1203.22	1355.48	1942.48
2073	763.88	1184.50	1337.29	1993.67
2079	709.39	1167.92	1320.55	2048.59

In any case, the Chinese population sill probably increase by more than 400 million over the next 40 years. That presents a formidable challenge to planners, and certainly, to decisionmakers.

The PRC economic plan calls for doubling the Gross National Product from 1980 to 2000. Beyond that, there are no stated goals, but there is the suggestion that the per capita income of china will reach the lower limit of today's developed countries in 50 years. In this study, I use a medium growth scenario. Our high-growth scenario would imply a pattern like Japan and South Korea during their take-off stages, and that is not realistic for China. But even this medium growth rate of 4.7% per year brings the per capita income of China to $4,000 in 1984 dollars by the year 2030.

Eibenschutz: China is designated by world energy planners as one of the most intensive users or producers of biomass, biogas, etc. What's their role in the future?

Lu: Presently, 80% of the energy in the rural regions is biomass, and of course we developed many hydro and biogas plants, they only account for a few percent of the total generation. So in the future we will still use biomass, but we will use more efficient means to save the biomass, and ultimately to supply commercial energy to the rural regions, so that by the year 2050, 80% will be commercial energy. The biomass will not increase in absolute amounts.

Larsson: When you say biomass you mean use of firewood?

Lu: No. Mainly agricultural waste. Our forests are meager. There is very little forest left.

Borg: Is that agricultural waste and dung?

Lu: Yes, but dung is the lowest efficiency, and makes bad smoke.

Shackelford: I was just going to ask how see the financial aspects working out.

Lu: We take on the average around 30% of the total investment in the power sector, including primary and secondary energy. It consists of almost 50% of the industrial investment for the past decade and in the near future.

Shackelford: I guess I was wondering how you feel about how the economy will go; and whether you'll be able to continue that sort of financing picture.

Lu: For the past decade we've seen a successful 30% investment to the energy sector, and it seems appropriate.

Davis: Will you be looking for outside financing?

Lu: Sure. We get outside financing sources, also but the common policy is that the total outside investment shouldn't exceed 30% of the internal to avoid debt problems.

Rossin: If the outside investment is very slow for the next few years, what happens to the plan?

Lu: That's quite possible, I fear. In particular, nuclear projects are heavily financed by outside sources.

Shapar: Is it fair to say that the use of coal in China will double by the year 2000?

Lu: To be more precise, last year we produced 1 billion tons of coal. By the year 2000, 1.4 billion.

Starr: Will you give us your guess as to what's going to happen on the environmental aspects of the use of coal?

Lu: It's very serious.

Starr: I know it's serious. But what do you think is going to happen? Do you think that your coal installations will put in flue gas desulfurizers, or do you doubt it?

Lu: I doubt that we will put in desulfurization equipment. I mentioned yesterday that on the one hand it needs high investment, and on the other hand most of the coal is low sulfur except in the Southwest region. So presently the most serious pollution comes from the particulates, the fly ash, and not the sulfur dioxide. Of course, sulfur dioxide and the acid rain not only pollute the city, they pollute the rural regions too. So the municipal governments don't care very much about the sulfur dioxide. That's the problem. And CO_2 emissions are CO_2 emissions. That's not going to change.

ELECTRICITY TRENDS

Dr. Stephen Meyers is in the Energy Analysis Program at Lawrence Berkeley Laboratory. He discussed a portion of the work they are doing on energy use patterns in various regions of the world.

Meyers: At LBL we've been looking at issues of energy demand and supply in developing countries as well as the industrialized countries at LBL. I've focused on the power sector. We look at the larger countries specifically, and try to do an overview of selected groups of developing countries in Asia and Latin America. We gather historical information

about these countries and about what their plans are. Then we make assessments of financial issues and environmental issues.

Researchers generally study relationships between electricity demand and growth in GDP (Gross Domestic Product). I wish to present aggregated data covering the seven years 1980-1987 for thirteen countries: nine in Asia: China, India, Indonesia, Malaysia, Pakistan, Philippines, South Korea, Taiwan and Thailand; and four in Latin America: Argentina, Brazil, Mexico and Venezuela. Table 10.9 shows the electricity growth and GDP growth for the year 1986-87 and for the seven years 1980-87.

In the larger Asian countries, but excluding China, energy has grown somewhat faster than GDP. Electricity has grown quite a bit faster, and the fastest growth has been in the residential sector. Although there are some similarities between Asia and Latin America, there are some differences that are quite striking. Energy and GDP have tracked each other quite closely, but the ratio of electricity to GDP has grown even faster in Latin America than in the Asian countries. There has not been very much growth in GDP, as we know, yet electricity has continued to grow at a fairly high rate.

Residential use has less impact on growth in GDP than growth in the industrial sector. Perhaps an important point is that although some new electricity supply has been added in these Latin-American nations, their economies have been beset with broader economic problems that resulted in little GDP growth during this period.

Table 10.10 shows the wide range of growth rates for the industrial, residential and commercial sectors for the countries in this study (1980-87). In the same table, the average growth rates for the nine Asian, four Latin American, and for all 13 countries.

Fulkerson: This raises an important question. Could I ask you about the credibility of the GDP as an indicator of growth?

Meyers: That's definitely an issue, but these GDP numbers are used by the International Monetary Fund and everybody else. But after adjusting them into real terms, like constant dollars, over a long period, I think there are some legitimate reasons to question the use of GDP.

Fulkerson: But the stories I have gotten from visitors from these countries is that the underground economy in most of these countries, which doesn't show up in the GDP records, is a major user of electricity.

Table 10.9 Average Annual Growth in Electricity Consumption and GDP

	1986-1987			1980-1987		
	Electricity (%)	GDP (%)	Ratio Elec/GDP	Electricity (%)	GDP (%)	Ratio Elec/GDP
China	11.0	9.3	1.2	7.4	9.5	0.8
India	7.0	3.6	1.9	8.5	5.1	1.7
Indonesia	12.4	3.3	3.8	15.8	4.0	3.9
Malaysia	7.6	5.4	1.4	7.7	4.6	1.7
Pakistan	10.3	7.7	1.3	10.5	6.9	1.5
Philippines	10.5	5.0	2.1	3.1	0.5	6.2
South Korea	12.9	10.9	1.2	10.0	8.7	1.2
Taiwan	10.3	11.1	0.9	6.7	7.4	0.9
Thailand	12.7	6.3	2.0	9.6	5.0	1.9
Argentina	6.4	1.9	3.4	3.3	-0.5	-
Brazil	3.5	2.8	1.3	6.7	2.8	2.4
Mexico	5.9	1.4	4.2	5.9	0.8	7.4
Venezuela	7.3	3.0	2.4	4.8	0.2	24
Asian-9	10.5	7.1	1.5	8.1	6.6	1.2
Latin-4	4.8	2.3	2.1	5.9	1.4	4.2
Total-13	8.2	5.3	1.5	7.4	4.4	1.7

Includes industrial self-production.

Tables 10.10 and 10.11

Table 10.10: Sectoral Growth Rates for Electricity Consumption, 1980-87

(% per year)

	Industrial[a]	Residential	Commercial	Total	GDP
China	7.0[b]	14.5	11.6	7.4	9.5
India	6.8	12.1	8.5	8.4	5.1
Indonesia	22.7	13.0	7.2	14.8	4.0
Malaysia	4.6	12.2	8.3	7.4	4.6
Pakistan	10.0	16.4	11.0	11.2	6.9
Philippines	-0.7	7.2	4.0	2.9	0.5
South Korea	9.2	11.6	12.5	10.1	8.7
Taiwan	5.4	6.6	11.7	6.6	7.4
Thailand	8.4	11.1	10.2	9.6	5.0
Argentina	3.9	3.5	4.3	3.7	-0.5
Brazil	6.9	7.4	5.9	7.0	2.8
Mexico	6.2	6.7	2.3	5.8	0.8
Venezuela	4.6	5.3	5.8	5.1	0.2
Asian-9	7.1	11.8	9.9	7.9	6.6
Latin-4	6.2	6.4	5.1	6.1	1.4
Total-13	6.8	9.2	7.5	7.3	4.4

(a) Not including self-production, except for China, for which official statistics include larger self-producers.

(b) Estimated by author to account for change in category classification in Chinese statistics.

Table 10.11: Average Growth Rates in Installed Electric Power Capacity (not including self-producers)

(% per year)

	Historic 1979-1987	Planned/Estimated 1987-2000
China	6.3	7.0
India	8.3	8.8
Indonesia	13.8	7.7
Malaysia	12.6	5.0
Pakistan	7.5	9.8
Philippines	4.5	4.7
South Korea	11.4	4.6
Taiwan	9.2	4.6
Thailand	11.3	7.3
Argentina	6.6[a]	2.8
Brazil	6.1	6.5
Mexico	6.2	4.9
Venezuela	11.1	2.7
TOTAL	7.5	6.3

(a) 1979-1985

Meyers: Right! That is probably one of the factors in Latin America.

Shapar: I note you don't include self-production in the industrial sector. (Self-production is defined as as energy generated in the home and used in the home.)

Meyers: In this case, we don't. But the main country where that's a large factor is Indonesia. In others it's generally estimated to be about 10%. But in Indonesia, it's quite large.

For these 13 developing countries as a whole, Table 10.11 shows growth in installed capacity, not including self-producers. Growth in Asia has been very high during this period. We gathered information on plans for the power sector in these 13 countries. Of course, these plans are often optimistic, sometimes quite optimistic. Take the case of Latin America, as we've heard, where the plans are in part a political document as well as a technical document, and financial reality is of course, something else.

For some of the other countries the plans are somewhat more realistic, particularly the countries in Asia that are doing better economically. Financing is especially problematic in Latin America, but it's also a problem in some of the lower income Asian countries where the power shortage situation is very severe, like India and Pakistan. But financing is an even greater problem in Latin America. In South Korea and Taiwan, (and it is questionable whether we still want to call them developing countries) and those at the next tier, such as Thailand and Indonesia, the growth in demand is extremely rapid now and to add sufficient capacity just to keep up with demand is somewhat difficult for them.

[In some countries demand growth is limited by supply. In China, as our participants noted, electricity is shut off at different times in various cities in order to keep the grid in operation.
Taiwan and south Korea, as Dr. Li suggested, should more properly be called "emerging industrial societies" rather than developing. Their capability to supply electricity is matched by high rates of industrial growth. This ratio of electricity growth to GDP is near unity, like that of the U.S. and other industrialized countries. In these emerging industrialized nations, both of these indices are growing more rapidly than in most nations.]

Meyers: Public opinion and environmental issues are becoming more important in these countries than they have been, and are starting to play a significant role. Mostly, it's been affecting planned hydro projects, in

Asia at least, and it's beginning to affect some projects in Latin America as well. Plans for nuclear power in Taiwan and South Korea are also beginning to be affected by public opinion.

One other point: In some cases the demand is very likely to grow slower than forecast because the forecasts are very optimistic in terms of economic growth, particularly in Latin America. In many of the Asian countries, on the other hand, the shortage of electricity is so severe that whatever the utilities are able to provide will be absorbed by consumers.

The numbers in Figure 10.12 are either official plans or our estimates out to the year 2000. Actually the plans are at a slower growth rate than what was actually achieved in a number of countries from 1980-87 in Indonesia, Malaysia, Philippines, North Korea, South Korea, Taiwan, Thailand and in Latin America as well. Part of this is due to the fact that official plans for economic growth were deliberately made for slower growth. Some of these countries are entering a more mature phase of their growth trajectory, the GDP in Taiwan and South Korea is growing somewhat slower, although they've found that things are happening faster than they thought, and in South Korea and Thailand it now appears that their estimates are somewhat conservative.

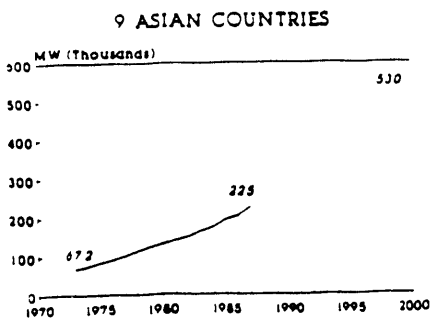
The Asian countries, including China, are projecting a growth rate of 6.8% per year, the Latin countries 5.2%, but again this is probably quite optimistic. The 6.8% for Asia is probably optimistic, but given the financial situation, it is certainly more achievable than the 5.2% in Latin America.

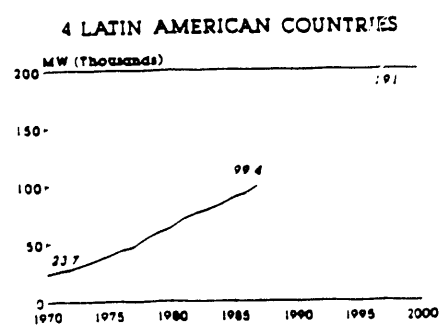
In terms of the fuel mix, what we're seeing is a movement toward coal in many countries. Figure 10.13 is the aggregate picture for the nine Asian countries, including China (which obviously weights things heavily toward coal) and then for the four Latin countries. You see the marked difference between these regions in terms of their fuel mix, and also in terms of the direction in which things are moving. In the Asian countries, coal will become more important. In the Latin American countries could come out a little bit different: hydro is to become somewhat more important.

Table 10.14 shows what the plans for installed capacity are for the different countries for the year 2000. The total is going from around 450 gigawatts in 1987 up to about 720. Probably some of the plans for hydro will have difficulty coming to pass. It's quite possible that some of the planned nuclear capacity will become something else, although that's

Table 10.12

Electric Generating Capacity
Historic Totals and Planned Growth





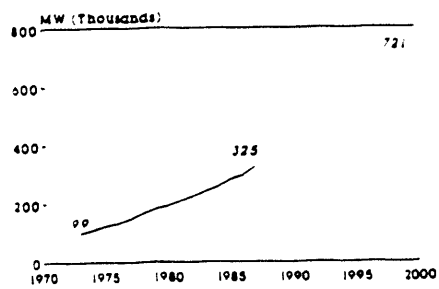
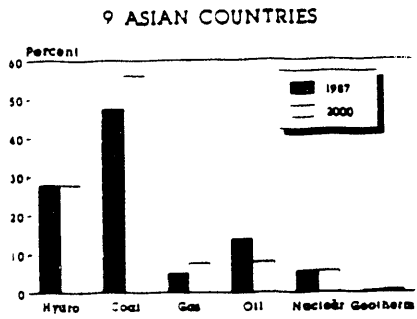
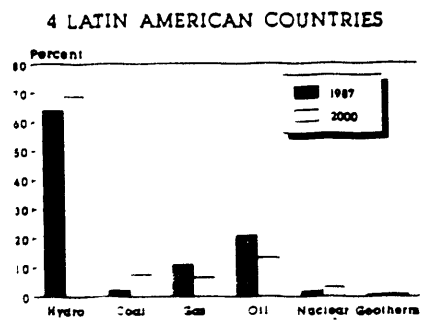
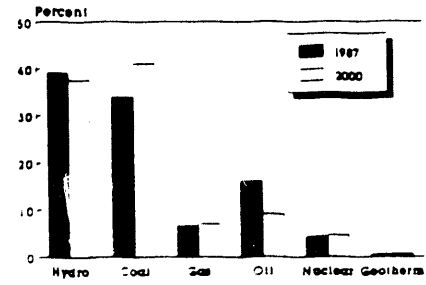


Table 10.13

Electric Generating Capacity
Current and Planned, by Fuel Type







hard to say. Taiwan is looking at alternatives to some of their plans; Korea too, perhaps. In all cases, in Asia at least, they're looking much more aggressively to try to bring in private power generation, mostly cogeneration, but also they are looking at various other options for financing power projects. Taiwan is implementing American PURPA-type type regulations, probably the most advanced in this region. They are also, as has been mentioned, looking at reducing losses and improving power plant efficiency.

[The PURPA regulations are only beginning to be implemented in the U. S., and how they will work out in terms of financing and performance remains to be seen.]

But because of capital constraints, it is likely that the roles of oil and gas are going to be larger than these countries are planning. Already countries are starting to move in the direction of installing fairly low-capacity gas turbines because of their capital problems. Some countries do have substantial natural gas resources that they're beginning to tap, and they will try to bring those on line as quickly as they can. Probably though, particularly if oil prices remain as most people generally expect them to be, there will be more use of oil than the countries have been envisioning recently.

Figure 10.14 Planned or Estimated Installed Electric Power Capacity in the Year 2000 (not including self-producers) (thousand Megawatts)

	Hydro	Coal-fired	Gas-fired	Oil-fired	Nuclear	Geothermal	Total
China[a] (P)	72.0	147.0	0.0	16.0	5.0	0.0	240.0
India (E)	41.4	86.8	15.3	2.0	3.0	0.0	148.5
Indonesia (P)	4.0	11.0	2.9	4.0	0.0	0.4	22.4
Malaysia (E)	1.8	0.6	5.4	0.8	0.0	0.0	8.6
Pakistan (P)	6.4	2.4	3.2	4.9	0.1	0.0	17.1
Philippines (E)	2.5	2.1	0.0	3.3	0.0	2.6	10.5
South Korea (P)	3.6	12.5	3.7	3.6	12.3	0.0	35.7
Taiwan (P)	4.5	11.9	2.7	3.6	7.1	0.0	29.9
Thailand (P)	3.6	7.2	4.9	1.7	0.0	0.0	17.4
Argentina (E)	9.1	0.2	6.5	1.2	1.6	0.0	18.4
Brazil (P)	93.3	3.0	0.0	3.6	3.1	0.0	103.0
Mexico (P/E)	11.0	11.1	1.1	17.6	1.4	1.5	43.7
Venezuela (E)	17.7	0.0	4.8	2.8	0.0	0.0	25.3
TOTAL	270.9	295.8	50.5	65.1	33.6	4.5	720.4

Source: Country plans (see country chapters) and authors' estimates

(P) = Official plan

(E) = Estimated by authors based on various information (see notes below)

(a) Includes some self-producers

We at LBL spend a lot of time looking at prospects for improving end-use efficiency in developing countries. One project Dr. Lee Shipper was involved in involved electric appliances in Indonesia. If you froze the end use energy intensity at 1988 levels but assume a certain increase in penetration of these appliances, which is occurring fairly rapidly in a lot of the Asian countries, you see a slowing of demand growth, and if you took more advanced technology that is almost cost-effective, it could take you down to around 50% of the energy use that it might otherwise be. These are rough numbers, but in any case there is a substantial potential, and the World Bank and other institutions are looking into this.

