Session 8

WORKING LUNCH

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CHAIRMAN: R.D. Yoder
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INVITED SPEAKER

TITLE: ENERGY AND FEAR

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Let us talk about Energy and Fear.

Many people today have fears about how energy affects our environment and creates risks to humans.

During the past 20 years or so, we have become more aware and concerned about matters such as black lung disease, nuclear wastes, rubble from shale oil, acid rain, and the potential devastation from the "greenhouse effect" from the continued use of fossil fuels.

All of these concerns are associated with the production and utilization of energy and we share many of them.

However, we have come to realize that there are two paths to energy catastrophe:

A. Risks associated with the production and utilization of energy that put too high a burden on the environment and people, and

B. Risks associated with insufficient production of energy which, in the extreme, could lead to war.

Throughout history, and still today, we have many examples of the risks or costs associated with insufficient energy:

A. Interruptions of electricity in San Diego and Key West, Florida cost industrial users 40 to 60 times the price of purchasing the needed electricity.

B. The drain on oil-importing developing countries has been enormous in the 1970's, cutting their per-capita GNP growth rate in half.

C. Many poor countries depend on wood for most of their energy. Where increasing population has outstripped the wood supply, a wood energy crisis ensued. An ever widening circle of trees were cut, erosion set in, top-soil was blown away, and eventually there were floods and the spread of a deadly cholera. Insufficient energy, even insufficient renewable energy, can be devastating.

D. Finally, there is war. How many wars have been fought over land, water, food, minerals or other critical resources? Energy is a critical resource and, if necessary, countries will fight over it.

In a very qualitative way, these two paths to energy catastrophe can be shown on a simple drawing (Figure 1). Here the word "costs" is used in its broadest sense - the combination of risks to humans and environmental, economic and societal costs. The costs associated with insufficient energy are displayed as much more severe than the energy production costs because they can be global, extreme, and can literally develop overnight.

In the middle of this drawing is an area labeled as an "acceptable range" and that is where we believe the nation is today. However, - and this is what we fear most - the depletion of oil and gas is pushing us out of this acceptable range and on to both of these catastrophic paths.

To appreciate why this is so, one must understand that about 72% of our energy comes from oil (45%) and gas (27%). Such high percentages for oil and gas use are rather typical of industrialized nations (Figure 2). While we are similar to other industrialized nations in this respect, we differ in two important ways. We consume a disproportionate share of the world's oil (Figure 3). Of the 21 signatory nations of the International Energy Agency,

Figure 1

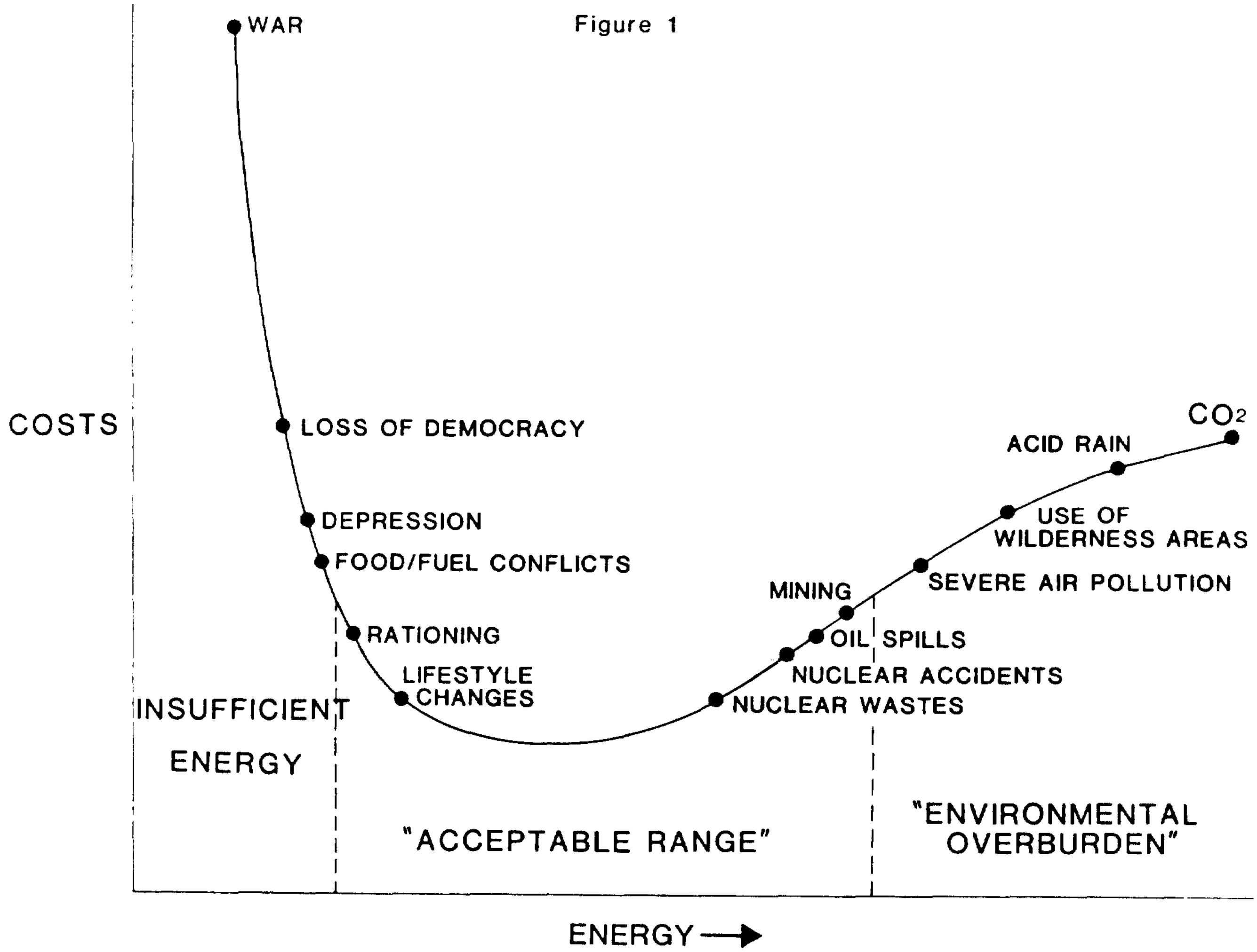

WAR
COSTS
LOSS OF DEMOCRACY
DEPRESSION
FOOD/FUEL CONFLICTS
RATIONING
LIFESTYLE CHANGES
INSUFFICIENT ENERGY
"ACCEPTABLE RANGE"
NUCLEAR WASTES
NUCLEAR ACCIDENTS
OIL SPILLS
MINING
SEVERE AIR POLLUTION
USE OF WILDERNESS AREAS
ACID RAIN
CO2
"ENVIRONMENTAL OVERBURDEN"
ENERGY

Figure 2

OIL AND GAS END-USE DATA (1972)

CANADA	81%	JAPAN	74%
DENMARK	80%	MEXICO	83%
FINLAND	76%	NETHERLANDS	90%
FRANCE	75%	NORWAY	57%
GERMANY	75%	SWEDEN	71%
ITALY	83%	U.K.	68%
		U.S.A.	72%

AVERAGE 76%

Figure 3

PETROLEUM CONSUMPTION IN SOME MAJOR INDUSTRIALIZED COUNTRIES –

(THOUSANDS OF BARREL/DAY)

	1979	1980
CANADA	1,775	1,730
FRANCE	2,107	1,965
ITALY	1,607	1,602
JAPAN	5,173	4,680
U.K.	1,690	1,420
W. GERMANY	2,664	2,360
UNITED STATES	18,434	17,006

the U.S. alone is responsible for more than half of the total oil consumption. U.S. transportation burns more oil than that used by Canada, France, Italy, England and West Germany combined. We also differ from many of our allies in terms of vulnerability. About 13% of our energy is imported. A much larger fraction of their energy is imported (Figure 4). Their vulnerabilities are of great economic and strategic importance to us. Since our destinies are linked together, our ability to cope with the depletion of oil and gas is of paramount importance to all.

Oil and gas are finite resources. In 1956, Dr. M. King Hubbert, a well known geologist formerly with Shell Oil, spoke near heresy by predicting that oil production in the lower 48 states would peak around 1970. He was right (Figure 5). The now widely accepted Hubbert mathematical model for predicting oil production indicates that we will be essentially out of oil by around 2020, some 40 years from now. Even if the remaining oil is 25% more than that predicted by Hubbert, it would only extend the 2020 exhaustion date by seven years.

Numerous other studies, such as those performed by the Congressional Budget Office (CBO) and the RAND Corporation, support the conclusion that our domestic oil production is inexorably declining. CBO states "although exploratory and drilling activities have increased greatly in recent years and discoveries have increased in number, they have not been large enough to compensate for the depletion of older, larger fields." Similar data from RAND appears in their report "The Discovery of Significant Oil and Gas Fields in the United States (Figure 6)."

An even more pessimistic analysis has been advanced by Drs. Cleveland and Hall of Cornell University. They observe that the

Figure 4

PERCENTAGE OF ENERGY IMPORTED

WEST GERMANY	54%
SWEDEN	70%
FRANCE	78%
ITALY	81%
JAPAN	86%

Figure 5

ANNUAL CRUDE-OIL PRODUCTION IN LOWER-48 STATES, SUPERPOSED UPON CURVE OF MATHEMATICAL DERIVATIVE BASED UPON DATA TO THE END OF 1971 (HUBBERT, 1978,)

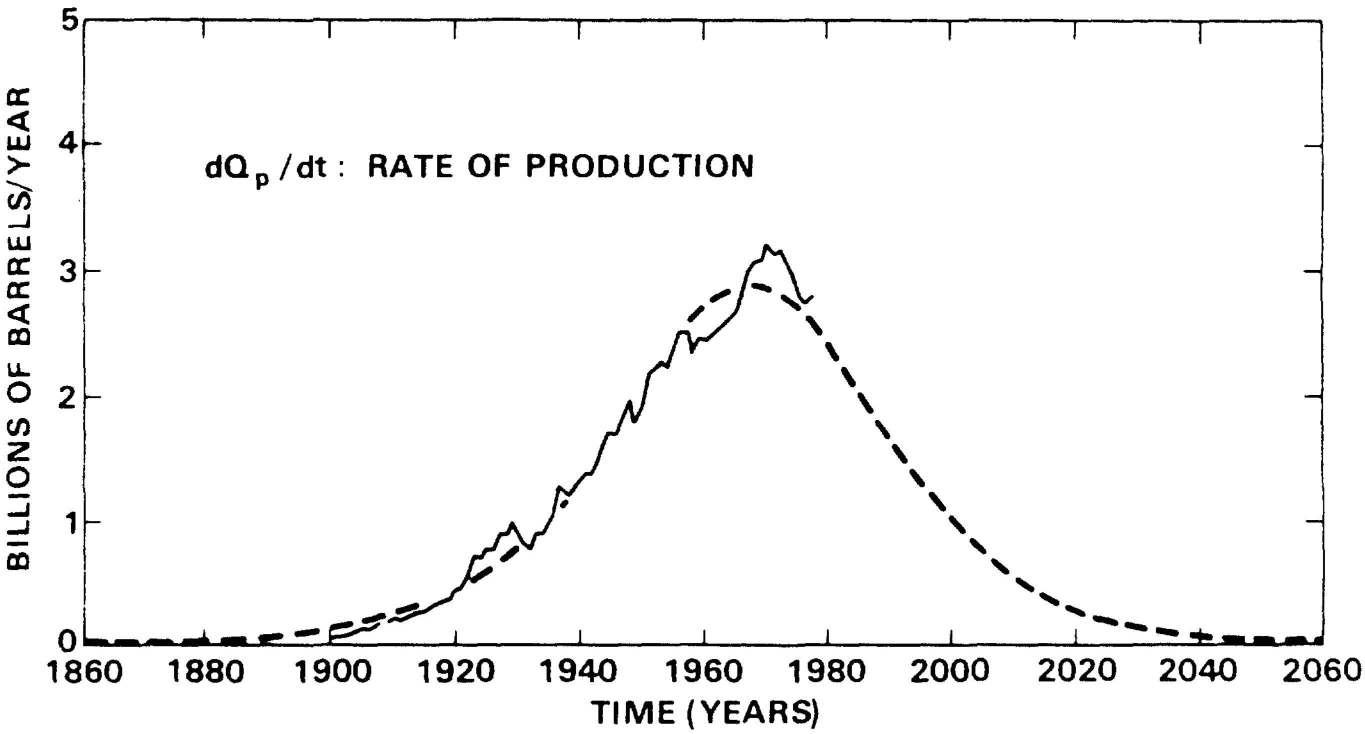
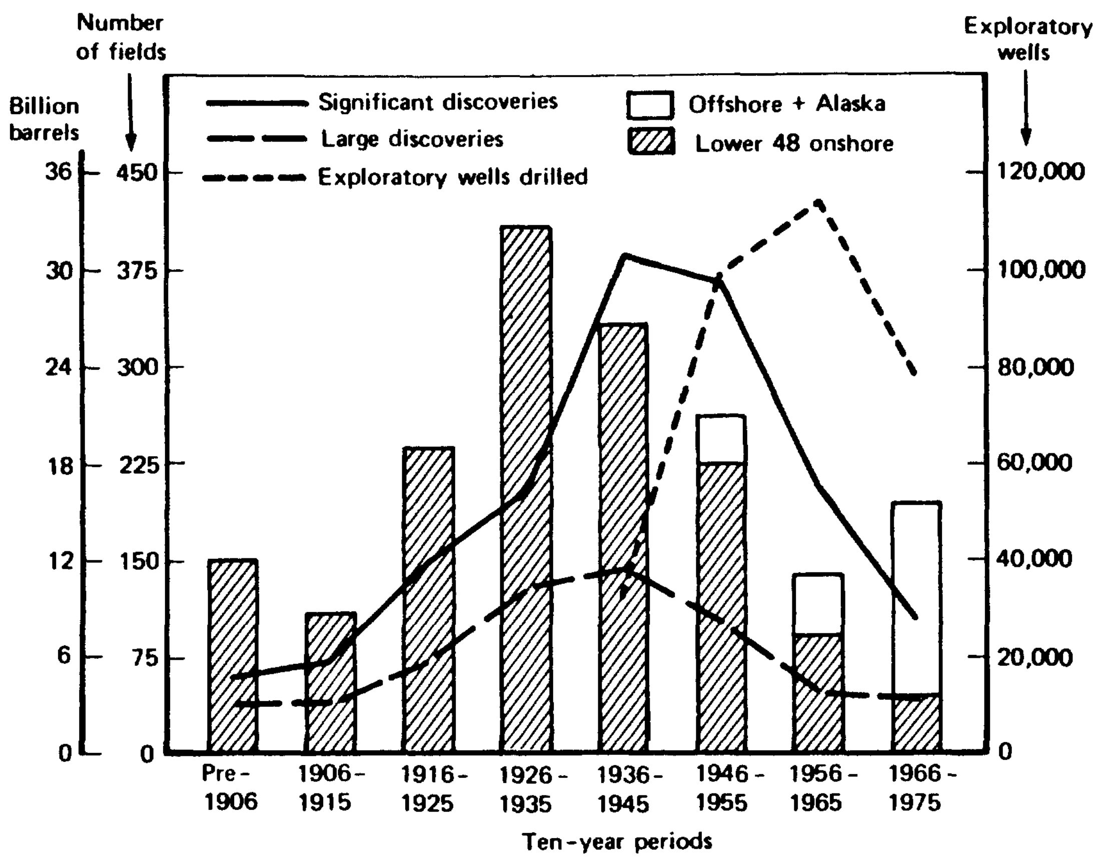