Wolfe: When you say that advanced conservation technologies are cost-effective in developing countries, is there a definition that we can use?

Meyers: These would be technologies that would probably be cost-effective in the neighborhood of the marginal cost of electricity, say, in the 5-10 cent per kilowatt hour category, as opposed to the others that might be in the 3-5 cent range. At LBL we've done quite a bit of analysis of appliances for the U. S. Appliance Standards. These would be technologies that, according to their calculations, have been cost-effective but haven't been included in the standards.

Wolfe: There are very few places in the developing world where electricity can even be generated for as little as five cents a kilowatt-hour! But the problem with many of those conservation plans is that they really require large capital investments up front.

Meyers: That's one of the key issues: to compare the additional capital investment for putting more insulation in a refrigerator with the capital investment in power generating plants.

Wolfe: Don't forget, it takes a lot of capital, energy and time to go into mass production of efficient refrigerators. Have you seen Amory Lovins' light bulb, the 18 watt light bulb?

Meyers: There's a group that has done a very interesting analysis with compact fluorescents for India and Brazil. They're doing that exact analysis you're talking about, looking at the additional capital cost, which is substantial with compact fluorescents, looking at the effect of that on the utilities, and doing a financial analysis at the consumer level, the utility level and the national level, and seeing how it's different in each case. Then they compare the supply side and demand side investments. That kind of more sophisticated analysis is obviously what needs to be done.

Wolfe: But what happens, it seems to me, is that those analyses don't always take into account the capital availability of the country of the people that are actually involved.

Meyers: A certain amount of capital is available for the power sector. What is the most optimal allocation of that among the various resources? Obviously, you can't just turn a switch and people are going to install compact fluorescents. You have to come up with a viable strategy that's really going to deliver that power.

Wolfe: And even for the compact fluorescent, in a place where capital and individual wealth is very low, you'd be using those kind of bulbs to a minimum extent, even if they have high efficiency. So it doesn't have the same savings as it does in a country like the U. S., where we might keep that kind of bulb on a lot of the time.

[Our participants from developing countries had explained that capital for the power sector is simply not available today. The investment is too risky. The question is whether international banks that might be hesitant to lend money for the construction of a generating station would lend money to the same utility or country for investments in demand-side management.]

Fulkerson: Lovins likes to point out that in India electricity prices in villages are so low that, in effect, it's almost free. Therefore it pays a utility to invest in a high efficiency lamp because that's less expensive, since people aren't paying anything for that power anyway. The less you use, the more money the utility actually makes, so there's a crazy economics going on there.

But the analysis should show whether I should invest my money on the demand side or should I invest it on the supply side? You take the best return and that's the way you go, obviously.

[As Sanchez-Sierra explained, the problem is that when rates are set so low in response to political pressures, there is not enough money left to invest in anything.]

Fulkerson: Your results, Steve, for Java indicated about what Chauncey Starr was indicating, which was that electricity is going to grow significantly. You can halve that growth by requiring very efficient appliances, but it's still going to grow. So you have a situation in the world where electricity is going to grow - period, and you can make it grow less by investing in efficiency to its economic justified level. But it's still going to grow.

Meyers: There's no doubt that implementing efficiency in most developing nations is much more difficult than in industrialized countries.

Starr: I'd like to make a comment on just one point in your tables: on the expected rate of growth in the future. In all these countries, that number is a political number. It is not really a planning number. What happens is, if you put down an expected rate of growth in the future that is the same as what you've had in the last 10 years, it looks too big. What happens then is you have to start worrying about applications for plant sites, financial resources, transmission and distribution lines, and buying equipment with hard currency.

But the disturbance that this creates to the plans for the economy is so great that there's a big psychological pressure on the people who come out with the future growth rate number to try to diminish it. This happens year after year after year. If you go back 5 years or 10 years to the same countries, you find the same phenomenon. When you look at the future growth rates, you have to find some other base than just a statement made by the country itself as to what the planners use.

Rossin: It's tough to close this discussion with so few answers. Thank you, Steve.

SECTION 11

DECISIONS IN NUCLEAR ENERGY

KEYNOTE ADDRESS:
Prof. Glenn Seaborg

This year will mark the fiftieth year of my involvement with nuclear energy, beginning with the discovery of plutonium. I was a staff member at the wartime Metallurgical Laboratory at the University of Chicago when Enrico Fermi achieved the first nuclear chain reaction on December 2, 1942. At the Met Lab, I was responsible for the development of the chemical process used in the isolation of plutonium for its use as the explosive ingredient in the atomic bomb.

In 1946 I was appointed by President Harry Truman to the first General Advisory Committee (GAC) of the newly established Atomic Energy Commission. In 1959, I was appointed by President Dwight D. Eisenhower to the President's Science Advisory Committee (PSAC) under its first chairman, Dr. James Killian. Consequently, during the first 15 post-war years I watched with interest the industrial development of nuclear energy for its use in the large scale production of electricity.

Perhaps the best first-hand demonstration of my interest is to present to you some quotations from my speeches of that era. The following is from my talk recorded for CBS in San Francisco on July 30, 1955 for release during the International Atoms for Peace Conference held August 8 - 12, 1955 in Geneva, Switzerland:

> "It will be a good many years before energy of this type will compete with common sources of energy such as coal. Such machines must run at high temperatures in order that the energy can be extracted in useful form, and this means that there will be many problems involving materials of construction, corrosion and so forth.
>
> "The materials of construction must be chosen from those whose neutron absorption is small and this limits the choice to uncommon substances. Adequate coolants must be found, and the method for control of the reaction must be assured. It will also be necessary for the chemists and chemical engineers to develop procedures to purify the plutonium and uranium, and also to re-purify these materials in order that the unburned fuel may be used again.

"Probably the most difficult problem, which may well be the limiting factor in determining the extent to which nuclear energy will be used for industrial power, is that of disposal of the tremendous quantity of radioactive nuclear waste."

(This statement I made 35 years ago!)

"Of particular importance to the future of nuclear energy in the field of nuclear power is the potential program of greater participation of private industry. This has been made possible as a result of a revision of atomic energy law in the form of the Atomic Energy Act of 1954. Under the old law the government had a complete monopoly over atomic energy. Under the new law, these restrictions have been largely removed and industry now has the right to use fissionable materials, the right to own and operate nuclear reactors, and a certain amount of right to patent inventions and discoveries in the field of nuclear energy."

(This was a great step forward 35 years ago!) Continuing from my speech:

"There is now a widespread interest in this field by many industries, and it is certain that they will take advantage of the new possibilities. However, in spite of these changes, I feel that progress in the field of nuclear energy for industrial power is being unnecessarily hampered by too much secrecy."

This first Geneva Conference did much toward relaxing secrecy and launching commercial nuclear power.

Next, in order to illustrate the rapid progress that followed, I quote from a speech I made about three years later, "Nuclear Power: Its Scientific Basis, Its Current Status, and Some Conclusions". This speech was at the Asilomar Conference on the International Atom, sponsored by the World Affairs Council of Northern California, on April 18, 1958:

"What sort of commitment to atomic energy in terms of ongoing large scale projects do we see as we look around the world today? In brief, we see a great deal of construction in England and the United States, quite a few plans and a moderate amount of construction in continental Europe, and an unknown but apparently only moderate amount of construction in Russia, some elaborate plans in Japan, a modest effort in India and very little development other than minor research plans anywhere else in the world....

"The nuclear Big 5 of the world are the United States, Great Britain, the Soviet Union, Canada and France. Within Europe, these five are

followed by Sweden, Belgium and Norway. Power reactors are also expected soon in Italy, Switzerland and West Germany. Through the rest of the world, the most likely place for large construction of nuclear power plants is Japan....

"The United States has been active in encouraging nuclear development in other lands. One form this aid has taken has been bilateral agreements to share information and design data, and to supply nuclear fuel, instruments, and reactors. We also were instrumental in getting the United Nations to establish the International Atomic Energy Agency. The first 18 signatory powers had agreed to the United Nations statute by July 1957, and the Agency was then officially in business. Some 53 nations had joined by October 1957. The headquarters of this agency had been established in Vienna and Representative Sterling Cole, formerly on the Joint Atomic Energy Committee of the Congress, is the first Director General.

"This agency has nothing to do with the control of atomic weapons, as a quick glance at its name might lead some people to assume. The United States has allocated 50,000 kilograms of U-235 for peaceful atomic development abroad of which 5000 kilograms is earmarked for this agency's use. The United Kingdom and Russia have added 50 kilograms and 70 kilograms respectively. The action of the United States in this matter can only be interpreted as one of great generosity.

"A six-member supranational authority called Euratom has been set up in Western Europe by Italy, France, the German Federal Republic, Belgium, Luxembourg, and the Netherlands. Under this agency, nuclear developments in these six nations will be free of many economic and manpower restrictions. In many ways, Euratom resembles the European Iron and Steel Community and the European Economic Community and, in fact, includes the same six nations. Euratom has made some very ambitious tentative plans calling for the construction of up to 15,000 megawatts of nuclear power in the six-nation complex by 1967."

Following a stint as Chancellor at Berkeley, 1958-1961, I was called on Jan.9, 1961, by President John F. Kennedy to come to Washington D.C. to serve as Chairman of the Atomic Energy Commission, a post I held until 1971.

I might say that when President-elect John Kennedy made this call, which was a surprise to me, to come to Washington to serve as Chairman of the AEC, I more or less said, "Gee whiz, how much time do I have to make up

my mind?" And he said, "Take your time - let me know by tomorrow morning!"

That night I went home, and at the dinner table with my wife Helen and six kids, told them about this offer to come to Washington. Of course, they would have to accompany me; it was a full time job and more, and the kids demanded a vote. They voted 7 to 1 against our going to Washington. I exercised the privilege of the head of a democratic household; I exercised a veto vote and we went.

Here's a picture soon after I arrived on January 31, 1961 (page 000). I saw President Kennedy, and he immediately said he would like to visit AEC's Germantown headquarters. On February 16, within about two weeks, he and I, and McGeorge Bundy and others flew out to Germantown in a helicopter. I gave President Kennedy a brief tutorial on nuclear physics and atomic structure, following which we went into the Conference Room for a briefing on the whole program.

In March 1962, Pres. Kennedy asked the AEC to take a "new and hard look at the role of nuclear power in our economy". (Actually, and I don't know whether I should confess this or not, my administrative assistant Howard Brown and I had planted the notion of such a study in the White House, hoping that this might increase the President's interest in civilian nuclear power and thus give it a higher priority. I might say, in this we were successful.)

The President asked that the study "identify the objectives, scope and content of a nuclear power development program in light of the nation's prospective energy needs and resources and of advances in alternative means of power generation."

The year 1962 was an appropriate one for a new and hard look. By this time 25 experimental or prototype nuclear power reactors had been funded by the government, while 12 others had been funded by cooperative programs with industry. From this work had come substantial advances in nuclear technology and considerable operating experience, sufficient to make the goal of economically competitive nuclear power seem attainable, at least in areas of the country with high conventional fuel costs.

Not surprisingly, such progress had stimulated increased industry interest in nuclear power and in the private ownership of nuclear fuel. On the other hand, general economic conditions did not seem to warrant the construction of additional experimental facilities without more definitive program guidance. Guidance was needed particularly to help determine what reactor

concepts should be emphasized in the coming period. The plants thus far built had been of several different types, each having its virtues and its champions.

Light-water cooled reactors had demonstrated their reliability, having been used extensively in nuclear submarines and in the Shippingport Atomic Power Station near Pittsburgh. They were not extremely complex, either in construction or operation, and could be built and operated with the available technology.

Gas-cooled systems were known to permit relatively high thermal efficiency. Potentially, the coolant gas could drive a turbine directly, and this concept, known as the HTGR (High Temperature Gas Cooled Reactor), showed promise of being able to use thorium fuel, which was in abundant supply.

Through operation of experimental reactors, it was known that liquid-metal cooled reactors could achieve high temperatures and high thermal efficiency. Their further development could therefore be considered essential to achieve the full development of nuclear power.

Heavy-water cooled and moderated reactors had been examined, but had limited support because of availability of enriched uranium fuel in the US. Heavy-water reactors could use natural uranium fuel but required larger facilities, because they could not produce as much energy per cubic foot of reactor as those using enriched uranium.

In November 1962, the AEC issued the requested report to the President. It was of major significance to the civilian reactor development program. It set forth program objectives and proposed planning for a national energy production effort for the President, the Congress, the utilities, the nuclear industry and the general public — all those whose support would be needed to carry out the program.

A major contribution of the report was to establish the national and international need for nuclear electric power and to set forth why there should be a civilian nuclear power program in the United States to help meet this need.

It did so by first analyzing the availability of alternative fuels for energy production. It then indicated that nuclear energy was technically feasible and economically reasonable for electric power and process heat applications, and that it should extend indefinitely the fuel reserves of the United States through the use of breeder reactors which could utilize available uranium and thorium resources.

Other advantages of nuclear power cited in that 1962 report to the President were that it would: 1) eliminate geographic variations in power costs, 2) place the United States in a position of international leadership, 3) improve the defense posture of the United States, and 4) reduce air pollution.

After the death of President Kennedy, President Lyndon B. Johnson continued as a strong supporter of nuclear electric power. Figure 2 is President Johnson giving me the word. This was a characteristic of Lyndon Johnson.

I recall a meeting of the Cabinet held on Oct. 20, 1964. You might have an interest in the topics we discussed at the meeting. (I might say that it's not a matter of my having such a fantastic memory that I remember all of this in such detail, but I kept a rather detailed diary for the whole period that I was in Washington.) On this date, we were discussing the extremely interesting information we just received that the Peoples Republic of China had just exploded their first nuclear bomb. I should also add that the CIA had reported immediately that the explosive ingredient was plutonium, and I had the task of gently correcting the CIA and informing the members of the Cabinet that the explosive ingredient was, of course, U-235.

At this same meeting we discussed the fact that the Soviet Union had changed leadership just a few days before. Brezhnev and Kosygin had just replaced Kruschev. And at this same meeting, we discussed the election in England that had been held just a few days earlier, where Harold Wilson, by just a couple of votes, had become Prime Minister of England.

One of the important trends in atomic energy development in the 1960's was the emergence of economic nuclear power. On March 26, 1964, the Jersey Central Light and Power Company applied to the AEC for a permit to construct a 515 megawatt nuclear power station at Oyster Creek near Thoms River in New Jersey. The company had chosen a boiling water reactor, a type for which there was a considerable accumulation of operating experience. While the capacity was large, other plants being planned were not much smaller. The plant was to be wholly investor financed.

The most significant aspect of the Company's application was its statement that nuclear power has been chosen over alternative, that is, fossil fuel generating systems, on the basis of economics alone. The plant vendor, the General Electric Company, took the bold step of submitting a firm bid for the turnkey construction of this plant.

Westinghouse and other nuclear reactor vendors also became very active. In the three-year period 1966 to 1968, US utilities ordered, without direct government assistance, 67 reactors — the units ranging in size from 450

megawatts to more than 1100 megawatts. By the end of 1970, three of these reactors were operable and more than 50 were being built. All but one of these orders were for light water reactors, the exception being an HTGR. Development of the various reactor concepts had proceeded more or less as planned and proposed in our 1962 report to the President.

Emphasis had begun to be placed on the development of high-gain breeder reactors, as recommended in the 1962 report also, especially the liquid-metal cooled fast breeder reactor. On June 4, 1967, at a climactic meeting of President Nixon's Cabinet, including some key members of Congress, I made a presentation proposing a vigorous program for the development of the LMFBR (Figure 3).

Following that meeting, President Nixon supported the idea, stating,

> "Our best hope for meeting the nation's growing demand for economical clean energy lies with the fast breeder reactor. Because of its highly efficient use of nuclear fuel, the breeder reactor could extend the life of our national uranium fuel supply from decades to centuries with far less impact on the environment than power plants which are operating today."

He also said that it was important to the nation that a commercial demonstration of a breeder reactor be completed by 1980, but the breeder reactor development was discontinued, as you know, during subsequent presidential administrations. (We may have helped a little bit in the preparation of that statement.)

As an aside I might add that I participated before and during my days at AEC in the development of the nuclear fusion program. And even recently, in Spring 1989, I was called to Washington to brief President George Bush and Chief of Staff John Sununu, on cold fusion (Figure 4). Fortunately, I assumed a very skeptical attitude. I must say that this was a matter of days after the announcement from Utah of cold fusion when it was at a high and everybody - well, an awful lot of people - thought that this was an answer to our energy problem. I look back with a little bit of satisfaction that I was able, even at that time, to assume a very skeptical attitude.

At the end of 1971, 130 central station nuclear power plants representing an aggregate capacity of more than 108,600 net megawatts of electricity were built, under construction or planned in the United States, as follows: there were 25 operable units including two licensed for fuel loading and subcritical testing, representing a total capacity of 11,400 megawatts; 52 units representing a total of 44,500 megawatts were under construction or being

reviewed for operating licenses; 39 units were under AEC review for construction permits representing 38,400 megawatts of initial capacity, and there were 14 units for which utilities had contracted but yet filed construction permit applications, representing 14,000 megawatts. However, many of the planned units were cancelled due to rising cost of construction and the success of the anti-nuclear movement.

On July 23, 1971, the U. S. Court of Appeals for the District of Columbia made an historic ruling directing the AEC to revise in several respects, its rules on consideration of non-radiological environmental matters in licensing facilities. That is, it directed the AEC to broaden its responsibilities.

The court held in the consolidated cases of Calvert Cliffs Coordinating Committee, et al, versus the US AEC, et al, that AEC regulations for implementing the National Environmental Policy Act of 1969 NEPA) in licensing procedures did not comply in several respects with NEPA. The petitioners had also questioned several aspects of the AEC's application of NEPA procedures to the Calvert Cliffs nuclear power plant of the Baltimore Gas and Electric Company, a facility near Lusbie, Maryland, on the Chesapeake Bay, for which a construction permit had been issued six month before enactment of NEPA, and the court agreed.

The AEC took several implementing steps immediately following the court's decision. The net effect was a severe setback to civilian nuclear power in the United States. The United States who had led the world in early nuclear power development was also the first country to be affected by its decline.

Over the past decade the US nuclear power industry has seen no new domestic orders due to a combination of low load growth, environmental pressure, regulatory uncertainty and increased costs. Many of these same pressures are now affecting nuclear power worldwide. However, in the US, which has led the world in the birth and then the decline of the nuclear power industry, there are signs that its rebirth may be imminent.