Figure 6

SIGNIFICANT OIL AND COMPOSITE DISCOVERIES, THE AMOUNT OF CRUDE OIL DISCOVERED, AND EXPLORATORY DRILLING OVER TEN-YEAR PERIODS IN THE UNITED STATES (EX-APPALACHIA)

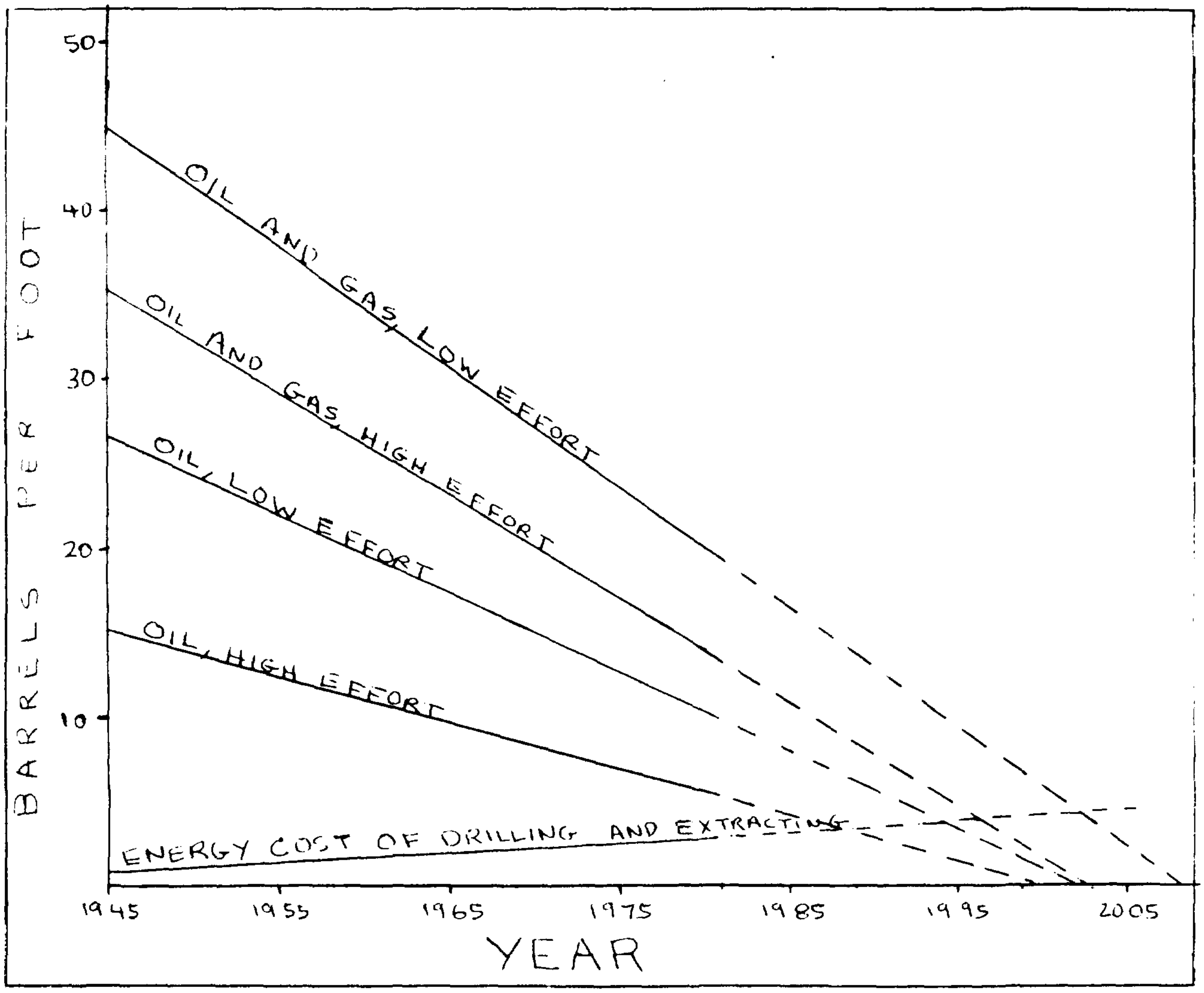


United States is probably the most "pin cushioned" country in the world with regard to oil exploration. About 2.5 million wells have been drilled. The average distance between wells is smaller than the size of a giant oil field, indicating that finding many new "giants" is unlikely. Cleveland and Hall have examined several decades of oil production per foot of exploration. Their analysis shows that there has been a decline in the number of barrels/foot for many years. They have also observed that it costs energy to extract energy. This energy investment is on the rise as we sink deeper wells, go offshore, and develop the Northern Alaska fields. With the energy investment on the rise and production (in barrels of oil per foot of exploration) on the decline, when does it cost a barrel of oil to extract a barrel of oil? Cleveland and Hall's extrapolated curves intersect about the year 2005! (Figure 7) Accordingly, there would be a net energy loss to extract the remaining oil after that date.

Other oil producing countries face similar situations. Oil production from the North Sea and from the Soviet Union is expected to peak in the 1980's, probably before 1985. World oil production is expected to peak in the 1990's and then start its inexorable decline. Hubbert's analysis of world oil production is instructive here too. By the year 2020 world oil production is estimated at about 60% of what it is today. Our "share" of this 60%, assuming the oil is democratically distributed according to the size of each nation's population, would be about 2% of today's world production. The prospects of large long-term importation of oil are dim, unless oil is taken from the weaker nations (Figure 8).

The production of natural gas peaked in the United States

Figure 7



50
40
30
20
10
BARRELS PER FOOT
OIL AND GAS, LOW EFFORT
OIL AND GAS, HIGH EFFORT
OIL, LOW EFFORT
OIL, HIGH EFFORT
ENERGY COST OF DRILLING AND EXTRACTING
1945
1955
1965
1975
1985
1995
2005
YEAR

ALTERNATIVE COMPLETE CYCLES OF WORLD CRUDE-OIL PRODUCTION (HUBBERT, 1978,)