Worldwide, the growth has actually been impressive. A nuclear electric power generating capability has been deployed throughout the world at an unprecedented rate on the order of five times faster than any other previous new source of energy. More than 430 nuclear power plants are operating around the world today, generating more than 310,000 megawatts of electricity in 25 countries.

Most of these countries depend vitally on the electricity generated by nuclear power. In 1988, France generated 70% of its electricity from nuclear

power plants; Belgium 66%, South Korea 47%, Taiwan 41%, Sweden 47%, Finland 36%, and Japan 23%. What may not be familiar is that in the Soviet Bloc, Bulgaria generates 36% of its electricity from nuclear power, Hungary 49% and Czechoslovakia 27%.

Furthermore, although the US is not a leader in percentage, it has the largest total electric output from nuclear power, 95,000 megawatts electric from 108 plants, generating 20% of the US electric power. And what I hadn't realized, since 40% of that 20% is generated from plutonium, there is actually more electricity generated from plutonium in the United States as a source of energy than from the burning of oil!

Nuclear power remains the ultimate component of an electrified, non-smoking energy system. As a non-smoking system it is exempt from the political and potential economic troubles of acid-rain from coal combustion or the longer-range concern over the Greenhouse Effect which mark all combustion systems. In my opinion, the need for nuclear power will intensify before the other promising non-smoking energy sources, fusion and solar, become both economically attractive and widely developed.

DISCUSSION

Fulkerson: You mentioned that nuclear power was going to have a rebirth. What is the basis for your optimism?

Seaborg: That's of course going to be one of the topics of discussion here. It has to do with a number of factors: the finite supply of some of the alternate sources of energy, such as oil; the problems of acid rain; the environmental effects of burning fossil fuels which has been referred to as the Greenhouse Effect, and the need, as we progress and begin to take a more rational attitude, to use some of these fossil fuels for sources of chemicals, for which they are indispensable, and for which we will be paying quite a price if we continue to just burn them, and as we run out of supplies as time goes on.

Starr: Glenn is one of the pioneers in the use of accelerators for making artificial elements. Would you want to take a guess, looking forward, as to the possibility of using accelerators again to break up the fission products into their stable components?

Seaborg: Well, I've given that a lot of thought. You're thinking really perhaps of more than accelerators, but neutrons, and I've read the studies that Professor Tom Pigford has made of all of this, and so forth, and I'm afraid my net conclusion is that I don't regard this very hopefully.

AEC Chairman Glenn Seaborg briefs President John F. Kennedy in 1961

President Lyndon B. Johnson talks with Chairman Seaborg (1964)

Chairman Seaborg discussing the breeder reactor with President Richard Nixon (1970)

President George Bush asks Prof. Glenn Seaborg about cold fusion in 1989

SECTION 12

LEADERSHIP AND THE ROLE OF THE UNITED STATES

After two full days of presentations and discussion, the participants discussed the points that they wished to include in the Action Statement. Dr. Davis chaired the discussion and encouraged participants to offer their thoughts and proposals. At the conclusion of this discussion, the Seminar split into small groups to draft specific items for consideration by the whole group.

Davis: What I would like to do is see if we can come up with specific recommendations that say what should be done, not what the goal is, but what should be done to reach those goals. Who should do what? It won't be helpful to say "The world should do such and such." It ought to be addressed to the people that *in fact* can take action. There is no sense in telling people to do things they can't do!

In terms of time frame, we should be recommending those things that should be done now. They may have an impact ten years from now or even thirty years from now. But regardless of the time frame of the impact, we want those actions that are needed now.

Our objective is to focus on electricity, though we need to keep in mind the implications on overall energy and environment. But we need to keep our focus.

We need to make a series of recommendations, but first concerning what should be done in the U.S. The report will get more attention if we get specific about the U.S., which of course would have wide international implications. We also need to make recommendations where appropriate with respect to international and global actions. But those would inevitably be less specific. I'll start with my short list:

I think there is a desperate need for leadership. This country, and many others as well, don't have any real dynamic leadership in the electric power area. We don't have it in our own government, we don't have it in the electric utility industry. I don't think our recommendations could have any impact, or be carried out, unless there is dynamic leadership.

One of the key questions is what is the balance we ought to give between the short-term problems related to energy production and the long term, that is, the greenhouse effect, and the short term more pressing problems of acid rain and specific pollutant emissions. In some respect, these may be incompatible. But we need to look for the right balance between them.

We've had a lot of discussion about energy efficiency. Certainly there is agreement that energy efficiency and conservation is an important subject. But what there isn't much agreement on is how you go about achieving it. If you are going to make recommendations, you can't just recommend that conservation is a great thing, you have to say something useful about how to bring it about. You can't just wave your hands. Are you going to drive it by economic forces? By taxation? By regulation? All of the above? How are you going to do it?

I would put more attention on the economic consequences of the various things that might be done. We tend to ignore the overall economic impact of energy and environmental actions. One of the problems, of course, is that the economists can't seem to agree on what the economic impact is of any particular thing. But we'd better make sure we look at them.

On nuclear power, one aspect is rather unique to this country. For the investor-owned utilities, they have the basic question of how they are going to get their invested money back. The recent history in this country with their state utility commissions has been that they have not been able to recover their investments. In order to allow new investments in electric generating plants, at least by the investor-owned utilities, that has to be fixed somehow.

However, the problem is not restricted to nuclear power; some states have denied rates for other types of major new facilities as well. For nuclear plants, the licensing issue looms extremely large. Is the new NRC regulation adequate or does more have to be done? And you cannot dodge the issue of nuclear safety, U.S. and worldwide. Finally, the ever-present issue of nuclear waste must be resolved.

Now, I feel we must deal with the issue of cost-benefit. Some people don't like to include the word "cost". But the fact is that we are plagued in many ways by arbitrary regulations which are not necessarily advantageous from the overall point of view. We have institutions which are basically prohibited from using cost-benefit analysis, like the EPA, and we simply don't have the money as a society to do everything, and at the very least we are going to have to set priorities. It has been suggested by

some of the speakers, and I concur, that we need to strengthen the cost-benefit approach in making policy decisions.

What should be done in terms of reactor development? Global climate change?

We've had lots of discussions on how to finance power plants in the developing countries. One of the problems there is who should one address suggestions to? But it is an area we must not ignore.

That's my short list of subjects for starters. Bart, do you want to add anything?

Shackelford: I tried to put answers to some of these questions into words. This is what I wrote on state utility rate regulation in the U.S.:

The investor-owned segment of the electric utility industry should commence a joint effort witn FERC and NARUC, aimed at revising utility rate-making and accounting practices to the end that utilities may have reasonable assurance that planning, engineering, construction and operating costs will be recovered with a reasonable rate of return. Specific factors which should be addressed include the treatment of CWIP, how to handle deviations of costs from estimates, equitable treatment of temporary excesses of generating capacity, amelioration of rate shock, and recovery of costs of aborted projects.

I have an idea about what it would take to mobilize thinking in the U.S. Whether it would be helpful in other countries, I'm not sure.

The President should declare that a reliable electric power supply is a national priority. He should call for NERC to prepare a national power survey for the next 25 years. It should include demand-side energy efficiency and energy-use reduction techniques to the extent they are economically justified, and measures for reduction of greenhouse gases. I recall that just after World War II, everyone was worried that there would not be enough power capacity. The utilities were worried that this might increase the Federal Government involvement in the process.

So at that time, the first national power survey was called for. It was managed by FPC. NERC grew out of it. It had the effect of mobilizing a lot of utility brain power. NERC continues, though its forecasts are not long term. It is going to be a problem for NERC to go long-term, but it might be helpful in focussing on the real problems.

On nuclear power: NERC would be able to indicate the need for base load power.

On risk assessment: I feel that measures to reduce environmental risk should be prioritized on the basis of reasonable evaluation of costs and benefits to society.

Starr: What is the one big message that has come out of all this discussion? The world is facing a chasm as far as electric power supply is concerned. And in varying degrees and different parts of the world, that chasm has various depths and various time scales about when you're going to hit the edge of it. And that chasm is so important it is going to override in importance around the world, including the U.S., the whole issue of environmental concerns.

Now I'm taking a position that some of you may want to argue about. What I'm saying is that its economic productivity and its wealth-production, which provides the health and welfare of the world, is a hell of a lot more important to the people of the world than some marginal, long-term and hardly measurable changes over time. That doesn't mean that environmental impacts are not important. But on a relative scale, sustaining the economies of the developed and under-developed parts of the world is the major objective of the peoples of the world in a real sense. And the amount of sacrifice they are willing to make on this for environmental improvement may vary with the various cultural groups and economic levels, but it is not the highest priority. Their economic health and welfare is their highest priority. And electricity supply is the key. It seems to me that unless you can get that across, you are not going to get support for the other things.

In all the discussions you've heard, from Mr. Lu about China for example, and about other countries in the developing world, this is a fundamental truth that seems to be coming out of the actual, empirical operations of society. Now if you accept that point, the other conclusions follow. Bart's suggestion that this be made the message of a presidential statement has the substance that the President might consider. The things that need to be said about conservation and efficiency follow logically.

The audience? The real audience is the media. Nominally you write it for the Department of Energy. But you are writing for the reporter who interviews one of us, and says, "Well, your group met. Tell me. What message does that group have?"

The supporting material must be there to take care of the endless arguments you will have with all the critics. To me, the media is the transmission line to the public.

Borg: We can't afford to be parochial. If we are going to have a global view, we can't just talk about the U.S. or various states. There's no way these recommendations we just heard would have any appeal to someone in India. Starting from what Chauncey said, some effort must be made on the part of the governments of all countries to disrupt the complacency we have with respect to electrical power, and to educate the general public to the effect that it is not only critical but is on the verge of being in short supply, and that the lead times needed are not there anymore, and that we are approaching an acute situation.

Kaprielian: But the press today, in the U.S., has before it all kinds of information which says that there is a terrible oversupply of electric energy in the U.S. And CEO's say that we are not going to be building anything for the next 10 to 15 years. Now, is a reporter going to believe what we say here? Or are they going to run across the Bay and say, "What is this? That's not what they are saying over in Berkeley! They say we are running short!"

Shapar: I agree with Chauncey Starr's analysis, but I think it would be wrong to say that energy deserves a higher priority than the environment. That would discredit our report if we say it. I think we have to say that there is a real energy crunch and we have to do something about it, taking into account environmental considerations, and not that environment deserves less priority than energy. In today's world, you cannot say that. This is my opinion.

Fowler: I heard Chauncey's statement differently. It has been interpreted as "Energy should override environment." I think what he is saying is that, unmanaged, it *will* override environmental protection actions.

So that the issue is if we don't do things in advance, the priority will not go to environment and overall good. The priority will go to meeting immediate needs. The whole point of management is to recognize those things that are going to overwhelm you, and be prepared in advance.

Starr: Ken, I accept the improvement in my comment.

Shapar: Now I agree!

Hubbard: In fact, that's a better environmental strategy anyway! My concern is that the environmentalists don't realize it. But one has to be careful how you phrase that. You see how easy it was to misinterpret Chauncey's statement in the first place!

Eibenschutz: I think it is very important to get across the message that Chauncey is saying. One has to be careful not to offend people, and not

put in words that would discredit the whole report. But the point is extremely important.

What I would like to add is that the lack of power has economic effects which are normally orders of magnitude more important than the excess in power availability. This phenomenon is particularly important in developing countries. Developed countries have suffered from this misunderstanding. I think it would be useful to say something at the outset about the difference between the cost of excess power and the cost of lack of power.

Starr: We have many studies which show that the insurance cost of electric supply is a very small fraction of the penalty you have to pay if you run into major deficiencies. That is the answer to why some of our utilities have a surplus at times.

Fowler: Is there dissent? Who disagrees with the statement.

Shackelford: I don't disagree with the general statement. I do think that somehow you have to make a distinction between countries that have an adequate electrical energy supply now and those that are striving to attain one. What I heard earlier in the Conference was that in countries that are striving to attain an adequate energy supply, environmental considerations are important, but they are not as important as in countries that already have it. I don't know how that is going to be said, but I think it is what I've heard.

Rossin: May I read a draft statement for your comments:

"Leaders do not have to imagine the consequences of not having enough electric energy supply capacity. Many nations in Latin America, Asia and Africa are unable to improve their economies, their life-styles or their environment as they wish, because of a shortage of electricity."

Is that the essence of what you are saying, Bart?

Starr: I think Bart said it better, frankly.

Gottlieb: The point here is that the overwhelming need for energy in the developing countries is so great, and its importance is so great, it tends to make the environmental concerns occupy a secondary role. However, the environmental consequences of the production of electrical energy are going to be dominated by the developing countries. Therefore, whatever we do to help the environmental situation with respect to our own energy supply will be useful but not dominant. It will be a relatively minor element in the world. Unfortunately! And we have to recognize that in the rest of the world, the basic needs are overwhelming.

Rossin: One of the things we heard is that those needs will not be satisfied automatically. There is nothing that says that we will actually build the necessary infrastructure for electrical and other energy needs. If we don't, the situation continues to deteriorate, with its environmental and health consequences at the same time.

Fulkerson: Therefore, and I think this was Gabriel Sanchez-Sierra's point too, if they want environmental concerns to be given appropriate play in development, the industrialized countries are going to have to pay part of that bill.

Rossin: Your group said that technology transfer can help if more efficient ways to use energy that are achieved in industrialized countries could be transferred so that as power systems are established they don't repeat the mistakes that we made concerning waste of energy in our equipment and ways of doing things. This represents another need for capital. Perhaps it can be shown that this is a better investment than some alternatives.

Fulkerson: The issue is integrated planning, like Ontario Hydro. This involves demand- and supply-side planning for future development, which applies just as well for utilities in North America as it does for utilities anywhere in the world. The point is to minimize the overall cost of supplying the services that are necessary.

Gottlieb: I got a different message from the developing nations. As much as they would like to be efficient, the very limitations on their capital will make them invest in inefficient systems just to get to some minimum level. So let's not be so rosy about this! We have to take reality into account!

Fulkerson: But one of the main reasons for that, Mel, is there is not an easy mechanism to apply capital to efficiency improvement. It is easier to apply capital to the supply option, even if that is a more expensive option. The trick is to get the capital to be available to both. Utilities or governments can provide that.

Gottlieb: It is meaningless to talk about improving the efficiency of an electric supply system that doesn't exist!

Eibenschutz: You are discussing two different points at the same time. One of them is that when you have nothing, it is much more important to have something. This is one point we have been trying to make. But the other point is that there are electric utilities, even in developing countries. There are, however, no agencies to improve efficiency in the utilization of electricity. That is what is lacking.

Fulkerson: The utilities could do it, just as they are it doing in North America.

Eibenschutz: But in order for that to happen, you must have a different setup. This is what does not exist in developing countries. The reason why you can apply this is that there has been some regulations, and because you have easy access to sources of capital.

Fulkerson: That's the trick. Do that in developing countries. I think it can be done!

Borg: Oh, no. Haven't you been listening?

Rossin: Stauffer and Sanchez-Sierra were arguing about how much harder it is than we realize. It's not a matter of if it can be done, it is a matter of *how* it can be done.

Fulkerson: Well, we're trying an experiment in the Dominican Republic, with the World Bank, along those lines: how to get funding for small-scale end-use efficiency improvement. The idea is to work the capital down through and into actual community social organizations who make loans to individuals. I think there are lots of ways of doing it.

Rossin: Let me summarize what we heard earlier: You can develop ways to use electricity more efficiently, and conservation measures which will save electricity in certain applications or sectors. The difference is that electricity, by its very nature, is so much more flexible that it is available for so many end uses. And there are some of those uses that are desperately in need. So when you say maybe we can save more by investing in conservation, that may solve a problem here, but the flexible need is not being solved unless you've got the capacity there to provide service to a broader sector.

Fulkerson: Certainly. It's the same point. If you don't have a system, you don't have anything to conserve.

Rossin: That point is one we have to make clear.

Sudarsono: Conservation and demand-management programs in the third world are being implemented. They are important and significant programs. But in many countries the main question is really tradeoffs in investments between the power sector and agriculture and health, and so on. It's a relatively minor part of the investment program. So most of the questions are, how should we invest the money that's available? Is it for the power sector or for health or for agriculture or for education? The main problem is to increase the electric supply. For now, we have only 20% of the population connected to the grid.

Starr: You have to distinguish between the theoretical objective and the ideal accomplishment over a couple of generations. Over the next few generations the developing countries are going to set priorities in which the environmental issues will not be at the top of the agenda. We have to recognize that and accept it. Long term, we should do what we can to help them move this priority up. But they have to make their own decisions. These decisions will involve compromises which we have to recognize will exist and will affect the global environment. Coming back to the Greenhouse Effect, we stimulated a lot of the discussion. We are not going to be able to run the rest of the world when it comes to Greenhouse issues.

[Over the past year, the European nations, Japan and some others have pushed the U.S. in international conferences to set ambitious goals for lowering emissions of Greenhouse gases over the next ten and twenty years. It is the U.S. that refuses to go along with them and adopt these goals as national policy. For that, the U.S. is being heavily criticized, and within the U.S., environmental groups are extremely critical of the Administration.]

McConnell: Bart suggested that we might recommend to the President an action by the NERC. I think that has some merit. After being chairman of the Engineering Comm. of NERC, I know its strengths and limitations. I don't know that NERC action alone would be adequate. When it comes to the regulatory disincentives in the U.S., I do not think real progress can be made without a change in the attitude of the regulatory commissions.

I do agree with Chauncey that even if you have your focussed audience (the President) you can still simultaneously communicate to the public at large, whether it's through the media or not. But to communicate to the media, per se, I think is a bottomless pit.

Rossin: You said the media is a conduit.

McConnell: I see three packages of information: communication that is factual and general, some recommendations that are specific to the U.S., and some recommendations that are specific and international.

Borg: That's the hard one. How can you give specific global recommendations?

Rossin: One example that came out of the international group was to have a specialized agency of the United Nations that focuses on energy investment.

Eibenschutz: Yes. It has to do with the environmental responsibility. We feel that developing countries share the responsibility of taking care of their own share of the global environment. But also, that the developed countries take some responsibility for history, for they are the ones who started the damage to the environment. In order to have a working mechanism we propose an international body that would put together all the energy and environmental agencies in a specialized agency. Now, you ask about UNEP? UNEP does not deal with energy. They are anti-energy! They are the people who claim to defend the environment, and try to push everything that way. If you don't have some sort of coordinating body, it is very difficult to have mechanisms that could make a viable solution for developing countries not harming the environment for the reasons we discussed here.

Davis: Do you think the UN is capable of setting up such an organization?

Eibenschutz: No. But we think that there should be an agency anyway. We do need consultation and coordination.

Starr: How do you tie the President into a global issue? Given a global issue, what role is there for the U.S. in managing that global issue? I'd rather phrase it that way, as far as a Presidential commission is concerned. I'm a little concerned about whether we want to get down into the specifics of what the U.S. must do to to clean up its own internal energy business. In the first place, it's sounds very self-seeking for people in the energy business. As to acceptance, if the report just sounds like another vehicle to tackle once again the U.S. problems, the global side of it will get pushed aside. What is it the U.S. can contribute?

Fowler: I noticed that we really do seem to be gravitating into fatalists and opportunists. We are saying that we don't know how bad the global problem really is, but the fatalists in this meeting are saying we don't know how effective any kind of a fix could possibly be. My proposal is to take the "do what you can" attitude, and to balance your ignorance of the problem with your ignorance of the solution.

Starr: Why can't we be schizophrenic about it? From the point of view of what we know about tomorrow and what we can do about tomorrow, we're all fatalists. From the view of taking care of the future, we're all opportunists. So we're both!

Shapar: One of the main trends that has been advocated is that we try to help the third world avoid the same mistakes we made. The way to do that is obvious: to have the wealthy industrialized nations provide technology

and funds to help the third world avoid the same problems we have been making.

Li: I think that in this meeting we should pay more attention to the U.S. than others. Secondly, I don't like the term developing countries. There are very few developing countries represented here, and we cannot speak for the developing countries.

I worked for an international organization for twenty years. And I can tell you frankly, I am very biased. I am against international bodies. They are bureaucratic and inefficient. So I suggest that when we talk to the press, the main direction should be about the U.S. If you talk about a developing country like India, what effect can anyone make? One friend of mine said that Japan was very wise. The Japanese give aid to many countries, but they do not give aid to India. Why? Because this would be a drop into the ocean. It would not be appreciated.

Another thing that occurs to me in talking about environment and adequate power supply: In my own case, if we don't show our concern about the environment, we will have no power stations. This is very definite. You know, we cannot build any new power stations! It is because of the opposition from the environmentalists. This is not only for energy plants; we cannot build any factory because of the opposition. So the environmental concern is, for me, not of second priority to agriculture or health. It is not!

Rossin: We've been struggling with this. I respect your statement, Dr. Li. But if we don't say in our statement that we either recognize the type of problems faced by some developing countries (and we have to be very careful that we don't imply that we could cover everything with one brush) in capital formation and the need for large amounts of energy that might have to be produced in environmentally less appealing ways, then I think we have failed to do our job. We still have to say that we are aware of the complexity of the situation.

Li: Yes, but make it clear that we are concerned about the environment. However, we do not know enough about the differences between countries.

Davis: Don't presume to make overall recommendations about developing countries, right?

Borg: Some of these insights we have gained from our various participants are not well understood by the public. Certainly, they have helped temper some of the ideas we raised concerning the U.S.

Li: My proposed paragraph is:

"As conditions in countries in different parts of the world are not the same, it is recommended that there should be several meetings on a regional basis with groups of countries facing similar problems. These seminars would examine subjects in depth. Experts from industrialized countries should be invited to participate."

Starr: You know, if we were dealing with the world's food supply, we wouldn't be having these sorts of arguments. Everybody would recognize the objectives, and how you get each part of the world working together to increase food supply. We'd be sending new seedlings back and forth, and doing experiments on hybrids, and everybody would be saying "Amen!" From my point of view, the energy supply is in the same category and has about the same lead time. The fact is that the public does not recognize this, which is our basic problem. I would suggest not too many messages!

I like the idea of Presidential attention, simply because it mobilizes everybody else to do something. Suppose the President connects the Greenhouse Effect, which he has recently stuck his neck out on, with energy and the economic development of the world, and says that this is a very serious mix of issues, we'd better have a good hard look at it, and although the U.S. is one of many actors, we have a responsibility. I'm going to ask our government agencies to see what they can do to work with other nations to resolve this problem. If the President would say that, it is about all you could ask for as an end objective.

Rossin: When the President says something, it is not so much the that the President believes it, but the fact that it has worked its way up through this fantastic structure of the bureaucracy and the Administration to the point where you've got it on the President's screen. If you get him to say it, it means there is support for it throughout the government, and something might come of it. I don't want to get the cart before the horse and suggest that we can just ask and get the President of the U.S. to say something. That just doesn't happen.

Davis: But I would remind you of the history cited by Glenn Seaborg. Here was a man who managed to persuade three successive Presidents of the U.S. of the positive aspects of nuclear power. That had an enormous effect, not only in the U.S., but around the world. Now, that is what you are going to have to have! Unless you have leadership of that sort, you are just talking nonsense!

I also think we need leadership from industry. We're in a period in which our utilities have been explaining why we can't do anything. They are very plain about it. They can't do it. They haven't taken the attitude of if we can fix some of these things, then we would be prepared to do what is absolutely necessary. They really haven't had a need to do this because there hasn't been a pressing need to build things until very recently. I think we should urge the electric utility industry into taking a positive position, which could be: If we can solve these problems, and we're working on them in a cooperative way with government, with the state commissions, etc. then we are prepared to meet our responsibilities. That is not what they've been saying, and it is not the perception that the public has.

[This is just what a group of utility leaders did with their Nov. 1990 statement about what it will take to get nuclear power back into the marketplace.]

Shackelford: I think it varies across the country, but generally I agree. However, that's why you have to extend your time frame out beyond ten years. There are utilities around that don't have a supply problem until the year 2000 or thereabouts, and they think they have solutions that will carry them a little longer. So there isn't a real consensus.

SECTION 13

RECOMMENDATIONS

GLOBAL ACTIONS IN RESPONSE TO GLOBAL ISSUES

We recommend that heads of government in industrialized nations exercise appropriate leadership:

* To turn public attention to the emerging problems of electricity shortfalls in many countries and their dramatic implications for health, employment, economic hopes, and the environment.

* To encourage a conservation ethic, balanced by a realistic assessment of the need for new electric generating capacity.

* To remove regulatory roadblocks and institutional obstacles to new power plants, without compromising safety requirements, environmental standards, or public participation, so that the energy industry can make sound decisions in time to meet growing demand.

* To respond to public concerns such as the safe handling of radioactive waste.

We recommend that government leaders send messages to their national parliaments and legislatures on electricity issues, as well as introduce action statements at international meetings such as the annual Economic Summit and the World Energy Council.

Further government actions should include:

* Steps towards more prudent electricity use in industry, in services, and by households.

* Research and development on improved energy technologies covering diverse options, including fossil, nuclear, renewable energy, fusion, and to identify, develop and evaluate the potential of new initiatives for conservation.

* Support of programs that will encourage young people to choose careers in science and engineering that will be vitally needed in demand management and in energy generation and delivery.

We further recommend that the industrialized countries initiate work with international organizations and the developing nations:

* To assist in financing their electric supply systems, including methods to minimize emissions to the environment;

* To explore innovative international investment structures for constructing electric systems in selected regions, even under current financial difficulties;

* To take advantage of technological progress in energy efficiency, conservation and reducing wasteful use of energy and resources;

* To achieve regional responses to global problems; and

* To avoid repeating the adverse consequences of the industrial revolution which now require costly pollution controls and cleanup efforts.

ACTIONS BY THE UNITED STATES

United States' leadership can help all nations achieve the goal of sufficient electricity and greater well-being for their people. Participants pointed out that what the United States does, or fails to do, will impact public opinion and political decisions in many nations.

We believe that the United States electricity supply situation is deteriorating to the extent that the President should deliver a special message to the Congress regarding the importance of adequate electricity to the economic and environmental health of the country. He should recommend specific programs to deal with the threat of electric power shortfalls well before they become realities.

We recommend that the President's program include a strong emphasis on conservation, but must also recognize the urgent need for new base load electric generating capacity in the United States in this decade. Specifically, we recommend that the President re-affirm that nuclear power and clean coal generating stations will be vital contributors toward meeting the United States future electricity needs.

Concurrently with the President, utility leaders should express confidence that they are prepared to move forward with new construction once sound recommendations are implemented.

We recommend measures to:

1) Encourage state regulatory commissions to provide for assurance of investment recovery needed to allow utilities or generating companies to undertake and finance needed major new generating facilities.

2) Improve regulatory procedures on the federal, state, and local levels to remove obstacles to economical and timely construction of new electrical

facilities. For example, retroactive application of emission standards after plant construction has been committed should be avoided, and nuclear power plants should be licensed in a one-step procedure.

3) Provide the public with assurance that nuclear waste storage will be accomplished safely and in a reasonable time period.

4) Develop, through the Federal Energy Regulatory Commission and appropriate legislative changes by the Congress, measures to clarify competition in the provision of bulk power to distributing utilities.

5) Ask the North American Electric Reliability Council for a long term (25 years) forward look at electricity demand and supplies including economic demand reduction and economic use of alternative sources.

6) Support increased research and development on environmental control technologies and understanding of global environmental effects, on demand-side energy management and efficiency, and on the total long-term impacts of promising energy conservation strategies; also work with the States on cost/benefit evaluation techniques for demand-side management investments.

7) Strengthen the program for development of renewable energy technologies, advanced nuclear power systems and fusion, and encourage demonstrations of emerging alternative energy sources.

8) Support improvements in the public education system, starting at grade school levels, which will encourage more students to enter careers in science and engineering.

SECTION 14

PRESS CONFERENCE

As a Summary, we offer the transcript of the Press Conference held at the end of the Seminar. Perhaps a most important test is how well we can explain our views to reporters, and through them, to the public. So we offer our own summations, the questions of the reporters, and our answers.

Only San Francisco and East Bay press attended and filed stories. We found that the national media were not particularly interested in future energy or electricity needs during January of 1990. Events since have shown that even a war does not sensitize the American public to energy issues that are not already crises. That is why this book is being published now.

Fowler: This is a conference that is hosted by the University of California and sponsored by the Department of Energy. We have had 32 representatives here from 12 countries over the course of the week. Dr. A. David Rossin, who is my co-host for this meeting, was a former Assistant Secretary of Energy for the Department of Energy and has helped to organize this conference. He'll comment on the Findings and Conclusions we have reached.

Rossin: What we've tried to do is bring together a group of people with experience and responsibility in the electricity supply world, and others who are in academia, government, or associations who have been working with these problems throughout their careers. We debated issues; we tried to identify important points that we thought were essential to communicate, and we've condensed these, with great sweat, into two pages.

The ten points in our findings and conclusions tell the story that we foresee problems in ensuring an adequate supply of electricity in the coming decade. Our concern, and the urgency we see for this, and why we're talking about it now when the lights are still on, is that the lead time for building power plants is long. The period of time for getting permits to build power plants is unpredictable. If we don't have the capacity ready that we're going to need later in this decade, we're going to find

ourselves doing quick fixes and facing what I call "The Downside Risks of Electricity Shortages".

We have written Environmental Impact Statements, and every day we hear and see stories about the risks to the environment of every form of energy production and use. Rarely does any report include any discussion of the possibility that we might not have enough electricity. That's the downside. We've been all to busy looking at the risks on only one side of the equation.

These are the Downside Risks:

1. You use the kinds of fuels that you would rather not use, if you had done your planning and your construction on time.

2. Regions may reach a point where there isn't enough electricity to go around. That means, in the extreme, that we find ourselves in a situation where electricity has to be rationed, or we have to resort to enforced conservation. We don't really know what that is like in the United States, but a number of our guests from other countries have been living with this kind of thing for a long time. Where some of them live and work, electricity is only on for a number of hours during the day, certain uses of electricity are prohibited except during certain periods of time, and in some countries, the government allocates electricity supply among uses. In some countries one has had to go to the government to get a permit if you're going to become a user of a large amount of electricity - like a factory that's going to produce some goods. All of this means bureaucratic control, delays and potential abuses. This has not been the history in the United States, where our unstated energy policy has been that utilities must be ready to meet future demand.

3. If utility companies fail to meet their obligations to the region they serve, the people may demand that government take them over, and then a politically-sensitive body will have to try to do the same things the utilities were trying to do.

4. In a region where there is not enough generating capacity being planned and built, employers will look ahead, see power shortages and rising electricity rates, and instead of staying and expanding, may move their operations elsewhere, and maybe overseas as well.

5. The final downside risk we discussed is war over fuel supplies and energy.

Our Findings and Conclusions and the Recommendations that we're working on tend to focus on the United States more than they do on the

world of nations. This reflects something that was pointed out by many of our participants: What the United States does, good or bad, has a profound influence on what the other nations decide to do, maybe an unpredictable influence, but certainly an influence. So if the United States fails to act responsibly, it may make it more and more difficult for others to set responsible policies in their own countries, when they've already got a tough enough time trying to get the electricity that they vitally need for the growth and well-being of their own people.

Fowler: We've had with us this week representatives from North America, Central and South America, Asia and Europe, and the situations are somewhat different from place to place. One of our most important conclusions from getting together was to confirm what we as organizers had thought from the bits of information we're getting, namely, that the potential for electricity shortages is in fact beginning to show up worldwide.

Lorne McConnell comes from Ontario Hydro where they've been trying to grapple with this problem. We've all heard discussions like these: do we conserve, do we build nuclear, do we develop something new, do we just go with small solutions a piece at a time, and will we have enough cogeneration and power from independent producers? Well, Ontario Hydro has spent a great deal of effort coming to a plan on how to deal with the future, that is now before their government for approval.

McConnell: I think its fair to say the situation that exists in every country in the world is a little bit different from each of the other countries. But then, on the other hand, there's a lot of similarities. As we talked this week, it became quite clear that one of the things that we have in common is that we can all benefit from using electricity more efficiently. In other words, use demand-reducing options to delay the need for new capacity additions. On the other side, we agree that demand-reducing options alone are not going to meet the big requirements that exist to satisfy all the peoples in this world.

We've pretty well agreed as a group that to make sure that we don't have shortages, we can't just go around saying don't do this and don't do that. We have to have an integrated plan that looks at the advantages and disadvantages of all the options. These integrated plans have to consider the demand-reducing options as well as the supply increasing options. At Ontario Hydro, we had to set priorities, but we did it after two years of studies, interviews with our customers and public meetings.

The 1989 Ontario Hydro 25-year demand/supply plan is an example of an *integrated plan*. This proposed plan meets future Ontario electricity needs as follows:

Total New Requirements	21,600 MWe
Demand-Reducing Options	5,900 MWe
Renewable and High-Efficiency Supply Options	4,200 MWe
New Base-Load Supply (Nuclear)	7,100 MWe
New Peak-Load Supply (Gas-fired)	4,300 MWe

We are committing an investment of more than $5 billion Canadian to reduce demand. But even then, we will have to build more generating capacity.

Fowler: Our next speaker is Gianfranco Cicognani from Italy:

Cicognani: The European community presents a complex situation as far as electricity production and capacities are concerned. Countries such as France, the United Kingdom, the Federal Republic of Germany, have a fairly good supply of electricity from domestic sources. I emphasize that this includes nuclear power. For example, in France nuclear power accounts for about 70% of the total production.

On the other hand, my country, Italy, imports a high percentage of both its total energy and its electricity. Domestic hydro and geothermal electricity account for only about 20% of our total needs. The balance of our electricity is produced by fossil fuels, most of them imported, and by direct importation of kilowatt-hours from other countries. No nuclear plants are in operation in Italy, following the referendum of 1987.

Despite our conservation measures, electricity demand is now strongly increasing at the rate of about 5% per year. We are now at the limit of imported electricity. Most of this comes from the French nuclear power plants. So we must get additional power plants connected to our grid. These, of course, must be fully compatible with environmental constraints.

In general the problem of future electrical energy supply in Italy has to faced within the European community, according to the harmonization goals outlined for 1993. These goals define the unified European market. This organization includes the energy sector, which includes electricity. Italy favors a strong role of the European Community, which means decision-making that incorporates the interests of all the 12 members. As far as energy is concerned of course, this includes decisions on infra-

structure, such as power stations, transmission lines, natural gas networks and so on. In this framework, Italy intends to work to obtain high efficiency and rational use of energy, without jeopardizing the competitiveness of Italian industry. Our industry demands about 60% of our present electrical power.

Fowler: For a different look at Europe we ask Mr. Lars-Gunnar Larssen from Sweden to comment. He's with the Federation of Swedish Industries.

Larsson: I represent a small country with only 8-1/2 million inhabitants. We have a very international industry. We export half of what we produce in Sweden. The situation on electricity supply is the following: In the 1970's the Parliament decided that we were not allowed to build any more hydro in Sweden. In the beginning of the 1980's the Parliament decided that we weren't allowed to build any more nuclear power in Sweden. In mid-1987, shortly after the Chernobyl accident, the Parliament decided that we would start phasing out nuclear with two nuclear power plants to be shut down in 1995 and 1996. And in 1988 the Parliament decided that we weren't allowed to release more carbon dioxide into the atmosphere. Now that means that all the viable, realistic energy sources are out. We now produce about half of our power by nuclear and half by hydro.

We in the Swedish industry have taken a very pro-active attitude toward solving our environmental problems. We recognize the environmental problems and we say we'd like to solve them. The largest threat to that policy now is inadequate power supply. I think we need to have the public and the politicians understand that specific threat to the environment. If not, industry will not be able to give the public what they request from industry, namely to produce the basics for welfare and quality of life.

Fowler: What you've seen in our Report and heard here are our key Findings and Conclusions. This situation is not well appreciated by the public. We are beginning to see evidence in trade journals. This morning we received a journal from the electrical engineering field which sounded the same concerns we are raising here. But the real purpose, having reached some consensus on the problems, is to develop recommendations.

Davis: There is a clear conviction that economic health and growth certainly requires adequate supplies of electricity. What we've had in the U. S. is a situation in which we've had enough electric capacity. The rate of growth in demand for electricity dropped off in 1973. We had more

plants under construction than we needed to reach the new expected demands. We have not, in fact, had a shortage of power plants for the period from 1973 to the present time. Now we're coming to the end of that period and we're seeing growing signs of increasing problems and potential shortages.

Our recommendations will come to nothing unless we can get the attention of leadership, and I mean both nationally and internationally. And by leadership, I mean that it is vital that the President of the United States take a strong position on the need for adequate supplies of energy to sustain our economy. Similarly, leadership is needed from other countries. In this country this also means courage in the Congress and also from the leaders of the electric utility companies, who are responsible for supplying the electricity.