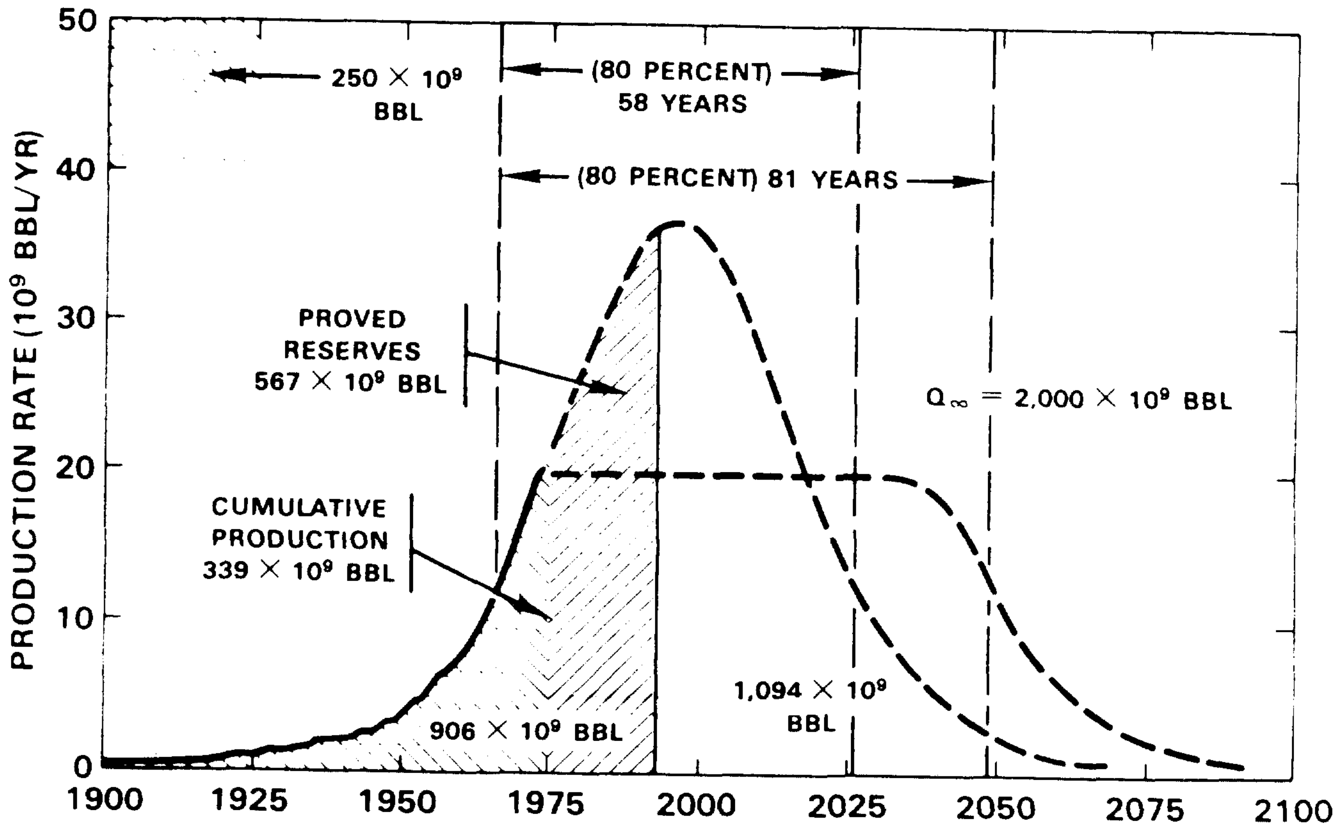


Figure 8

in 1973. The decline in natural gas from conventional resources is not expected to be as rapid as the decline in "conventional" oil. Nonetheless, natural gas production by the year 2000 is estimated by ORNL to be some 36-56% of the 1980 production. Additional production of gas many come from unconventional resources, but at a much higher price. By the time we are out of oil around 2020, gas production may well be quite limited and reserved for petrochemical applications. The National Audubon Society has made similar forecasts. They anticipate that oil use would drop from 44% of today's energy budget to 20% by the year 2000 and gas would decline from 25% to 19%. Assuming no growth in overall energy use, alternate energy supplies (coal, nuclear, solar) would have to more than double in the next 20 years to offset this decline.

Earlier we said that we feared that this depletion of oil and gas might drive us up both paths to energy catastrophe. Let's return to that thought and examine the energy insufficiency path first.

We are spending enormous sums of money on imported oil. In 1979 we spent 60 billion dollars. In 1980 we spent 83 billion dollars, even though our imports dropped 21% from 1979 to 1980. This is money that could be better spent here. One estimate is that one billion dollar creates about 100,000 jobs. Yet even these staggering costs undervalue the impact of imported oil because they are based on just the direct, or market, price of oil. The Institute of Gas Technology recently evaluated the indirect costs of imported oil, taking into account its effects on employment, inflation and national security and concluded that the real price of oil to the economy is on the order of $80 to

$110 per barrel. Similar numbers, $100/barrel, have been calculated for OECD countries. With these figures, the real cost of oil for 1980 was about one quarter of a trillion dollars - about $1000/year for every man, woman, and child in the USA. In spite of the present decline in oil prices, we still face further sharp and sudden price increases. The outbreak of the IRAN-IRAQ war caused a rapid doubling of oil prices, yet there was only a 4% reduction in the free world's oil supply. The previously shown acute vulnerability of our allies to imported oil underscores their sensitivity to oil shortages and the volatility of oil prices.

The cost of oil has had many other effects within our country. There have been shifts of jobs and companies away from the energy poor regions in the country, such as New York and New England. There have also been disproportionate accumulations of capital. Not too long ago, SOHIO bought out the large Kennecott Copper Company. It only took one year's profit for SOHIO, yet SOHIO is not even among this country's ten largest oil companies.

Rising energy prices have created a structural change in the nationwide distribution of industrial profits, with oil and natural gas industries in the Fortune 500 dominating the net-income picture at the expense of other industries, according to a House Energy and Commerce subcommittee report.

The "alarming" shift in corporate earnings to this energy industry is evidenced by statistics reflecting industrial activity between 1978-80, the report said. For example, during that period, the Fortune 500 firms increased their overall net income by $19.6 billion, with $19.2 billion or 98% of the increase accruing to 56 oil, gas and energy service and supply companies on the list.

What course Democracy when so much wealth is in the hands of so few?

More attention should be paid to petrochemicals, oil's priority use. There are thousands of petrochemical products that we use including plastics, fertilizers, and pharmaceuticals. Efforts should be made to create a petrochemical oil reserve. This would ease the burden on future generations who face the task of finding economical substitutes for this prized feedstock. Synthetic fibers, one of the many petrochemical applications, is a good example. Synthetic fibers today are the equivalent of 21,000,000 acres worth of cotton. This is 2.7 times more land than the cotton farms in Texas, our foremost cotton producing state. With land use already near its limit, it would be prudent to have a strategic petroleum reserve for oil as a feedstock, as well as an energy source (Figure 9).

Other examples are available to illustrate the effects of insufficient oil. Among the more ominous ones is the recent reinstatement of draft registration, an outgrowth of oil tensions.

Let us turn our attention to the other path, the effect of oil on the environment. As domestic oil has become more scarce, we have increasingly turned to exploitation of ecologically sensitive areas such as the Georges Bank Fishing Area, the Bob Marshall Wilderness, California's Big Sur, and the northern slopes of Alaska.*

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* Figure 6, years 1966-1975, vividly makes this point where the majority of the oil discoveries for this period came from offshore and Alaskan sources.

Figure 9

PETROCHEMICALS

EXAMPLE: COTTON (1980)

SYNTHETIC FIBERS 2.7 x TEXAS PRODUCTION

EQUIVALENT OF 21,000,000 ACRES

Figure 10

A PROPOSAL

1. A LOW ENERGY FUTURE OF ABOUT 55 QUADS

2. AN ENERGY FAMILY — A MIX OF COAL, NUCLEAR, AND SOLAR

Increased scarcity means higher prices. Higher prices means more pressure to go into more remote or fragile ecological areas. Consequently, the ecological price for oil is on the rise. Lest we overrate the present so-called "oil glut" and think that this ecological challenge is behind us, we should remind ourselves how small this glut really is: about 3.5% of the world's annual oil use. The chief economist at the International Energy Agency believes that fully 1/3 to 1/2 of the present reduction in energy demand by OECD nations is because of the economic slowdown. In our own country, with unemployment at a 40 year high, what will happen to the oil glut when the economy improves and unemployed people start to drive to work again and the energy intensive steel, auto, and construction industries revive? Will insufficient oil then drive us like the people caught in the wood crisis and bring on renewed pressures to exploit the ecologically sensitive areas?

Now who among us would choose one path to energy catastrophe over another? Yet, to ignore that oil and gas depletion is the dominant energy risk, is to travel both paths to catastrophe.

What follows is a plan designed to keep us in the acceptable energy range over the next 40 years as we transform our society into one where all end uses - transportation, agriculture, industry, residential and commercial -- can be accomplished effectively without oil and gas. The overall goal is:

A LOW ENERGY FUTURE

USING A MIX OF COAL, NUCLEAR, AND SOLAR ENERGY

(Figure 10)

This approach, strong in both conservation and new energy supplies, would reduce oil (and gas) use most rapidly. To reduce oil use most rapidly is to travel the path of minimum risk. A mix of these energy sources is attractive because coal, nuclear and solar often draw upon different infrastructures for their development. Oil and gas can be displaced more rapidly by pressing the development of all three sources, rather than having the pace set by one overstrained source. Coal, nuclear, and solar often serve different markets because of their inherently different characteristics. The diversity of this mix of energy supplies lends itself to a more rapid penetration of the markets now dominated by oil and gas. Consequently a mix of energy sources is more rapidly developed and more readily deployed.