This kind of leadership will influence the public; it certainly will have an impact on our energy policies; it will have an impact our our relationships in the international energy scene. And certainly it would drive us to do those things that have to be done by the Congress and by the regulatory agencies to ensure that we have the power to sustain our economy. So what I'm stressing is leadership, and the vital need for it if our recommendations are to come about.

Seaborg: The energy problem has always had my intense interest. I think this is a very timely study. I agree with its Findings, and I'm pleased to be a part of it. We certainly do need to assure ourselves that our country, and the world, if we could, have an adequate supply of energy in the future. The indications are that we will not, unless we make some changes in the way we are going.

Fowler: There is much public concern in the industrialized countries, particularly the U. S. and Europe, about the environment, and about the impact of energy use and energy generation on the environment. One thing that one must not overlook: when it comes down to the bottom line, if one is really not prepared with adequate electricity, the priority will go to providing it.

The result of this, something we refer to as downside risks, will very likely be that very bad decisions are made in response to public outcry upon finding themselves in a situation that they cannot tolerate.

In much of the developing world, as we heard in the report from the Peoples Republic of China, electricity usage has gone up 100-fold in the last forty years and will go up many, many times in the next fifty years.

This is not to reach the energy use level of the U. S., but to a level corresponding to per capita energy use in Spain and South America.

In many countries the constraint is not environmental concerns but lack of financing. But if we do not deal with this inability to supply electricity responsibly, first in the industrialized countries that are already the big users, and then in all of the world, environmental issues, rather than being resolved, as is now the hope of the public, will just become worse.

QUESTIONS FROM REPORTERS

Question: What is your response to the critics, probably mostly environmentalists, who have said that no one is doing much to develop renewable, alternative sources of energy? This is a common complaint. We saw a small surge in the US in the 1970's, but now tax credits have been removed, and there does not seem to be much getting done.

Fowler: The fact is that a lag in interest in energy means a lag in research. It goes across the board, no matter what form of energy you are interested in, from conservation and efficiency to more distant things like fusion and solar energy. Public apathy due to lower oil prices has had an enormous detrimental influence on funding for research. How to balance research investments is still important, and depends on what people see as the potential value of each path.

McConnell: In the 25-year plan we developed for the province of Ontario, about 20% of our future needs are met from what we call renewables and high-efficiency cogeneration. Of course you are all familiar with the fact that hydroelectric generation is renewable. It is part of our supply now, and is a piece of our future, although it is inherently limited.

We've done research on other renewables, such as solar, and of course the amount of energy per square meter that's falling on the Earth's land surface varies over the world. In our particular case in Ontario, we have some solar installations which are relatively modest, and serve isolated users. We do not see them providing a major contribution in the next 25 years, although our research will continue, and we will be watching what's happening in the rest of the world.

Our plan does involve electricity production from municipal waste. As an example, this year we placed a contract for a station that is using methane drawn off of a landfill project. It will generate up to 22 megawatts for about 15 years. The garbage is the "renewable". Our plan incorporates using wood waste from the pulp and paper industry. As far as wind is concerned, in Ontario, with the exception of the hot air that is

associated with the area around our Federal government, our wind velocities are very low. To give you an idea of the land use, if we were to substitute windmills for one of our nuclear stations, it would take six times the land area of Toronto. The environmental impacts with our low velocities do not make wind tractable. We do use wind generators at some isolated stations in Northern Ontario. So we do not exclude alternatives, and give them priority when they can make a contribution, but we have to be practical about what can be done.

Rossin: When I was at the DOE one of the battles that went on all the time was where all the money goes. Of course, the battle between nuclear power and conservation and renewables was always visible, but it was just one of the many, many battles about money. The fact is that even today the amount of money for nuclear research and the amounts of money for conservation and renewables aren't that different. That is because a lot of the DOE money is going into cleaning up old facilities, and more of that came out of the nuclear budget than anywhere else.

The point is that what responsible people have been saying all along is that we are going to need all of our options. Utility people will tell you that if we could get 1% of our power from solar, we'd be delighted. It would be marvellous! I don't know a nuclear engineer anywhere who is the least bit in opposition to solar energy, because they are perfect complements. Nuclear plants are base-load plants. The Sun shines during the day. That's when the peak loads occur. Solar can help, but in reality it competes with natural gas that we burn at peak load times, rather than with nuclear which is a base-load source. So there has never been any actual competition between solar and nuclear in the real energy supply scheme.

The competition for research dollars? That's a political thing. We are eager to see the development of all viable alternatives, and there will be continuing battles over research budgets. Simply stated, no one source is going to do it all. Conservation isn't going to do it all. And certainly, no responsible person has ever said that nuclear is going to do it all.

Question: Mr. McConnell, in looking at Ontario Hydro's plan, nuclear power is about a third (30%) of the additional capacity. Is that typical? You say you have to be practical about what you can do. Is that kind of reliance on nuclear power what you can see as typical on a global scale?

McConnell: I don't say that it is typical. I commented earlier that the options that are available in different countries, and indeed in different parts of

the same country, call for different solutions. In Canada, hydro power, which is renewable, is meeting most of the needs in British Columbia. And we see that happening for some time. In Alberta, most of the needs are being met with fossil fuels. We see that continuing. The Province of Quebec uses mostly hydro and has a couple of nuclear plants, and we see that balance continuing. So it varies from one location to another, the indigenous resources, the costs and the environmental impacts. I think the same applies to other countries. What is optimum in one part of the U.S. is not optimum in other parts of the U.S., or in Russia or in China.

Erdmann: You asked about new technology development. We are doing a lot in Europe on this, but actually, it will take too much time to fill the gap between growing electricity demand and existing capacity. The same thing is also happening with nuclear energy, if decisions are not made about new capacity. Because it takes time before you can get electricity out of these plants, decisions must be taken now. This is because we foresee the demand for electricity will still continue to grow, even if additional measures to improve electrical efficiency will be undertaken. In all countries of Europe, there have been different kinds of approaches, but no country has succeeded in stopping or reducing the growth in electricity demand. Therefore, we need more capacity. The situation is the same in America. People are sleeping, when they should be deciding now!

Question: Does the U.S. need to rely more heavily on nuclear power?

Rossin: I'd say it is a tradeoff. If we do decide to add more nuclear plants, that can be done. If we don't, we're going to have to make it up by making power another way, even assuming that conservation initiatives are successful. We're going to have to make that difference up by burning coal, oil and gas. What we see right now in the U. S., since utilities aren't building large power plants of any kind, either large coal or nuclear, is that 90% of the planned additions to capacity in the U.S. today are small power producers, either independent power producers or cogenerators, and they are designed to burn natural gas. Now that's too many eggs in one basket for the future. The fallback for this will be to burn oil in existing stations that are on standby. Utilities have tankage there for standby, so that if they really get into trouble they can burn oil. That's OK for emergencies, but I don't believe that's where you want your long-term planning to be headed. We just don't have anything else in the planning stage, other than those small plants, with few exceptions.

Question: Why is that? Why haven't we planned for the future?

Rossin: We had a bubble in electric capacity because 18 years ago when electricity demand was still growing at 6 to 7% per year a lot of power plants were ordered and under construction, both nuclear and coal. After the OPEC embargo, the growth rate in demand dropped dramatically to 2 to 3% per year. Even though it was still growing, a lot of nuclear plants that were not finished were cancelled. What we're seeing now is projections for the future of growth at 2% per year when the actual data are coming in at 3% or even 3-1/2%. What has happened in the U. S., and it's happened in other countries too, is that the growth in total energy use has almost levelled off, but the growth in electricity use has continued to track the growth in the economy. Demand is rising more slowly, but supply is going up even slower, and we are beginning to see large reserve margins whittled away every year.

Fowler: Our main concern is to not let this become a sleeping problem that causes wrong short-term decisions. A coal plant or a nuclear plant is a long term investment; it takes a long time to build it. We are now at a state where good luck has made us complacent so we are not even doing what we know we need to do about long-term things and research, and a state at which we don't understand the urgency. Hence our concerns about doing it right in terms of coal emissions, nuclear wastes, and all the other environmental issues are not equally balanced by the concerns about what happens if we do nothing at all.

Davis: The history is even more complicated. Starting with the OPEC embargo in 1974, we had a period of more than ten years in which our use of fossil fuels stayed constant, and even went down in some cases. But the electricity use increased, though at 2 - 3% per year rather than the previous 6-7%. So we had adequate supply of conventional energy, declining imports, but the amount of energy that was going into electric power was steadily increasing. In 1973 we used about a quarter of all our energy to produce electric power. Last year it had risen to 36%.

Electricity has become the mainstay of our industrial development and our standard of living. But when it comes to building any kind of plants, nuclear, coal, or even hydroelectric, not only is it going to take five years to construct it, but also, we have built up a licensing and regulatory structure that has more than doubled those time periods. Now we're starting to look at real shortfalls in electricity supply in the 1990's in a number of parts of this country. We simply don't have ten years time to build new plants! So we have a feeling of urgency, and even the public is beginning to sense that we may have to do something that few felt was

necessary before. Now we are beginning to find public opinion polls that say that 70 - 80% believe that there is an energy problem and that more power plants may need to be built. And polls also show that 70-80% say that they would be willing to see some of those be nuclear power plants. Now that's quite a change in the last few years. It is why I say that we need real leadership to get this going.

Question: Why has electricity use increased? Are we using more toasters?

Davis: Well first of all, we've got a lot more people, and electricity is very versatile.

Rossin: The Electric Power Research Institute has published reports that show what is happening. Time after time in industrial processes, people figure out a way to do something with induction heating or laser energy that used to be done by burning oil or gas at the work site. You get a cleaner production process, you get much more precise control, you actually use less energy to do the job, energy costs are saved, the products become more competitive, production increases and you end up using more electricity. And the shift from direct use of fuel to using that fuel to make electricity is continuing. The most dramatic thing is the possible future impact of electric cars. You look at the Los Angeles air quality plan, and it is vehicle emissions that drive the problem. If we are ever able to develop a successful electric car, the impact on this is going to be tremendous. Then the question is how are we going to get the electricity to charge these cars from the power plants we have today?

How counterproductive it would be if we ended up charging electric cars by burning oil and gas to make steam to make electricity to charge batteries! Talk about the need to improve efficiency! That is a terrible way to do it!

Question: Given the danger you folks foresee in the lag time between building capacity and demand, would it be an equally good idea to curb population growth as it is to produce more electricity? Do both need to be done? It seems to me that population has gone up 2 - 3 billion in the last few years.

Rossin: We talked about it, but we doubt that this group can have much influence on this. But, you are right on target. Our participant from China expressed this very clearly. It is not only that population is increasing. But the demands of people and the aspirations of people keep rising. We said, "Well, how are you going to supply this electricity?" The answer is, "Mostly coal." The only thing that will really change that very much

is the extent to which they can do some of it with nuclear. The rest is going be coal. We asked him about environmental controls, and it was clear that these are a lower priority than getting the electricity.

Davis: We have a relatively low rate of growth of population in the U. S. and in the industrialized countries. As Dr. Starr pointed out, if you look at the increase in the standard of living combined with the growing population, and you find that the increase in the demand for electric power grows very rapidly. And the proportion of this that is sought by the developing countries combined with their population growth combines to have a major impact on the demand for electricity in the world. This is something that is continually overlooked in energy projections, and we must face up to it.

Rossin: Right now, the emissions of CO-2 are dominated by the industrialized countries. But in three decades, that won't be the case any more. The emissions of CO-2 for power generation and heating in the developing world will totally dominate this issue in the next century.

Fowler: The equilibrium between demand for electricity and supply has not been reached for a large portion of the world. And the evidence shows that where there is enough electricity, there is better health and sanitation, a better standard of living and longer life.

Education is a very large concern. Prof. Seaborg was co-chair of a large meeting on pre-college education here last month. Glenn, would you care to talk about that?

Seaborg: I could talk about that all day, but not this morning. In the U. S., relative to many parts of the world, we are not doing as well in science, math and engineering at the pre-college level. Changes in the high-school curriculum have not made as much of an impact as we had hoped. Sec. Watkins of the Dept. of Energy has taken a special interest in this. But it requires melding of differing points of view and more resources.

Question: The environmental restraints on the production of more electricity seems to be at the core of this debate. Mr. Larssen said you are aware of the environmental concerns but the threat of a limited energy supply is the greatest threat there is. Could you explain that?

Larsson: Let me give examples from Sweden. We had a Government investigation because people get more allergies and sicknesses — school kids, people working in office buildings. They found out that one of the reasons is that we have sealed and insulated our buildings to such an

extent that the air in our buildings is not healthy anymore. They strongly recommended that we increase the ventilation in our housing and our office buildings. And that will mean we have to use more electricity. That shows that we must get away from the general attitude saying that "No, we cannot have more energy because of the problems of producing it." Instead, we have to look to see where we use that electricity. In many cases, electricity will help in improving the environment.

Another example is the electric car. Provided that, with research and development, the industry will be able to develop them, they would be a great help for the environment in our cities. So putting any limit on the use of electricity can give us problems on the environmental side. That is the message that is quite new, and I think even the environmentalists will have to recognize that.

The labor unions in Sweden are now taking a very strong stand. I have been sitting on a committee after the Chernobyl accident. I represent industry and there were representatives from the labor unions. Together we wrote a motion. We feel that not having enough electricity is a threat to us as an industry and to the labor unions about their jobs. And what I am trying to say is that it is also a threat to the environment.

Please get me right: I am not talking about unlimited growth. But by stopping all options on the electricity supply, we will not be able to reach those goals on the environment that the public at large request from us.

Fowler: There really is a strong connection between electricity and the environment. Our French delegate, Dr. Remy Carle, who had to cancel his travel at the last minute, wrote to us that as a result of their total energy policy, they contribute positively toward global environmental protection. In the U. S., for every thousand dollars of GNP we produce, we send two tons of CO-2 into the air. For the same amount of GNP in France, the emissions are only half that amount.

Thank you all for coming.

SECTION 15

REFLECTIONS

More than a year after the Seminar, we continue to be struck by the timeliness of the Findings and Conclusions of the First 1990 Group on Electricity. Much has happened during 1990 and 1991 to heighten our concerns about the energy future. The most momentous was the Persian Gulf War. At the same time, there has been evidence of continuing relaxation of tensions between East and West in Europe, which gives hope for reaching understandings in other areas. Both superpowers have moved toward cuts in their nuclear arms arsenals.

During the same time, much has come to light about the deterioration of infrastructure in the East Bloc nations, about insufficient electric generating capacity, and about serious environmental problems that will require massive investments for solutions.

Other voices have echoed our warning of the risks of future electricity shortages. In the U. S., the Department of Energy completed two years of studies and hearings, and issued a National Energy Strategy (NES) that calls for a wide variety of supply-side and demand-side measures. Critics were quick to point out that a number of demand-side proposals were dropped in the final negotiations. Some, such as increased mileage requirements for motor vehicles, will be debated on the floor of Congress. But at the same time, governments, utilities, industries and citizen organizations are developing environmentally sound energy conservation initiatives. These are vital, because improvements in efficiency and real energy-saving programs are going to be an essential part of the future. This will be true not only in the industrial and emerging economies, but in the developing nations as well.

The future of most developing nations is clouded by immense issues, among others: difficulty in raising capital to build infrastructure, which impacts both energy supply and demand management progress, and the continued pressure of population growth.

Of most importance to the United States' electricity picture, the NES calls for removal of road-blocks to progress on the first repository for high-level radioactive waste, and for key reforms in the nuclear licensing process. Both

of these require actions by Congress that have been difficult to achieve in recent years. But if the licensing reform proposal is enacted into law, that would remove one of the most important barriers to new orders for nuclear power plants in the U.S. The other nations are watching carefully, because what the U.S. does or fails to do has impact on political processes on every continent.

The U.S. nuclear industry announced a program that should lead to licensing of standardized designs, followed by new orders by utilities. Groups opposed to any revival of nuclear power argue that new capacity will not be needed, that conservation and alternative sources will be sufficient, and raising public concerns with claims that not only high-level waste, but low-level waste represent technical problems which should be solved before new orders are allowed, rather than political problems that can be solved by responsible leadership and public understanding. They are also opposing the renewal of operating licenses for the earliest plants, whose 40-year licenses will end in the next decade, and even calling for shutdowns. Opposition has emerged in Japan and Taiwan, where support had been solid.

Our updates do reveal some positive developments for nuclear power. French nuclear plants continue to operate well, and contrary to publicity, they are proving their economics, saving money for French ratepayers, and reducing Electricite de France's long-term debt (as noted in Sec. 7). China's nuclear program is moving slowly, but the seriousness of their heavy dependence on a single fuel (coal) and its implications for both local and global environmental concerns is recognized by the government. In Sweden, the shutdown deadline for the first two reactors has been set aside, as a new, hard look at its implications reveals potential limitations on the nation's future well-being. And an important research milestone was reached when the decision was made to proceed into the 5-year Engineering Design Activity (EDA) of the ITER fusion program (Section 4). The international headquarters for the EDA will be at a site near the campus of the University of California at San Diego.

Yet, after a year of momentous developments, our bottom lime remains the same. Where is the leadership at the highest levels of government and industry who will recognize and tell their people that plans for new electric power plants must be started now? Every budget, governmental and industrial, is under pressure. But short-term thinking is driving decisions. It will take courage for leaders to face their citizens and teil them that new thinking is required now. A climate must be created that once again makes it possible to attract investment for the long term, for large, efficient and environmen-

tally sound electric power plants to ensure electricity for the future that our children and grandchildren are counting on.

Our Findings have not lost their urgency during the passage of a year. If anything, time has passed without very many critical decisions being reached. Our hope is that the actions they call for will not still be just recommendations two or five, or even ten years from now.

APPENDIX 1

LONG-TERM ENERGY DEMAND AND THE CO_2 PROBLEM IN THE PEOPLES REPUBLIC OF CHINA

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The global carbon dioxide issue and the probable climate change that could take place have already attracted the attention of not only the global academic community but also people and governments all over the world. Numerous studies have been carried out in many countries and regions, as well as in the whole world. However, the situations in the developing countries have not yet been studied extensively, in particular in the biggest one—the People's Republic of China in which over one fifth of the world population now lives and less than one eleventh of the total energy is consumed.