This emphasis on conservation serves two purposes; it results in an energy future that would have a more limited impact on the environment and it produces a state of sufficiency at a lower, and therefore more rapidly achievable, energy level.

This plan might be considered an extreme case for conservation as it is even lower in energy use than a number of solar energy studies and lower than the low energy futures studied by the National Academy of Sciences (Figure 11).* In this analysis, national energy use was reduced from our present 76** quads down to only 55 quads by the year 2020. Using Census Series II population growth projections, the resultant energy use per person would only be one half of what we use today.*** Much of this

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* Note that Figure 11 includes forecasts from National Audubon, UCS.

** One quad equal 10^{15} BTU's.

*** This approach is in sharp contrast to our historical energy consumption patterns (See Figure 11 A).

Figure 11

PROJECTED ENERGY DEMAND
1978 - 2020

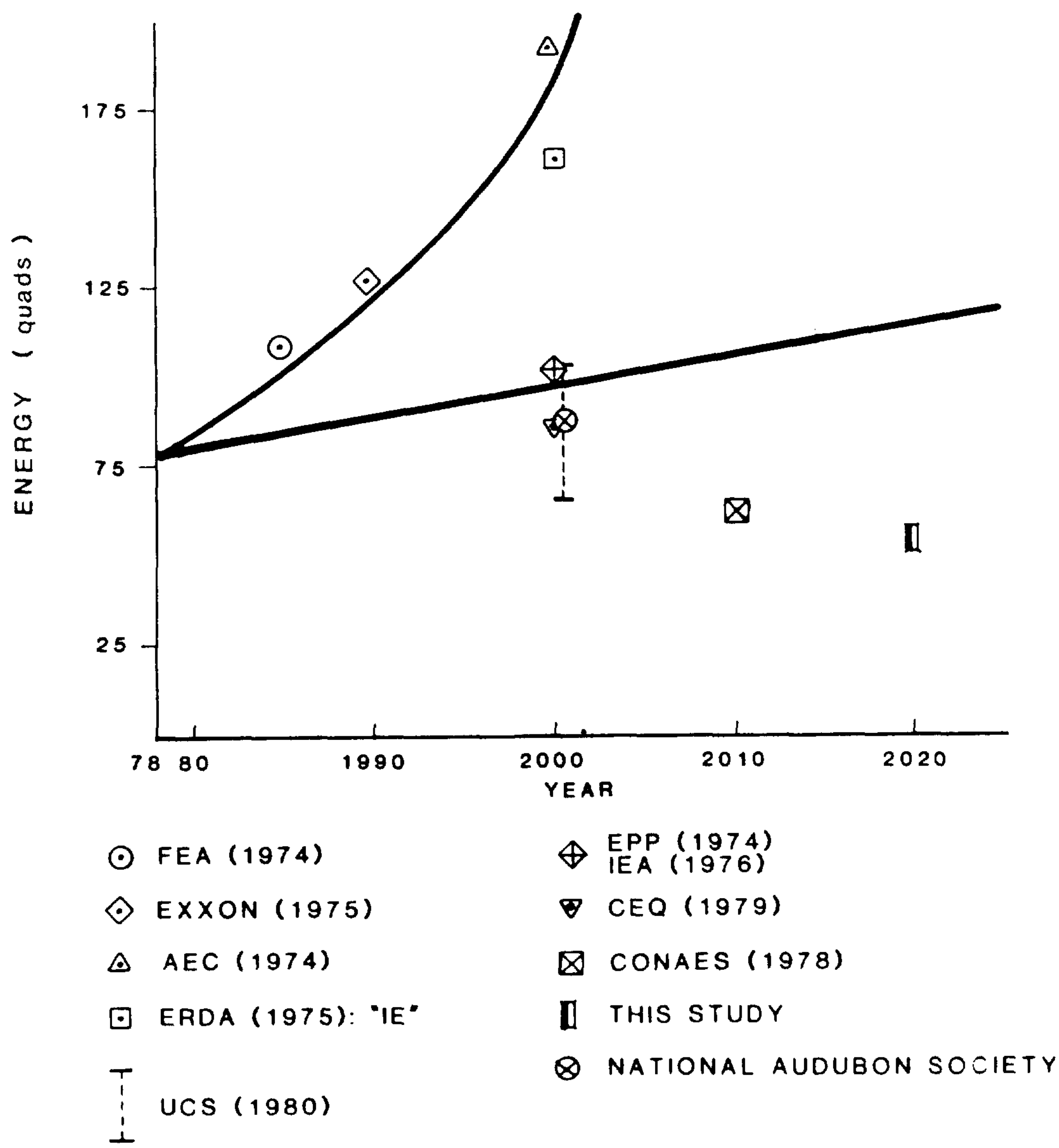
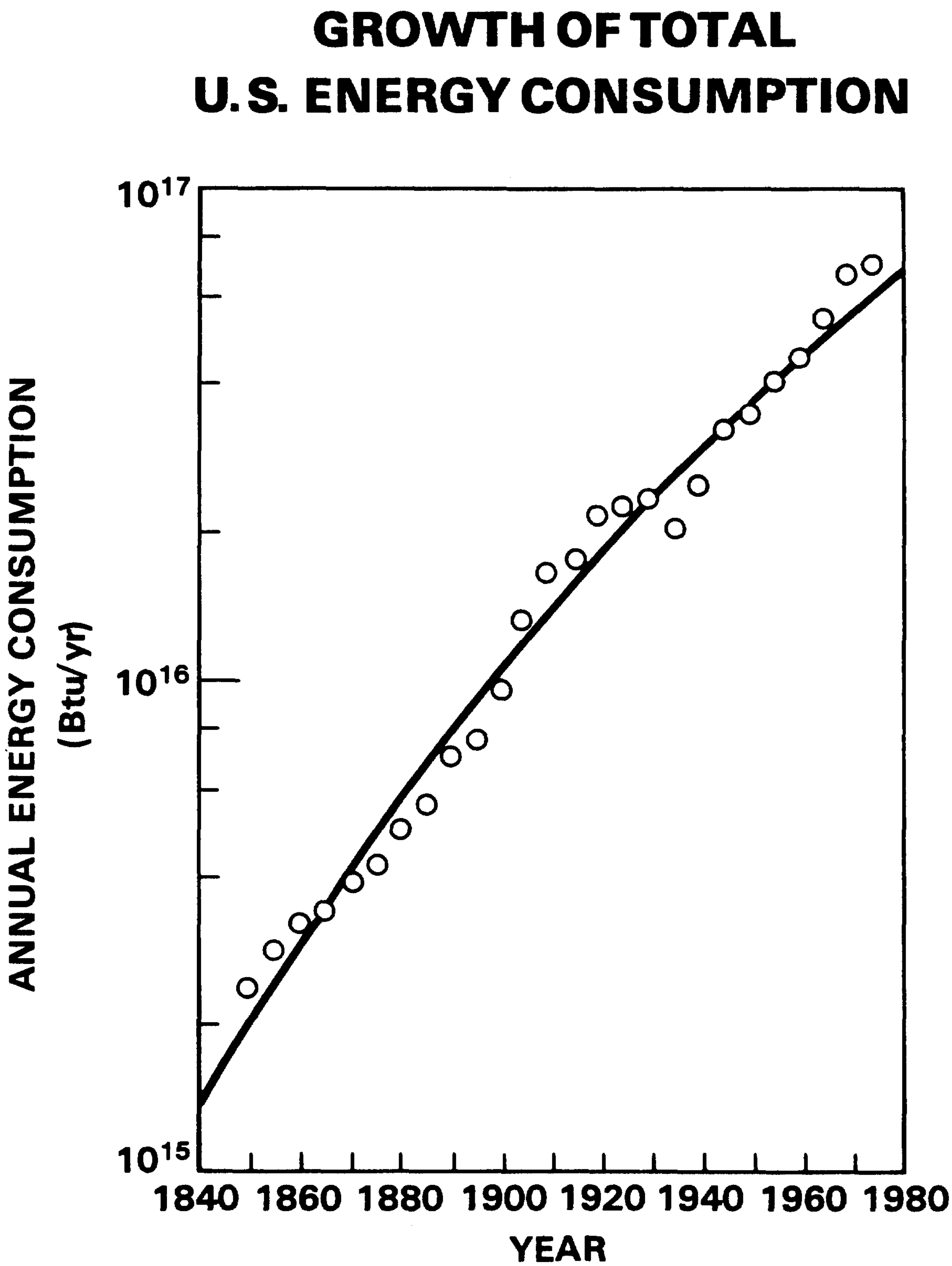


Figure 11A


GROWTH OF TOTAL
U.S. ENERGY CONSUMPTION
10^{17}
10^{16}
10^{15}
ANNUAL ENERGY CONSUMPTION
(Btu/yr)
1840
1860
1880
1900
1920
1940
1960
1980
YEAR

conservation is achieved by actions like more home insulation, more efficient vehicles, and improved appliances. However, significant additional gains in conservation are achieved by two forms of cogeneration:

(a) Using industrial steam to generate electricity

(b) Using rejected heat from coal and nuclear plants for district heating and other processes.

Even with such a low energy future, we can draw two important conclusions:

(1) There is scope for coal, nuclear, and solar energy, for each will have to grow significantly.

(2) Not only must there be large increases in the above energy supplies, they must be accompanied by modifications and expansions of our energy distribution networks (e.g. pipelines, transmission grids) and changes in the end use devices - cars, space heaters, industrial processes - to enable them to use these new energy supplies. We are talking about a restructuring of our whole energy system in just 40 years.

It is possible today to develop general guidelines on how to make an effective mix of coal, nuclear and solar energy. Let us examine how space heating and domestic hot water needs might be met in a post oil economy future. First strong conservation measures like proper insulation are applied. With regard to supply, population density is a key for establishing space heating mixes. Solar heating is most effective in low population density rural areas and least effective in city areas where it is limited by shadowing, minimal energy collection area per resident and by heavy and oversized energy storage systems.

District heating-piping in the heat now discarded by electric power plants - exhibits the opposite population density characteristics. It is most economical in cities, but it doesn't pay to run hot water pipes to widely scattered farm houses. Solar heating and district heating are complimentary energy sources because their inherent characteristics make them serve different markets. Recognizing these characteristics, the country was divided in rural, suburban, and city areas according to U.S. Census Bureau data (Figure 12). Solar heating was assigned 60% of the heating needs in rural areas, tapering off to 30% and 3% in suburban and city areas, respectively (Figure 13). The overall solar heating contribution is consistent with General Electric solar studies. District heating was assigned 75% of city needs, 25% suburban and zero for rural areas. The overall district heating contribution, 34%, is well within the 50 - 60% values calculated by Brookhaven National Laboratory to be economical. A 20% heating contribution from biomass can be made in rural areas without interfering with food or forest production and would minimize the transportation of these bulky fuels. Well suited to suburban heating needs are community nuclear heating plants. These small, extremely safe nuclear plants produce heat only -- no electricity -- and operate at temperatures and pressures like those of a car radiator. Sweden and Finland are developing such plants and France has several versions of its own. Throughout all three areas electricity and coal synthetics (e.g. coal gas) provide supplementary heat sources.

The transportation energy mix was determined with similar considerations. A 50% reduction in energy use in the transportation sector was assumed to occur through greater use of mass

Figure 12

U.S. POPULATION DISTRIBUTION

POPULATION SEGMENT	NUMBER OF INHABITANTS PER SQUARE MILE	FRACTION OF POPULATION
CITY	GREATER THAN 3300	0.31
SUBURBAN	BETWEEN 150 AND 3300	0.42
RURAL	LESS THAN 150	0.27

Figure 13

SPACE HEATING AND HOT WATER

ENERGY SOURCE	LOCAL NEEDS MET BY ENERGY SOURCE, %			NATIONAL NEEDS MET BY ENERGY SOURCE, %
	CITY	SUBURBAN	RURAL	
LARGE DISTRICT HEATING SYSTEMS	75	25	0	33.8
COMMUNITY NUCLEAR HEATING PLANTS	0	25	0	10.5
COAL SYNTHETICS	12	12	15	12.8
SOLAR HEATING	3	30	60	29.7
ELECTRIC HEATING				
FROM ELECTRIC GRIDS	10	8	2	7.0
FROM WIND MACHINES	0	0	3	0.8
BIOMASS	0	0	20	5.4

transportation, carrying more goods by pipeline, and more efficient cars, trucks, and planes. Electric transportation would be emphasized in city and suburban areas where it is more practical and to minimize air and noise pollution. Methanol from coal would provide the liquid fuel necessary for planes, ships, and intercity travel where electric transportation is less attractive. Although methanol would only supply about half of this highly conservative transportation future, some 610 million tons/year of coal would be needed. Today's coal production is about 800 million tons/year(Figure 14). Coal's priority use in the long term is for liquid and gaseous fuels.

The same principles were applied in the industrial sector. Conservation steps would be taken first to improve efficiency and energy supply would come from a mix---40% coal, 35% electricity, 15 and 10 percent nuclear and solar non-electric sources, respectively (Figure 15). Process steam is an example of a non-electric energy supply.

Summing up the various contributions for all the different end uses, the relative contributions would be 53% coal, 33% nuclear and 14% solar. Coal production would have to double, nuclear power would increase by a factor of 11 and solar energy by a factor of 9 even though energy conservation was so successful that energy use per person was cut to half of what it is today (Figure 16).

The role of electricity in this analysis is interesting. Even after applying conservation measures, electricity use in the post-oil era would be at least 90% greater than it is today.

In these times of slowing electricity growth and cancellations of new power plants, a 90% increase in electricity for a

Figure 14

TRANSPORTATION

50% REDUCTION IN ENERGY USE

55% FROM METHANOL – $610 \times 10^6 \dfrac{\text{TONS OF COAL}}{\text{YEAR}}$

45% ELECTRIC VEHICLES

Figure 15

INDUSTRY

40% COAL

35% ELECTRICITY

15% NUCLEAR NONELECTRIC

10% SOLAR NONELECTRIC

Figure 16

GROWTH IN ENERGY SOURCES

COAL (53%)	FACTOR OF 2
NUCLEAR (33%)	FACTOR OF 11
SOLAR (14%)	FACTOR OF 9

low energy future may seem out of place.* The reasoning behind this growth is the changing role of electricity. Whereas in the past electricity growth was linked to our increasing material wealth, the new driving force would be as a replacement for oil and gas in the end uses. Present utility planning uncertainties are due, in part, to the difficulties of a nation switching from one driving force to another.

The need for large increases in electricity to replace oil and gas has been recognized elsewhere. A number of solar future studies show figures much larger than the 90% given here, even after applying strong conservation measures (Figure 17). Over the next 20 years or more, major increases in electricity from solar energy are not expected. However, the present build-up of nuclear and coal supplied electricity lays the groundwork for more solar electricity as it becomes more competitive. By expanding our present electrical transmission systems and increasing the number of oil-displacing electrical end uses (e.g. electric heat pumps), we create a ready market for solar electricity. In other words, growth in coal and nuclear electricity today accelerates the future deployment of solar electricity.

The mix in this larger electricity future was determined by pushing hydropower to its land use and environmental impact limits, wind-power to the point where we probably would run out of good sites, greatly expanding industrial co-generation of electricity, and using some small contributions from photovoltaics, biomass, and geothermal sources (Figure 18). The remaining electricity would be generated by coal (28%) and nuclear

* See Figure 17A for Historical Data on US Electricity Consumption.