A preliminary survey of the CO_2 issue in the PRC was made by the author in early 1987, in which the increasing Chinese share of the global CO_2 emission was forecast and relevant policy issues addressed.(1) Since then a more elaborate long-term energy demand forecast has been carried out by ITEESA (2) and a number of studies on global CO_2 issue have been published all over the world (3), a more in-depth investigation of the Chinese role in global scope can be made and relevant policy suggestions re-evaluated. These up-dated results will be summarized in this article.

Economic and Energy Development in the PRC

Economy and energy production have grown very fast in past years, particularly since the recent economic reform. In Table A.1 the growth of aggregated and per capita national income (no GNP statistics are available before 1978), as well as the relevant growth rate are listed, which could be compared with the annual increases in both energy production and consumption shown in Table A.2. It is seen that the energy consumption elasticity amounts to 1.2178 during the past 35 years which drops to 0.537 after 1980. This reduction in elasticity implies the adequacy and achievements of the Chinese energy policy in this period which has been discussed in another recent paper of the author.(4) One conclusion is the possibility of maintaining such a low elasticity throughout a rather long period extending into the next century. More detailed analysis of the future energy demand in China confirms this trend, which will be summarized in the following sections.

Table A.1 **Growth of National Income in PRC**

(Incomes in current prices; percentages in constant prices)

Year	Aggregated National Income		Per capita National Income	
	10^9 Yuan	%	Yuan	%
1952	58.9	100.0	104	100.0
1957	90.8	153.0	142	135.5
1962	92.4	130.9	139	111.5
1965	138.7	197.4	194	156.7
1970	192.6	294.6	235	203.6
1975	250.3	384.7	273	237.6
1980	368.8	516.3	376	298.1
1985	703.1	826.6	673	448.1
1987	932.1	985.9	868	520.0

Table A.2 **Growth of Energy Production and Consumption**

Year	Energy production		Energy Consumption	
	10^6 tce	%	10^6 tce	%
1952	48.71	100.0	54.11	100.0
1957	98.61	202.4	96.44	178.2
1962	171.85	352.8	165.40	305.7
1965	188.24	386.5	189.01	349.3
1970	309.90	636.2	292.91	541.3
1975	487.54	1000.9	454.25	839.5
1980	637.35	1308.5	602.75	1113.9
1985	855.46	1756.2	770.20	1423.4
1987	912.65	1873.6	859.43	1588.3

Table A.3 **Scenarios of the Population Growth in the PRC (in millions)**

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1983	1022.07	1022.07	1022.07	1022.07
1989	1095.56	1095.56	1100.10	1101.63
1995	1147.99	1147.99	1179.35	1207.88
2001	1191.21	1191.21	1254.04	1307.73
2007	1218.68	1247.35	1309.60	1385.78
2013	1233.57	1288.35	1353.35	1454.25
2019	1234.37	1312.92	1392.14	1530.74
2025	1221.10	1323.77	1424.52	1609.14
2031	1192.55	1328.81	1441.57	1672.32
2037	1148.47	1324.11	1441.58	1718.55
2043	1091.68	1306.09	1431.36	1761.73
2049	1026.19	1278.07	1416.53	1809.33
2055	956.37	1248.54	1397.58	1855.70
2061	887.64	1223.79	1376.16	1898.15
2067	823.27	1203.22	1355.48	1942.48
2073	763.88	1184.50	1337.29	1993.67
2079	709.39	1167.92	1320.55	2048.59

Population Growth

The current population of China has already exceeded on billion which is the highest in the world. Although rather effective population control has been implemented since the late seventies, Chinese population will continue to increase steadily through the mid-21st century. Four scenarios have been suggested by researchers in the PRC which have been adopted as the basis of the government's population policy.(5) The assumptions of these scenarios are as follows:

Scenario 1: The average fertility of Chinese females will decrease steadily from 2.63% of 1982 to 1.70% by 1990 and 1.5% by 1995 and then it will be kept at 1.5% afterward;

Scenario 2: The same as above before 2001, but after 2001 the fertility will return to and be kept at 2.0%,i.e., adopt the policy of "two children each family" next century;

Scenario 3: The average fertility will decrease slowly from the 1982 value of 2.63% to 2.0% by 1990 which is kept afterward; and

Scenario 4: The average fertility will be kept at its 1984 level of 2.40% indefinitely. The results of these scenarios are shown in Table A.3.

Scenarios 1 and 2 had been preferred by the authors and recommended to the government as two ideal scenarios, in which the total population is seen attaining its maximum by 2019 at 1,234,370,000 or by 2031 at 1,238,810,000 respectively, and then declining. However, later development of events denotes that these scenarios are unrealistic, and the third scenario is more likely. Thus the present forecast is based on this third scenario which gives the peak population of 1,441,580,000 by 2037, which varies very slowly in the next century, always staying above 1.3 billion. It is noted in particular that during the next four decades the Chinese population will have a net increase of more than 400 million, which presents a formidable challenge to all the planners, as well as the decision-makers.

Economic Growth

The target of economic growth of the PRC has been set as the quadrupling of the gross national product by the year 2000 as compared with this figure in 1980. However, no official target has been declared beyond that point, except a more or less vague suggestion that the per capita income of Chinese people will match that of the low limit of the developed countries after another 50 years or so.

Based on the analysis of the possible developments of various newly industrialized and lower developed countries, e.g., Brazil, South Korea, Greece, Spain and Italy, three scenarios have been proposed, and the estimated economic growth as well as the relevant per capita GNP up to 2050 are listed in Table A.4 and A.5 respectively.

In Table A.4 the assumptions made in these three scenarios and the average growth rate are estimated. It is believed that the second scenario will be more probable.

The high growth scenario is considered possible when comparing the relevant factors with those of Japan and South Korea during their take-off period in 1960-1975. However, taking into consideration the probable influences of some non-economic factors, the scenario of medium growth may be more feasible. In the following, therefore, the medium growth scenario is taken as a most probable case for analysis.

Structure of National Economy

In order to estimate the possible change of the structure of the future national economy during a period as long as 60 years, a comparison with typical countries of different developing levels has been made, and the trends of structural change identified. It is concluded therefrom that:

(1) the share of the agricultural sector will decrease steadily to 3-5% from its present value of 36%;
(2) the share of the service sector will increase steadily to around 60% from its present value of 20%; and
(3) the share of industrial sector will not vary much, though the share of manufacturing industries will decrease somewhat to about 26%.

A forecast of the change of the economic structure in China based on the above analysis is given in Table A.6.

Energy Demand Forecast

Sectoral analysis is carried out in forecasting the future energy demand of the Chinese economy. The final energy demand of each sector is determined first, and then the primary energy demand is calculated by allowing the losses in exploitation, conversion and distribution.

Industrial Energy Demand

The energy intensity of Chinese industry is compared with different developed countries and the cause of the great discrepancy is identified:

First, the large share of energy-inefficient small and medium industries which contributed about 70% of the total value products, among which the small industries make up over 50%

Second, coal is extensively used in the industrial sector and in power generation, which caused low efficiency as well as pollution.

Third, the share of obsolete equipment and processes which resulted in additional waste of energy.

With more detailed analysis of various energy-intensive industries and the estimations of the relevant potentials of energy conservation within these industries, a conservative assumption has been made that the energy intensity of Chinese industry in 2050 will approach those that the developed countries had in 1985, or a 65 year lag. However, this requires an annual energy conservation rate of 3.5% from 1980-2020, 3.0% from 2020-2030, and 2.3% from 2030-2050. The relevant energy demand under such an assumption is shown in Table A.7.

Table A.4 **Scenarios of Chinese Economic Growth (in percent)**

Scenario	Growth Rate Syn. Factors	Elasticity of Capital	Elasticity of Labor	Average Growth Rate
High	3.5	0.4	0.6	5.5
Medium	3.4	0.4	0.6	4.7
Low	2.5	0.4	0.6	3.9

Table A.5 **Forecast of Per Capita GNP (in 1984 U.S. Dollars)**

Scenario	2000	2030	2050
High	800-1000	5,000	14,500
Medium	800-1000	4,000	10,000
Low	800-1000	3,100	6,700

Table A.6 **Forecast of the Structural Change of Chinese Economy**

Average GNP per capita (1984 US$)	Sectoral Share, %				
	Agriculture	Industry		Service	
		Total	Mfg.	Total	Trans.
2000-3000	10	45	29	45	6
4000-5000	8	40	27	52	6
10000-15000	4	36	26	60	6

Agricultural Energy Demand

The share of the future agricultural sector in the total GDP will decrease substantially as seen above. However, since the present mechanization and electrification level of the Chinese agricultural economy is very low, the modernization of this sector will require more input of commercial energy than it did before. As a result, the absolute increase of commercial energy supply will be high, as shown in Table A.8. The elasticities of both electricity and petroleum products are foreseen to be much higher as compared with the industrial sector.

Transportation Energy Demand

Since the transportation sector is an oil gobbler in most developed countries, the future energy consumption in this sector deserves particular attention in this forecast. However, the transportation modes and intensity depend on many factors, such as the structure of the economy, the size and natural conditions of the territory, the life-style and the development of the technology. Very careful analysis is therefore indispensable in the determination of the future traffic level as well as the intensities of various modes of transportation. The final results of such an analysis are summarized in Table A.9.

Energy Demand of the Service Sector

The present level and energy consumption of the Chinese service sector (excluding the transportation services) are very low. And besides, this sector has been disregarded in national statistics since it is considered to be so low. Also, this sector has been long disregarded in national statistics since it is considered non-productive and hence a parasite to the productive sectors.

The situation has been changed very much since the recent economic reform: more and more attention has been paid to the development of this sector. As a result, the development of this sector will be the fastest among all the sectors in the coming decades, so the relevant energy demand will skyrocket as well. The forecast of the energy demand in this sector is shown in Table A.10.

Residential Energy Demand

The rise of living level in both urban and rural regions of China will require a substantial increase of energy supply. In the urban region, the increased share of house heating and hot water supply in total households and the popularization of electric appliances will result in a rapid increase in the

Table A.7 **Forecast of Chinese Industrial Energy Demand**

Item	Unit	2020	2030	2050
GPD per capita	1980 US$	2,000-2,500	3,000-4,000	8,000-10,000
Population	Million	1,393	1,441	1,416
Share of Value Added in GDP	%	45.0	40.0	36.0
Value Added	10^{12} US$	1.25-1.57	1.73-2.31	4.08-5.09
Energy Intensity	kgoe/US$	0.43	0.32	0.20
Energy Demand	10^{8} tce	7.68-9.64	7.91-10.65	11.66-14.54

Table A.8 **Forecast of Energy Demand of Agricultural Sector**

Item	Unit	2000	2015	2030	2050
Growth Rate of Value Added	%	4.0	3.0	2.0	2.0
Elasticity of Electricity	%	1.0	0.9	0.8	0.8
Elasticity of Petroleum	%	1.0	0.8	0.65	0.5
Growth Rate of Elec. Consum.	%	4.0	2.7	1.6	1.6
Growth Rate of Petr. Consum.	%	4.0	2.4	1.3	1.0
Elec. Demand	TWh	51.0	76.0	96.4	132.4
Petr. Demand	10^{6} ton	12.78	18.24	22.14	27.02

Table A.9 **Forecast of Transportation Energy Demand**

Item		2020	2030	2050
Population		13.9	14.4	14.2
GNP per capita US$	High	2500	4000	9000
	Low	2000	3000	8000
Freight Traffic:				
Total 10^9ton-km	High	10700	17800	39600
	Low	8600	13400	35000
Energy Intensity	High	12.4	12.0	11.3
kgoe/10^3ton-km	Low	10.3	9.7	9.3
Energy Demand 10^6toe	High	132.68	213.60	447.48
	Low	88.58	129.98	325.50
Passenger Traffic:				
Total 10^9man-km	High	2970	4944	11000
	Low	2370	3698	9790
Energy Intensity	High	20.0	19.4	18.3
kgoe/10^3man-km	Low	16.7	15.9	14.4
Energy Demand 10^6toe	High	59.40	95.80	201.30
	Low	39.60	58.80	141.00
Total En. Demand 10^6toe	High	192.08	310.40	648.78
	Low	128.18	188.78	466.50

demand of electricity and fossil fuels. Since the oil supply will decline in the next century and the prospect of natural gas in China is still uncertain, coal gasification seems indispensable for the clean energy requirement. The results of the study are summarized in Table A.11.

Residential energy demand in the Chinese rural region is quite different from that in the urban region. In the year 1985, about 76% of the total residential energy came from non-commercial sources, mainly from straw and stalks. Only 72.64 million tce (tons of coal equivalent) of commercial fuels was supplied to the rural region, less than 100 kg per capita per year. However, due to the declining availability of biomass fuels and the ecological equilibrium consideration, the consumption of non-commercial fuels in the rural region will decrease and the supply of commercial energy must increase substantially in the next century. On the other hand, since the population in the rural region will decrease substantially due to rapid urbanization, the total energy demand will eventually decrease, although the per capita consumption increases. The results of our forecast are shown in Table A.12.

The total residential energy demand is summarized in Table A.13, in which the demand of commercial energy is seen almost to double from 2020 to 2050, while the consumption of electricity would triple. However, when compared with most developed countries, the per capita electricity consumption in China will still be low, even by 2050. The predominant role of coal in the urban residential energy structure will give rise to serious environmental pollution if no technical solution is found in the near future.

Total Energy Demand Forecast

A sum of all the above sectoral forecasts is listed in Table A.14, in which the losses of conversion and distribution are added to obtain the total energy demand. A comparison of Chinese sectoral energy structure by 2020 and 2050 with the 1985 figures of OECD countries is also shown in this table. It is noted that the 2050 structure of China is quite similar to the OECD structure while the 2030 one is obviously different. The coincidence of the 2050 value demonstrates the suitability of this approach and the validity of the results.

Energy Supply Forecast

The Availability of Energy Resources

Most of the conventional energy resources are abundant in the PRC. In Table A.15 the proven reserves and the potential resources of these fuels are

Table A.10 **Forecast of Energy Demand in the Service Sector**

Item	Unit	2020	2030	2050
GDP	10^9 US$	2780-3480	4320-5670	11300-14100
Share of Service Sector in GDP	%	39.0	46.0	54.0
Value Added	10^9 US$	1080-1350	1990-2650	6100-7610
Energy Intensity	kgoe/US$	0.087	0.067	0.050
Energy Demand	10^6 tce	134-168	190-254	436-543

Table A.11 **Forecast of Urban Residential Energy Demand**

Item	2020	2030	2050
1. total Energy demand, 10^6tce	226	357	584
2. Shares by Use: (%)			
- House Heating	36	36	37
- Cooking	16	14	11
- Hot Water	40	39	36
- Lighting and elec. Appliances	8	11	16
3. Shares by Kinds: (%)			
- Coal	55	49	42
- Gas	32	32	31
- Electricity	8	11	16
- Heat	5	8	11

Table A.12 **Forecast of Rural Residential Energy Demand**

Item	Unit	2020	2030	2050
Per Capita Useful Energy Consum.	kcal/man-day	1600	2400	3800
Rural Population	million	890	720	430
Energy Efficiency	%	25	28	30
Share of Biomass	%	45	40	30
Electrification	%	85	90	95
Non-commercial Energy Demand	10^6 tce	134	129	85
In which:				
- Fuelwood	10^6 ton	90	90	90
- Agr. Wastes	10^6 ton	173	153	67
- Others	10^6 tce	1.4	1.2	1.0
Commercial Energy Demand	10^6 tce	163	193	199
In which:				
- Coal	10^6 ton	215	257	268
- Petroleum	10^6 ton	2	2	2
- Electricity	TWh	53	52	41
Total Energy Demand	10^6 tce	297	322	284

Table A.13 **Forecast of Residential Energy Demand**

Item	Unit	2020	2030	2050
Total Res. En. Demand	10^6tce	523	679	868
In which: Commercial	10^6tce	389	550	783
Non-commercial	10^6tce	134	129	85
Per Capita En. Demand	kgce/man-yr	375	471	613
Per Capita Comm. En.	kgce/man-yr	279	382	553
Per Capita Elec. Cons.	kW/man-yr	146	261	553
Energy Structure:				
Share of Comm. En.	%	74	81	90
Share of Non-comm. En.	%	26	19	10

Table A.14 **Forecast of Total and Sectoral Energy Demands**

Item	2020		2050		OECD
	En. Demand 10^8tce	%	En. Demand 10^8tce	%	1985 %
Final En. Demand					
- Industry	7.68-9.64	36.3	11.66-14.54	26.7	26.3
- Agriculture	0.30-0.40	1.5	0.50- 0.60	1.1	1.1
- Transportation	1.83-2.74	9.6	6.67- 9.27	16.2	20.9
- Service	1.34-1.68	6.3	4.36- 5.43	10.0	8.4
- Residence	3.70-4.08	16.3	7.43- 8.22	16.0	13.5
Sum Total	14.85-18.54	70.0	30.62-38.06	70.0	70.5
Conversion and Distrib. Losses	6.37-7.95	30.0	13.12-16.31	30.0	29.5
Total Demand	21.21-26.49		43.74-54.37		

Table A.15 **Energy Resources of the PRC**

Resource	Proven Reserve		Potential Resource	
	Total	Per Capita*	Total	Per Capita*
Coal	769.2 Gton	719 ton	>3200 Gton	2994 ton
Oil	5.5 Gton	5.2 ton	60 Gton	56 ton
N. Gas	1000 Gm^3	936 m^3	33000 Gm^3	30882 m^3
Hydro	--	--	19 TWh/yr	1778kWh/yr
Uranium**	10 kton	0.01 kg	--	--

* Based on 1987 population value.

** Based on official published figure of uranium supply available for 15 GWe nuclear power plants.

Table A.16 **Forecast of Petroleum Production**

Scenario		1	2	3	4
Production in 2000	Mt	175	185	180	200
Peak Production	Mt	200	225	240	300
Peak Time		2010/20	2010/20	2020/30	2020/30
Resource Requirement:					
Final Proven Reserve	Mt	46450	50340	60130	70820
Ratio of FPR/Potential		.59-.76	.64-.82	.76-.98	.90-1.15
Decision Evaluation:					
Coeff. of Confidence		0.94	0.72	0.39	0.11

summarized, in which it is noted that the per capita values of some resources is rather low. Only the coal resource is really abundant on a per capita basis, while all the others are small as compared with the future huge demand. In particular, the most important petroleum resource seems too low for future development.

The petroleum supply will be the most critical issue in a long-term forecast. The rapid depletion of this resource will result in the declining of production soon after the turn of this century as predicated by the author in 1984.(6) More recent work gives the peak production and the timing of various scenarios as shown in Table A.16. It is seen in this table that the peak production is a function of the coefficients of confidence, i.e., the lowest production (200 Mt. annually) is most likely to be realized, but the highest one (300 Mt.) is the least likely. However, under any conditions, the maximum production will not exceed 300 million metric tons per year and the peak time will be around 2020/2030.

Hydroelectric power resources are seen as rather abundant — amounting to 1800 kw-hr per capita, or 3.8 times the consumption today. However, as compared with the tremendous increase of electricity demand by 2050, hydropower will only occupy some 20% of the total power generated, thus its share will be almost the same as it is today. Other energy sources are therefore needed to produce power on a mammoth scale.

The resource of Chinese coal seems to be unlimited but there are other restrictions for its utilization. The geographical distributions of coal resources are highly uneven, so the production sources are always far from the consuming centers. A description of such a situation is summarized in Table A.17, in which the distribution of coal reserves is listed against that of the GDP. The mismatch of these two distributions is easily seen, and this fact results in a tremendous burden on all modes of transportation.

It is noted in this table that the gaps between the relative shares of coal reserves and energy demand are the highest in four most important developed regions, i.e., North-East China—11.4%, East China—17%, Beijing/Tianjing/Hebei region—8.6% and Middle-South China—18.8%, while the surpluses are seen in Shanxi/Shaanxi/Inner Mongolia region—50.5% and North-West China—3.9%. Taking into account the volume of coal to be transported in 2050 in case no other alternatives could be deployed, it is estimated that about 3 billion tons of raw coal will be transported from Shanxi/Shaanxi/Inner Mongolia and Xingjiang region all the way to the far East coast region of China — a task in which even the technical feasibility will be subjected to suspicion, not to speak of economic rationality.

Table A.17 **Uneven Distribution of Coal Resources and Regional Shares of Energy Consumption**

Region	Proven Coal Reserves			En.Con.Share,%	
	10^9ton	%	Condition	2020	2050
Shanxi/Shaanxi/ Inner Mogolia	479.8	62.4	Plenty	11.0	11.9
North-east	64.1	8.3	65% utilized	19.1	19.7
East	46.9	6.1	Deep/depleted	24.0	23.1
Beijing/Tianjing/ Hebei	17.8	2.3	65% utilized	11.9	10.9
Middle-south	23.4	3.0	Small scale	20.6	21.8
South West	74.3	9.7	Transport. Difficult	9.0	8.3
North West	63.0	8.2	Plenty	4.7	4.3
Sum Total	769.2	100.0			

The second and more knotty problem of the burning of such a huge amount of coal is the environmental impacts encountered. A detailed discussion has been the subject of other papers of the author, hence it will be mentioned only briefly here.(7) The air pollution and the associated acid rain has already been considered one of the most impending problems in many Chinese cities, and some positive measures have been suggested to alleviate the situation. The best option is to develop alternative energy sources to replace coal as much as possible, and among those are both nuclear and solar energy.

The Structure of Primary Energy Supply

Taking into account all these resources, constraints, and possible technological advances in the early part of the next century, a rational primary energy mix for the future Chinese energy system is suggested, as shown in Table A.18. It is noted that nuclear energy is assigned an outstanding role, since a sizable amount of coal should be substituted due to the above-mentioned reasons. However, other new energies are also assigned an important role, in which solar energy will occupy a prominent place. The share of new energy is seen larger than that of oil by 2050, i.e., 4.8% vs. 3.2% or 250 tce vs. 166 tce in absolute volume. It is therefore a very challenging task.

However, much more challenging is the development of nuclear power. In order to replace coal by 10.7%, 20.7% or 30.7% from the primary total energy supply, nuclear power will have to increase annually at 4.82%, 7.16%, or 8.58% respectively from 2020 to 2050. The installed capacity of future Chinese nuclear power will then correspond to 150%, 280%, or 418% of the total world total capacity of 1987! No doubt some new, safe and economical reactor design will have to be pursued in order to implement such an ambitious program if there is no other choice in the Chinese energy future.

The Chinese Share in Global CO_2 Emission

The share of CO_2 emission in the future Chinese energy system is out of proportion to its energy share because of the high percentage of coal consumed. On the same energy output basis, coal will emit about 120% more CO_2 than natural gas and 50% more than oil. By comparing with the forecast of global carbon emission made by Edmonds, et al (8), the share of Chinese CO_2 emission is summarized in Table A.19. It is noted that the share will obviously be out of proportion to the population share in 2050, except in the ultra-high nuclear case C. The three nuclear options will reduce the share by

Tables A.18 and A.19

Table A.18: Scenarios of the Structure of Primary Energy

Item	Unit	2000	2020	2050		
Total	Mtce	1500	2400	5200		
Oil	Mt	200	250	116		
	Mtce	286	358	166		
	%	19.1	14.9	3.2		
Nat. Gas	Gm^3	40	100	200		
	Mtce	53	133	266		
	%	3.5	5.5	5.1		
Hydro	GWe	83	174	263		
	TWh	291	609	921		
	Mtce	100	210	320		
	%	6.7	8.8	6.2		
New Energy	Mtce	0	10	250		
	%	0.0	0.4	4.8		
				Case A	Case B	Case C
Coal	Mt	1470	2280	5100	4370	3640
	Mtce	1051	1626	3640	3120	2600
	%	70.1	67.8	70.0	60.0	50.0
Nuclear	GWe	5	30	291	563	835
	TWh	30	180	1750	3378	5008
	Mtce	10	63	558	1078	1598
	%	0.7	2.6	10.7	20.7	30.7

Table A.19: Chinese Shares in Global CO, Emission

Item	Unit	2000	2025	2050			
Global:							
Carbon	10^9ton	7.2	10.3	14.5			
China:							
Population	%	19.17	20.91	19.92			
				Case0	CaseA	CaseB	CaseC
Carbon	10^9ton	1.131	1.717	3.952	3.455	2.991	2.627
Share	%	15.71	16.67	27.26	23.83	20.63	17.43

3.43%, 6.63%, or even 9.83% (Case C) respectively in the above table. Thus this fact will eloquently justify the decision and the effort of an ambitious Chinese nuclear power program.

Energy Policy Issues in the PRC

The above long-term energy demand forecast and the relevant analysis of the supply strategies suggests a series of policy considerations on the future of the Chinese energy system. Detailed analysis has been carried out in a separate paper (4) but some conclusions will be briefly noted as follows:

(1) Control the population growth, in particular in the rural region.

According to optimistic estimates, China will breed roughly one Malaysia, or one GDR, or one Czechoslovakia, or one Australia per year within this decade, or create more than one United States plus one Japan from now to 2050. The pressure of population growth and the peoples' thirst for a better life will always drive the anxious Chinese decision-makers to venture into every possibility for the rapid development of this huge country.

(2) Rationalize the country's economic policies, in particular to carry on the economic reforms more thoroughly.

Only successful economic reform could give the energy industry new impetus for such large scale energy development and get rid of the chronic energy shortage in the PRC.

(3) Emphasize energy conservation.

The forecast denotes a long-term elasticity around 0.50-0.55 which demands a very hard effort on energy conservation. Not only energy-saving equipment and processes should be utilized in the future economy, but also a less energy-intensive structure of economy and life-style should be pursued.

(4) Better utilize energy resources and develop alternative energies.

The rational and clean use of coal, of course, will be one of the most important policy issues in the PRC. On the other hand, the depletion of domestic petroleum resources and the substitution of oil has attracted more and more attention. The important role of nuclear energy in the future Chinese energy system has been repeatedly discussed by many authors, and, as a result, the Chinese decision-makers in the Ministry of Energy have also emphasized this policy. There are still serious obstacles in both the safety and the economy of this nuclear option.

(5) Pursue long-term integrated planning.

Long-term integrated planning considering the interaction of energy, economy, environment and social developments is indispensable for a fast growing economy and energy system. The study of a number of issues is still needed in the long-term energy forecast of the PRC, e.g., capital investment, technology options, manpower and other resources requirements, etc. The global issue of climate change presents a new and challenging problem to Chinese decision-makers, which requires also an integrated approach in a global context.

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9. Table A.20: The Growth of Electricity Consumption of the PRC; Source: The Statistics Year Book of the PRC, various volumes.

10. Table 21: The Forecast of the Electricity Production of the PRC, Source: Wu Z, et al, The Energy Demand of the PRC by 2050, Institute of Nuclear Energy Technology, Beijing, China, December, 1988, p. 126.

Tables A.20 and A.21

Table A.20: The Growth of Electricity Consumption in the PRC (Ref. 9)
(in terawatt-hours per year)

Year	Electricity Cons.	Year	Electricity Cons.
1949	4.3	1969	94.0
1950	4.6	1970	115.9
1951	5.8	1971	138.4
1952	7.3	1972	150.0
1953	9.2	1973	164.0
1954	11.0	1974	165.9
1955	12.3	1975	192.2
1956	16.6	1976	199.6
1957	19.3	1977	218.8
1958	27.5	1978	251.1
1959	44.3	1979	275.0
1960	59.4	1980	300.6
1961	48.1	1981	309.3
1962	45.8	1982	327.7
1963	49.0	1983	351.4
1964	56.0	1984	377.0
1965	67.6	1985	410.7
1966	82.5	1986	449.6
1967	77.4	1987	496.0
1968	71.6		

Table A.21: Forecast of Electricity Production in the PRC (Ref. 10)

Year		2000	2020	2050		
Item	Unit			Case 1	Case 2	Case 3
Total Energy	10^9 tce	1.50	2.40	5.20	5.20	5.20
Share of Electricity	%	29.0	40.0	50.0	50.0	50.0
Electricity Product.	TWh	1200	3008	8150	8150	8150
Installed Capacity	GWe	240	600	1630	1630	1630
Among which:						
Hydropower	GWe	83	174	263	263	263
Coal	GWe	152	396	1076	804	532
Nuclear	GWe	5	30	291	563	835

APPENDIX 2

UPDATE: ENERGY RESOURCE DEVELOPMENT IN CHINA IN THE 1990'S

A Ten-year Plan

Abstracted from a paper written by the staff of the Division of Planning, Ministry of Energy Resources, PRC. "Energy Resources in China," Vol. 2, No. 3, March 25, 1991. Translated and furnished by Prof. Chi Wang, Oregon State Univ.

In China, the last decade of the 20th Century, encompassing the seventh and the eighth "five-year plan", is of great importance to China's goal to raise the standard of living of the Chinese people to a decent level. To this end, the objective of the energy industry is therefore to ensure that the demand of energy is adequately met during this crucial period. The basic policy in future energy development will be centered around electric power, with emphasis placed on: coal production; hydroelectric power; nuclear power; petroleum and natural gas production; energy conservation measures aimed at saving electric energy, petroleum and coal; cogeneration; utilization of waste heat; continued effort to replace petroleum with coal; improvement of energy use-efficiency; and reduction of environmental contamination.

Basic objectives for the next ten years are:

(1) Ensure that the growth rate of the energy industry is keeping pace with the growth rate of the Gross National Product (GNP). It is estimated the GNP will go up about 6% yearly during the next decade. Production of once-through energy resources should grow about 3% a year and electric power generation should increase by 7% a year.

This would mean that production of once-through energy resources should reach the level of 1.2 billion tons standard-coal-equivalent (SCE) by 1995 and 1.4 billion tons SCE by the end of the decade. Coal production should be increased 0.4 billion tons SCE a year by the year 2000; petroleum production should be increased 4.7 million tons standard oil equivalent (SOE) a year — i.e., 2.7 million tons SOE of petroleum and 1.50 billion cubic meters of natural gas; generation of hydroelectric power should be increased 10.0 billion kW-hr a year to the level of 21.0 billion kW-hr a year by the year 2000 and generation of nuclear power should be increased to the level of 10.0 billion kW-hr a year.

- The rate of energy conservation of the society as a whole should reach 3%.
- By 1995, coal consumption in thermal power plants should drop to the level of 350 g/kw-hr. Coal consumption in new thermal power plants should be about 330 g/kw-hr. Replacement of old coal-fired power plants with generation capacity estimated to be 5000 MWe.
- Reduction of power consumption within power plants.
- Gradually increase the role of coal in electric power generation to the level of 33% by the year 2000.

(3) Accelerate construction of hydroelectric facilities, aiming at a level of 13,200 MWe generation capacity by the year 2000, of which 2700 MWe will be medium to large-size facilities.

(4) Accelerate mining of coal, aimed at production of 1.4 billion tons of coal a year by the year 2000. Facilities for improvement of coal quality will also be expanded.

(5) Accelerate development of nuclear power, thereby placing nuclear power as one of the important resources of energy. By the year 2000, nuclear power plants with a total generation capacity of 5,300 MWe should be in operation, and plants with generation capacity of 5,700 MWe should be under construction. Manufacturing technology for nuclear power plants having a generation capacity of 600 MWe should be mastered for domestic manufacturing of nuclear power plants by the end of the century.

(6) Strengthen petroleum industry development, aiming at the goal of producing 170 million metric tons of petroleum and 30 billion cubic meters of natural gas by the year 2000. Redoubled efforts should be made in exploration tasks aiming at an addition of 4.3 billion tons to the present level of confirmed reserve. New efforts should be focused on the regions in western China.

(7) Development of power generation facilities in the rural area should be enhanced, including construction of medium size and small hydroelectric facilities having a total generation capacity of 3,500 MWe, and small solar-power, wind-power and geothermal plants.

(8) Making use of technological advancements, improvement should be made in management, efficiency, productivity, and environment protection. Several giant-sized projects will be undertaken making use of sophisticated technology. The development plan for the next decade includes:

(a.) Hydroelectric facilities at Three Gorges (Yangtze River) with a generation capacity of 16,789 MWe, at Lung Tan with a generation

(a.) Hydroelectric facilities at Three Gorges (Yangtze River) with a generation capacity of 16,789 MWe, at Lung Tan with a generation capacity of 4,000 MWe, at Er Tan with a generation capacity of 3,000 MWe and a number of large pumped storage stations;

(b.) Thirteen thermal power plants, each having a generation capacity of 3,000 MWe;

(c.) Two nuclear power stations, each having four 600 MWe power reactors and two nuclear power stations, each having two 1,000 MWe power reactors, a total of 6,800 MWe;

(d.) Establishment of a nation-wide transmission grid with 500 kV lines;

(e.) New coal mines to produce 80 million tons of coal and manufacture of mining facilities having a capacity of 10,000 tons per day;

(f.) Development of sophisticated techniques for exploration of oil and natural gas at desert and ocean shore sites, and technology for long-distance pipeline and ocean-to-shore transportation of oil and natural gas.

(9) Making use of modern technology and scientific management skills to improve efficiency and productivity. Planned items include:

(a.) Improve coal mine productivity by 5% a year, aimed at 2 metric tons per worker by the year 2000;

(b.) Raise the ratio of mechanized coal mining from 61% in 1989 to 84% by the year 2000;

(c.) Raise productivity of power plant workers by 5% a year;

(d.) Reduce coal consumption in power plants by improved thermal efficiency;

(e.) Condense construction time for power plants (600 MWe or higher coal-fired) to 24-30 months. Condense construction time for medium and large sized hydroelectric facilities to 2-4 years. Condense construction time for coal mines (1 million tons/year or larger) to 4 years.

Comment by Prof. Chi Wang, Oregon State Univ., July 5, 1991:

At this point, China is doing better in her economic development program. Thus, China's foreign currency reserve has increased from a low of $8 billion U.S. in 1988 to the current level of over $36 billion. China's first nuclear power plant, the Qinshan-1 plant, is scheduled to be on line by the end of 1991. The official policy in nuclear power development has been declared by Chinese leaders as "basically self-reliance, but seeking foreign advanced technology when needed."

Presently, China's Liaoning province is trying to purchase 2 VVER-1000s from the USSR by means of compensation trade, and the Shanghai nuclear power group is informally seeking foreign contractors to participate in the design and construction tasks of 2,600 MWe PWRs at the Qinshan site. In 1990, China's National Nuclear Industry Corp. (CCNIC, formerly the Ministry of Nuclear Industry) began discussions with Westinghouse Corp. to pursue cooperative development in some areas of the AP-600 program. However, the U.S.- China Nuclear Cooperation Agreement has not yet been forwarded by the White House to the Congress for ratification. Early in 1991 CNNIC negotiated with a foreign manufacturer for cooperative tasks in manufacturing fuel elements for the proposed 600 MWe nuclear power plants to be built at the Qinshan site.

However, there is no doubt that shortage of allocated funds from the central government is slowing down progress of China's nuclear power development. It is possible that the severe power shortage currently prevailing in Guangdong and the noticeable effect of "acid rain" in several coastal provinces may soon induce Chinese leaders to pay more attention to nuclear power development.

APPENDIX 3

SOCIAL MOVEMENTS AND ENERGY ISSUES

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The two questions I find most often asked are: What criterion of choice should we adopt and defend? and, Why is it that people opposed to various aspects of modern technology keep denying this criterion of choice?

In order to explain this I'm going to range very far afield and to talk to you about things you've never heard of and will sound even stranger. The only assurance that I will give you is that they are true, which is even stranger.

Consider the case of the rational potato. When mother told us that we should eat the jacket because the vitamins are there, she was right. But mother doesn't know everything; and she did not know that every living creature and everything that grows, in order to defend itself, has to be able to ward off predators. This is also true of the homely potato, which has a fair amount of poison in it. Indeed, on some very rare occasions, when potatoes decompose and concentrate their decomposition, the unfortunates who have drunk that little brew have died. Now if you were to go with this image of a parlor game, a rational potato, and you had to decide where to put your poisons, would you put them in the white, soft, pulpy center or in the harsh, rough, abrasive bark? Being a rational potato, you would put your poisons where the vitamins are. And this gives the first, and one of the most important, clues about understanding risk, namely that the good and bad consequences of every product, element and process are inextricably intertwined in the same objects.

Risk is spoken about as if there were not one tree of life but two. There's the healthy apples, and there are the sick apples. Choose healthy apples, not sick apples. What kind of statement is that? The reason we have any questions at all is that apples have both good and bad things inextricably intertwined for us. An Alar-tainted apple, for example, has one third of the carcinogenicity of a glass of Berkeley tap water: chlorine is transformed to chloroform, which is a weak carcinogen. So if we then ask, how are we to get more of the good that is in things rather than the bad, we have to come face to face with an anomaly, an apparent anomaly, that easily dissolves upon thought.