Figure 17

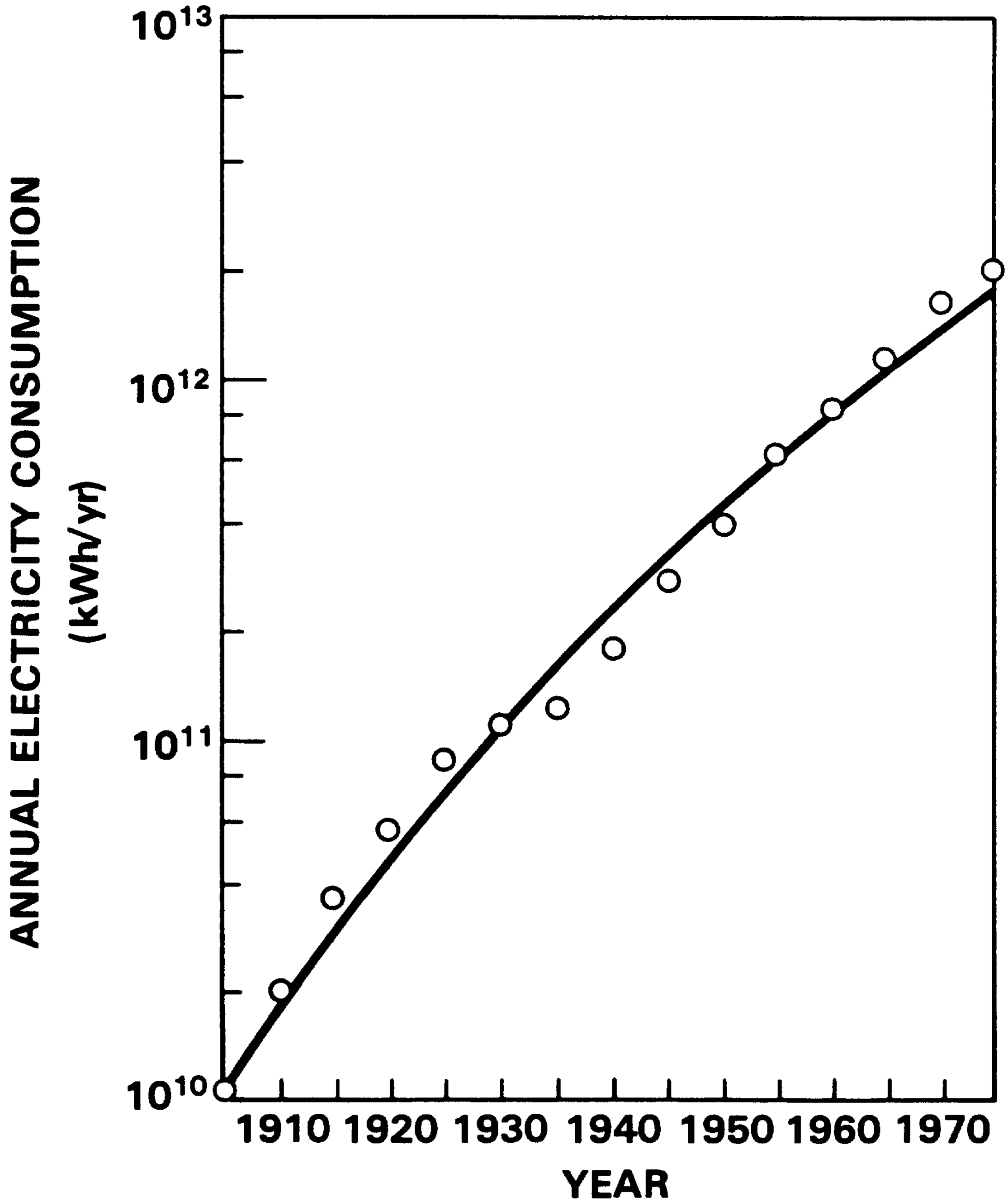
ELECTRICITY GROWTH

- SOME SOLAR SCENARIOS -

	Increase	Year
NATIONAL AUDUBON SOCIETY	+ 30%	2000
SWEDEN BEYOND OIL	+ 136%	2020
DEPARTMENT OF ENERGY (FOE)	+ 160%	2025
UNION OF CONCERNED SCIENTISTS	+ 173 to 263%	2050

Figure 17A

GROWTH OF U.S. ELECTRICITY CONSUMPTION



power (44%).

Nuclear power was assigned 1½ times more electricity than coal for two reasons: coal has greater supply constraints and greater risks. Large demands would be placed on coal for fuel synthetics, for direct use in industry, and other uses that have higher priority than using coal to make electricity. In addition to doubling coal production for domestic needs, we will need to increase our coal exports to help meet world energy demands. Mining and delivering all this coal would be difficult. With regard to risks, the General Accounting Office has examined the relationship between the production of CO_2 from coal and the role of nuclear power. They observe that if the CO_2 problem requires phasing out of coal early in the next century, then both coal and oil, (and gas) would be simultaneously declining. Under such conditions nuclear power would have to be in a very strong position to replace these fossil fuels. Consequently, nuclear power was given a larger role than coal in the production of electricity.

Achieving this low energy future will be a gigantic accomplishment. To get a somewhat deeper appreciation of this, some of the resource requirements for coal and solar are given in figures 19 and 20. The information in Figure 19 on coal requirements allows for a reasonable export capability and is keyed to the year 2000. Missing from this table are the efforts needed to expand our coal ports, the additional miners, the expansion of the factories that manufacture unit trains, the widening of coal barge traffic pinchpoints and the disentangling of pipeline/railroad rights-of-way conflicts. Also missing from this table are the very large efforts required to bring about a coal synthe-

Figure 18

ELECTRICITY

SOURCE OF ELECTRICITY	PERCENTAGE OF U.S. NEEDS
HYDROELECTRIC POWER	9
WIND TURBINE GENERATORS	3
COGENERATION	12
COAL PLANTS	28
NUCLEAR PLANTS	44
OTHERS (E.G. PHOTOVOLTAICS, BIOMASS, GEOTHERMAL)	4

Figure 19

RESOURCE REQUIREMENTS FOR COAL PRODUCTION & TRANSPORTATION

Nominal Facility	*Estimated 1980*	*Total in 2000*	*Total Additions* 1980–2000*
Underground mines (capacity 2 million tons per mine per year)**	173	427	450
Surface mines (capacity 4 to 6 million tons per mine per year)	105	229	235
Unit trains (capacity 10,500 tons per train)	268	948	984
Conventional trains (capacity 7225 tons per train)	2,856	4,282	3,327
Coal trucks (capacity 25 tons per truck)	9,060	16,615	39,596
Coal barges (capacity 21,000 tons per barge)	68	106	76
Coal slurry pipeline (25 million tons per line per year)	1	27	26
Land area (acres)	144,565	158,034	—
Water (acre feet per year)	103,370	323,900	—

*Additions include replacements for retired capacity as well as increases in total capacity.

**There are presently approximately 5000 underground coal mines in the USA. These have been lumped together in mines producing 2 million tons each per year for comparison purposes.

Figure 20

SOME RESOURCE REQUIREMENTS FOR SOLAR

- 34000 LARGE WINDMILLS
  - REQUIRES 4 FACILITIES EACH THE SIZE OF GENERAL ELECTRIC'S LOCOMOTIVE FACILITY
- 30% INCREASE IN HYDROPOWER
- EXPANDED BIOMASS
- SOLAR HOT WATER, SPACE HEATING FOR 145 MILLION AMERICANS
- PHOTOVOLTAICS

tics industry, which would have to start making major contributions soon after the year 2000. Unquestionably, many other items could be added to this already long list.