Let us stipulate to critics that many things come into the world that are bad for somebody, and many existing things are bad for somebody. Human variability is very great. And let's say that new things are always coming in that are going to hurt someone. If that was all there is, as the scare stories in the newspapers suggest, why aren't the stretcher bearers carrying the youth of America away? Have you visited our campuses? Do you notice students falling down, one after the other? On the contrary, we see that our country, in common with other advanced industrial countries, is not only among the richest but the safest and healthiest countries in the world. Indeed, we get a clue from this. In every country of the world, richer countries, with high per capita GNP, have people who are healthier than poorer ones. Within every country richer people are healthier than poorer people. Within every ethnic and regional group that I've been able to study, richer people are healthier than poorer ones. The many campaigns to denigrate American institutions, especially capitalism, tell you that the United States is eighteenth in infant mortality. That's true, but of course saying that doesn't tell you whether we're doing better or worse. Answer: we're doing better, except for those that feed crack to their children.

But, more than that, people in most of the countries are infinitely better off than people used to be, and moreover, most of them are bunched at a certain level. If, however, you took the Caucasian population, the U.S. is right up there with the leaders. But more than that, the leader in the world in good infant mortality is the Japanese. They have 6 per thousand, which is just out of this world, by historical references. But I don't want our Japanese representative go get a swelled head, because according to my theory (I've started looking for the data) the Japanese in America should be doing as well or better than the Japanese in Japan.

The American rate for Japanese-Americans is 4 per thousand which is just incredible. And indeed, when I run up against data for American Swedes and Norwegians and Danes, I believe we will find the same thing. From this example I mean to ask: What is it that's responsible for the enormous improvements in health and safety that have occurred in the last 100 years, in the last 50 years, in the last 20 years, in the last 10 years and last year? So far as I know, nobody has asked this question. For years I went around asking economists where their economic theory of health and safety was. You mean in the business schools you're going to teach people to make their children's fingers fall off and make their wives' stomachs fall out in order to make money? Surely you must think that corporate capitalism is better for people's health than if it didn't exist and, if you don't think so, why are you doing it? Why are you destroying life instead of enhancing it?

The basic answer to this question is that health and safety, as Chauncey Starr told you, is almost a direct function of our standard of living. You already know that your neighbors are a very important part of your standard of living. If you've ever lived in a place where they back out real fast and they're accident prone, you understand this very well. But more than that, health and safety, in a very general way, depend on the accumulation of fungible resources, like knowledge, information, energy, wealth and organizational capacity. I mention organizational capacity because that's often neglected. I realize I wrote a book on this theme called, "Searching for Safety", and that I neglected it also. But it is very important, and an aspect of know-how is knowing how to organize, as the entire life of Prof. Glenn Seaborg testifies. I don't know if he lists on his vita "organizational genius", but that is a very important part of the reason America has done as well as it has in the last decades.

When you have large amounts of generalizable and fungible resources, fungible meaning convertible into other things, you can then meet the axiom of uncertainty, because then you know that the idea being currently pushed — that there are going to be inherently safe reactors — is a no-no. Why would any one speak up for something that his whole life testifies to is wrong? To err is human. There is nothing associated with human beings in which there are not errors. Why should we do something so that the first time it goes wrong (and what doesn't) — didn't the great Dr. Samuel Johnson speak of second marriage as a triumph of hope over experience — why, we know that's not realistic. So what we need are systems that are going to do several things:

* Take advantage of our mistakes so we will do better in the future.

* Decentralize research, so that we can figure out what are the better things to do without investing too much in any one of them.

* And we need systems that will enable us to deal with bad things after they occur, because of the impossibility of predicting them.

In a wide-ranging search, I have concluded that nothing of importance has been predicted in our time. Not the computer revolution, not Naziism, not Bolshevism, not feminism. You name it and, if its important, we haven't predicted it.

My favorite is the 1903 Patent Office in this country, whose Chief said it could close down now because everything that could be discovered, had been. If it is true that the accumulation of generalizable resources is good for your health, that explains one thing: Why, in the presence of natural

disasters, people in rich countries do so much better than poor ones. You see what happens to poor countries. They have one of everything and it's usually missing. They don't have the facilities for early warning, and if they did, they don't have the transportation to get out of the way. They're sicker to begin with. They don't have proper clothes and shelter. Everything is more fragile, and the result is that people who live in countries that are more technologically advanced are richer, and do better under virtually every circumstance you can imagine. Why, then, do we listen and give in to people who tell us that poorer is safer? I believe in the adage of the great Yiddish red hot momma of my youth in Brooklyn, Sophie Tucker, who was very clear in her views that "I've been rich and I've been poor, and believe me, rich is better".

But all the mechanisms that we are offered to make us safer, do make us poorer. Ralph Keeney is about to come out with a paper to tell us how much we lose when we spend money on regulations and other things that are not productive. We already know that a 1% increase in the employment rate does better for peoples' health than every damn safety measure you could imagine, except maybe for two: plumbing and public health.

Out of this consideration comes a very important criterion of choice. It is very well known. I don't accept credit for it. It is only that an eternal verity is being denied. The criterion is called "net benefit". And it just tells you to weigh up, as best you can, as fallible as you are, the good and the bad health effects of things. I never talk about money because then they say, "It's only money". Money is life, money is babysitters, money is vacations, money is hospitals, money is health. Now if bad things are coming into the world at a tremendous rate, which they are, and they're harmful to somebody, what is happening so that our health rates are better every year? What is happening is that indeed these things are bad for somebody, but they're good for more people that they're bad for. So they take more good out of the intertwined good and bad in objects. The result is that, over time, unlike Greece and Rome where you died at age 30, our life expectancy and our health at different ages keeps growing.

Why, then, do we hear from environmental and so-called safety groups that net benefit is anathema? It's not wrong, its anathema. They say that if any substance does some harm to somebody, it has to be stopped. I call this "trial without error". No trials without prior guarantees against error! If we follow that rule, our wealth will decline, and then our health will decline. It's wrong to promise health and bring sickness. You should not let your opponents take the moral upper hand. On the contrary, why then do we have this enormous

opposition, not only to nuclear power, but to the release of genetically engineered organisms, one of the best things ever to come our way, whose benefits are immense and growing, and whose dangers are so remote, they can't be seen by even the most advanced microscopes? Why?

Take your clue from a basic aspect of human life. Life is with people. Whatever else people care about — they may care about dogs and cats — but always they care about their relations with other people. And what you want to do is to translate your position and that of other people's positions, into social relations. What matters most to people is other people and how they relate to each other. So let's start, as in any good scientific endeavor, a little obliquely, with a five minute exercise in conceptions of human and physical nature. And then I will show you how you can use this analysis to explain what's happening.

If you are a competitive individualist, a la Milton Friedman or our local biologists whose pride and optimism shines through every paper they write, they're going to re-create the world from micro-origins for breakfast, and everything left over they're going to have for lunch. Why, a competitive individualist's view of nature is that nature is a cornucopia. There are no resources that are natural. Human beings give whatever creativity there is. If you want to read a book that breathes the spirit, Julian Simon's "The Ultimate Resource" tells you man is the ultimate resource. So they believe in a life of incessant bidding and bargaining, Individuals believe that in order to justify incessant bidding and bargaining, they argue that whatever bad things you create from it, you'll be able to pick up afterwards by creating more resources.

Now take radical egalitarians, people who believe in greater equality of conditions. Like what? Like reducing the power differences between men and women, parents and children, animals and people, gays and straights, blacks and whites, and all the rest. Their views of nature, which you can get several times a week in your mail, from environmental groups: NOTICE: NATURE IS FRAGILE. Why, the least little upset to Mother Nature and she will wreak such havoc upon you as you will not believe! They say nature is fragile in order to emphasize that corporate capitalism, big people, people with too much money, people with too much power, exploit nature just like they do human beings. I've discovered that the comparison does much better when you reverse it.

Suppose you're a competitive individualist and want to say nature is fragile. How would you justify bidding and bargaining? How would you justify

capitalism? You would have to have immense regulation. No, you can't do this. Supposing you're an egalitarian and you said nature is cornucopian, why then should you share it? What is the need for equalizing measures if there is always enough? If you have a hierarchical disposition, then you say that nature, the physical world, is "perverse tolerant": perverse if you don't follow the rules and abide by the decisions of the great experts, tolerant if you do follow the rules and the experts.

Now there are also fatalists: people who believe that life is like a lottery, to use the words of Mrs. Gaskell's great nineteenth century novel about class warfare in Britain. Nature is random, and therefore there's no point in intervening in it because you can never figure it out. You could get rich. You could run into a great legacy or a bag of gold could fall from the sky, but from your own effort, never.

What we are living with is the externalization upon the contemporary scene of different visions of the natural world, designed to support different types of social relations. In order to understand this we have to go from models of physical nature as they are attached to a desire for different social relations to models of human nature. And that's all — no more variables.

If you are individualistic, your model of human nature is that human beings are plastic. They respond to incentives. If you are hierarchical, your model of human nature is that human beings are born bad. This is where original sin comes from. There's a lovely book by Elaine Pagels on St. Augustine in the fourth century and why his theory dominated the Catholic Church. Before Augustine, the church did not say that human beings were born bad; they had more optimistic views. But imagine that I've appointed you all, not scientists, but Roman legates! You're going out into the field and you walk down to someplace conquered by Rome and they tap you on the shoulder and they say, "In Rome, what is your conception of human nature?" And you say, "Human beings are born good but corrupted by evil institutions, like Rome". No - it is the egalitarians that keep telling you that human beings are born good but corrupted by evil institutions. Why? Because the coerciveness of the hierarchies and the structured inequalities produced by competitive individualism are terrible. If your norm of life is that everybody should have equal power, then you lash out against those who you think stand for inequality.

Thirty years ago, we didn't hear this cacophony of opposition in the history we were given. It only came in the last 20 years. When the AEC was founded it did not exist the way it does now. There was trouble aplenty, but not the

incessant hostility, the visceral contempt that we see now. It was unimaginable then that you could throw away billions upon billions of dollars on facilities like it was nothing; as if some ancient tribe met up with a curse and decided they had to do something quite different. Well, if you were fatalistic you would not object. What would it matter? What was the point of objecting? If you're an individualist you believe risk is an opportunity and man's creativity overcomes obstacles. If you're hierarchical you believe the experts like Seaborg are correct. Didn't President Kennedy appoint him? Doesn't he have the right credentials? Isn't he in tune with the other nuclear experts? All of which is true. So you see right away, the opposition can't come from there.

Let me give you a little different vocabulary. You have noticed, haven't you, that the critics are all on the left; that you almost never find a conservative among them. So who's doing this? It's the radical egalitarians who are doing this. Why? Because they first saw nuclear power as an example of the inequalities they despise and abhor. If you want to understand them, think not of the big C for Cancer, think of the four Cs: Corporate Capitalism Causes Cancer.

What you are hearing, what you are getting every day, is that your abominable behavior is part of a larger system that oppresses, represses and suppresses people. It has to be put down, and what better way to do it than to make people fearful of their waste products! What better way to do it than to say that you have to have total purity, no errors, be completely spotless, the perfect everything. Well, of course nobody can meet those criteria, and that's exactly the point.

Let me put it another way, perhaps more understandable. We are in the midst of struggle over the validity of our institutions. Don't think for a minute that because democratic capitalism has been victorious in Eastern Europe that its victory is assured here. On the contrary, you have only to know the hostility, the contempt, the rage, the anger that is expressed toward our institutions among egalitarian elites. Like whom? Like a majority of the Democratic party outside the South. Like almost all the public interest groups who, survey after survey shows, prefer the government of Nicaragua to their own. Is that crazy?

I heard from Dr. Starr that being a member of a great committee, the EPA Committee on Acid Rain, you discover it's not a wonderful phenomenon and basically it's not beneficial, but if we spent 40, 50, 100 billion dollars in a decade, we'll get a slight alleviation in about 40 years. This sort of thing

could never happen unless you had a strong and powerful movement. Again, what are the major movements of our time? Civil rights, feminism, children's rights, animal rights, and so on. They're all egalitarian movements. In other words, the anti-science part is not separated from the rest of our lives. It is an integral part of everything we experience. When's the last time you saw a TV thing or a movie that showed a businessman leading a good life?

The basic theory is in the book that I've been telling you about, that I did with a great anthropologist named Mary Douglas, called "Risk and Culture". Its thesis sounds strange: People choose what to fear to support their own way of life. For that you have to understand that objects do not come with brands on them telling you what they are. They do not come with neon lights blinking on and off saying, "Safe" or "Dangerous". These identifiers are socially constructed. It is human beings that have to agree on the meaning of things. You can't go through us or around us. Even science ultimately requires consent.

I was looking for some survey, being too poor to produce it myself, that would enable me to compare peoples' perceptions of different dangers. And along came Carl Dake from the Psychology Department with just the right thing. Now our psychologists are wonderful, though they have their limitations. Their limitation is they don't ask enough people. Their advantage is they ask hundreds of questions — they must chain their subjects to tables. As a result, I was able to do something I've been trying to do for years and craft not one dependent variable — one question — like perceptions of dangers from technology, but perceptions of dangers from war, social deviance, economic decline and technology.

Not to make too fine a point on it, I will give you the results very quickly. If you are a radical egalitarian who believes in greater equality of conditions, and who thinks our institutions are gravely lacking in producing this result, you are bombed sick out of your mind with worry about the consequences of technology. They're a great danger. Their consequences cannot be limited. No good they could ever do could compensate for this. These are all answers to questions I'm reciting back to you. But how about social deviants? There's no problem there. How about war? That's something the establishment tells you in order to perpetuate inequality. Now, if you are of a hierarchical bent, and ask, "Is technology a great danger?", they say, "Our experts say it's all right; it's not a danger." But social deviance, that is a terrible danger. They are sick with worry about the consequences. Though this question was not asked, I imagine they are very much like those you read

about and may talk to that think that AIDS is retribution for sin, for social deviance.

Risk? Risk is opportunity. Deviants? If they don't bother me — they won't make me sick — I won't bother them. Their habits are their business, as long as they don't bother me. Is it true then, that individualists are not worried about anything? Wrong, they're worried about war. And since I have an older boy who is just like this, I called him up and I got just the right answer. Why are you worried about war? Because it stops business! And the bastards conscript you!

What you see here is that these people are choosing what to fear. The evidence is the same for all of us, wherever we are, but peoples' perceptions of what is and is not dangerous vary enormously. The latest thing that I have seen is a monograph of the Russell Sage Foundation, called "The Risk Professionals" in which they interviewed 240 people who are risk assessors in government and industry, from environmental groups and the colleges and universities. A finding which is uniform across all studies, is that knowledge doesn't matter. Except there is a tendency for those who know more: whatever they know more about is both safer than other people think and won't perform as many wonders.

Now what about the other studies that are all relevant to this? What they show is that variables like trust in institutions or left/right splits explain a great deal. Knowledge doesn't explain anything. What you see is any variable that allows you to put your sense of how the world ought to work to so as to impose it on objects, that discriminates right away. Isn't it true with your own experience, that if you can find a strong supporter of nuclear power, it's rare to find a liberal? There are liberals among them, but they're very few. If you find people who are terribly worried about recombinant DNA or something, and they're terribly worried about nuclear, they're almost all perfect-type liberals, are they not?

In my book, "Searching for Safety", I have chapter on the law of torts. The law of torts is the law of personal injuries. It had a reasonable rationale which was that if a product or a person harmed another, the person who was harmed could sue and therefore there would be an incentive not to create harm. But the original idea was based on fault. That is, you had to show that the business or the person was in some way culpable, that they knew something about what could go wrong, that they could have prevented it, but did not take reasonable care. That way, it's terrific. One good thing about the tort law is that it's resilient and spontaneous, that is, you can't sue unless you got hurt.

But in recent decades, the tort law has become a means of redistributing income. And its had terrible effects. The Rand Corporation did a study of thousands of cases and this is what it shows: Supposing two people are in a terrible accident, God forbid, and one gets terribly hurt, so you sue the insurance company of the other and you collect X thousands, X tens of thousands. If one of you is a city it's 4X, if one of you is a corporation it's anybody's guess.

And now a final point. You can conceive of the world as an egalitarian or an individualist, or any way you want, but nature does not need to comply. Nothing that I have said implies relativism of any kind. I can imagine the world to be any way I want, but I can't make it come out that way. We saw in Eastern Europe promises of a better life through central command economies. They can promise all they want, but they are not able to make that good. In the same way, those who say that net benefits should be rejected, who are opponents of almost every technology that you ever heard of, who think that poorer is healthier and safer, may be able to get away with what they are doing. They are dominant in our country.

I know for a fact that I am losing. I hear it everywhere I go. I am not under any illusions that there's any majority in support of the views that I have expressed here. But I also believe, from my knowledge, that if the opponents ultimately prevail, our country and other countries will eventually end up both poorer and sicker. And to the best of our ability we should try not to allow that to happen.

Supposing there is in the Santa Cruz hills a grizzly axe murder. Somebody has been slashed into many pieces and you instantly turn on the radio to your local sociologist-cum-anthropologist: "Who is to blame?" And you will hear, "The system done did it!" The *system* has replaced the butler as the ubiquitous evil person here.

In my whole life I memorized one table which I will give you because it tells you what a serious situation we are in here. It comes from Sidney Verba and Gary Orrin's book, "Equality in America". First of all, the respondents are all elites. These are not general citizens. Here is the question: Who is to blame for poverty: the system or the individual? I'm going to give you those who argued the system/blame side. Blacks - 84% for system blame, feminists 74%, Democratic activists 64%, media elites 50%, businessmen 14%, Republicans 12%. What you see here is as clear a picture of ideological polarization as you could ever find.

What is happening to nuclear power and other aspects of technology is not something strange, it's not out there on Mars, it's not apart from other things

that happen in our lives. It's part and parcel of tremendous ideological division. And those who are on the fearmongering side, they have public opinion on their side, which is why the politicians cater to them so much.

To summarize then: if we want, based both on theory and observation, to improve the health of the citizens of the world, the way to do so is to continue with at least moderate economic growth, to extend science and technology. I'm now doing a book on Poland, to exemplify it as a case of why these regimes — Communist political economies — decline so rapidly. The whole point there is that their use of materials and energy is two to three times at least more intensive than ours, and that's one basic reason they are so polluted. Adopting a completely different system is only going to increase pollution, not decrease it.

The best criterion of choice is net benefit. The best social and economic systems are democratic, decentralized, private property oriented. The reasons for the differences among people have virtually nothing to do with knowledge; they have everything to do with preferences for a different way of life.

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