The resource requirements for solar energy shown in Figure 20 is also a partial listing. Finding acceptable sites for 34,000 wind-mills is not a small task. Providing solar heating and hot water for 145 million Americans would require a major new industry. Because of enormous materials requirements for a active solar heating program of this size, emphasis should be put on passive solar systems. A general comment on other resource requirements is appropriate here. Solar energy is diffuse and consequently large collection areas are required. This often means that large amounts of materials, e.g. steel, aluminum, and glass must be used in certain solar designs, which in turn results in high initial prices, large investments in energy to construct these collectors, and severe strains on mineral resources. A photovoltaic system investigated by MIT illustrates this point. In order to add the energy equivalent of four to five large (1000MWe) coal or nuclear plants each year, the development of this photovoltaic design would consume the following portions of our present national use:

Aluminum	45%/yr
Steel	15%/yr
Arsenic	5-35%/yr
Silicon	30%/yr
Cadmium	250-1100%/yr
Gallium	7500-51000%/yr

It is unlikely that such demands for mineral resources can be met. Coupled with this is our already large dependency on other nations for mineral resources (Figures 21, 21A). Consequently, significant gains in solar energy hinge on the development of less material intensive designs.

The rate of development of nuclear power, with much of its manufacturing capability idle now, will most likely be set by public acceptance. Using nuclear power for process heat requires further development. Gas cooled reactors look most promising here.

Many of the simpler, less expensive conservation steps have already been taken today. Conservation can be pushed much further, but it will become more complex and more expensive.

All the above only deals with the energy sources and conservation. As mentioned earlier, new or enlarged means are needed to distribute this energy such as expanded electrical grids, district heating systems, coal slurry pipelines. Add to this the electric heat pumps, electric vehicles, planes that can run on methanol, and all the other end uses that must match the forms of the emerging energy sources.

Forty years to the end of the oil era seems a long way off. Yet, when one considers the magnitude of the job to be done - even for this very low energy future - there is no time to waste.

Let us pause here to recapitulate some of the major conclusions of this analysis:

1. Oil and gas depletion is the dominant energy risk.
2. We need strong programs in both conservation and new energy supplies.
3. Much of our whole energy system will have to be restructured.
4. We will experience a renaissance in electricity growth.
5. There is scope for coal, nuclear, and solar.

Figure 21

IMPORTED MINERALS 1975

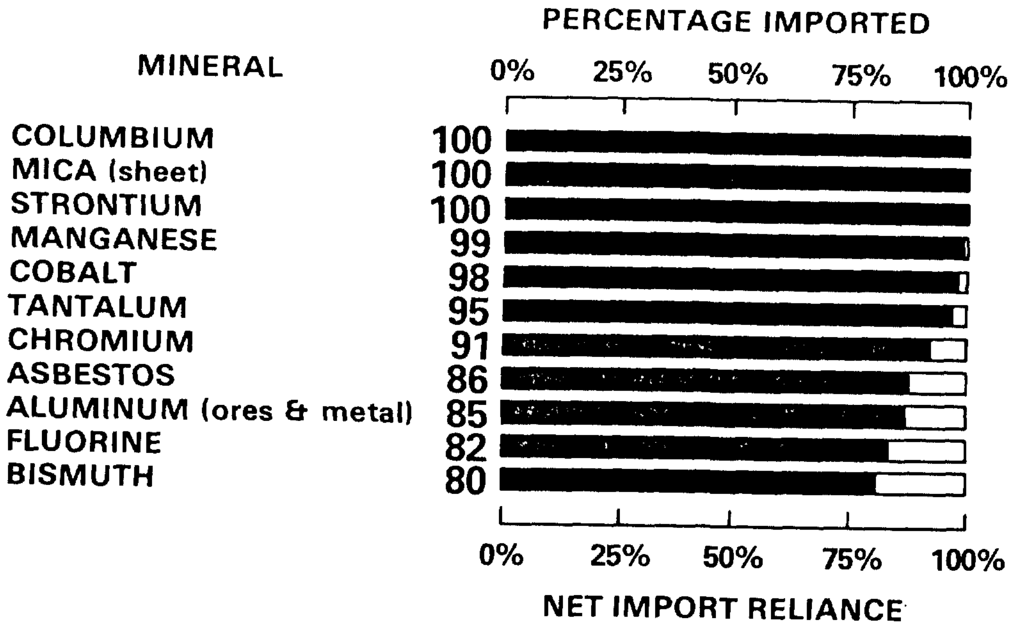
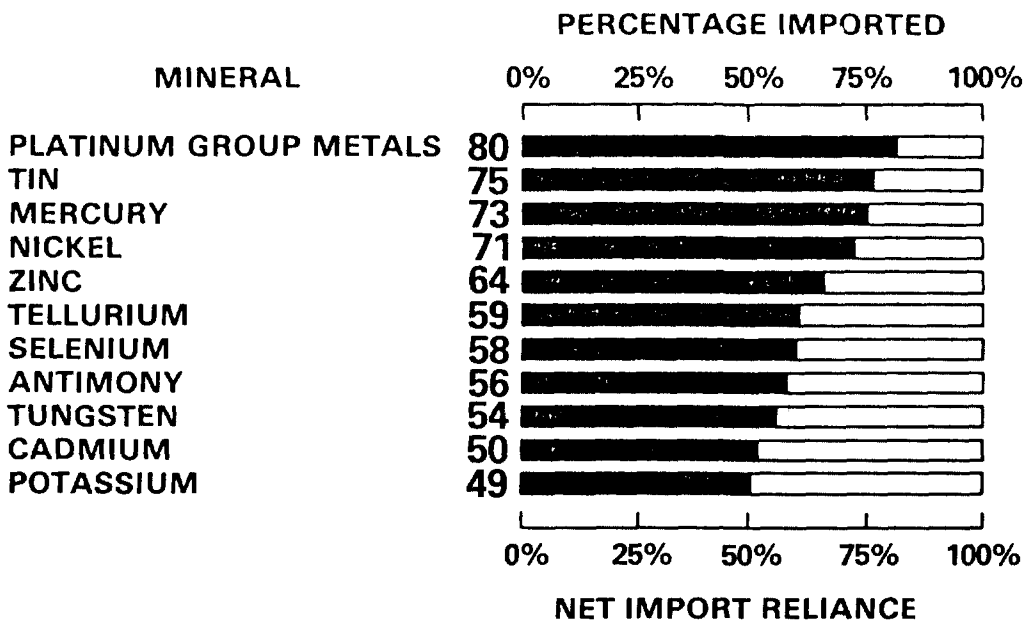


Figure 21A

IMPORTED MINERALS 1975 (cont.)



6. These energy sources often serve different markets.
7. Coal's priority use in the long term is for liquid and gaseous fuels.
8. Coal, nuclear, and solar are not mutually exclusive. Combinations of these energy sources often offer special advantages.
9. Coal and nuclear power help lay the ground work for a larger future solar contribution.

Further examination would reveal:

1. Urbanized countries like the United States can not function with decentralized energy sources alone. Practical energy systems are a mix of centralized and decentralized systems.
2. Even all-solar futures are highly centralized with their biomass, windmill, and photovoltaic "farms", their solar power towers, and their hydropower and pumped storage systems.
3. We will likely run out of oil and gas before any all-solar future could be put in place. Coal and nuclear power are essential to bridge the gap between today's oil economy and a distant solar future.

Like all analyses of energy futures, this low energy future with its coal, nuclear, and solar mix is subject to uncertainty. We may well need more than 55 quads. The hoped-for breakthroughs in photovoltaics may come sooner than expected, recent congressional progress on nuclear wastes may encourage greater public accpetance of nuclear power, and burning coal in fluidized beds may reduce some environmental concerns. On the other hand, there are also setbacks; windmills have torn themselves apart, many nuclear steam generators are performing badly, many active solar systems have not lived up to expectations, and superinsulated homes have led to serious health concerns, especially about the build-up of radon gas.

These kinds of technological uncertainties are to be expected and the roles of conservation, coal, nuclear, and solar will be defined more precisely with the passage of time.

Such technological uncertainties do not void the overall conclusions.

How different these overall conclusions are from the themes of the polarized national energy debate that has weakened and confused us. Arguments of centralized versus decentralized energy, growth versus no growth, solar versus nuclear are irrelevant, wasteful, and dangerous. Yet these arguments shape our energy policies.

Our technological uncertainties are small compared to the political uncertainties brought on by this protracted polarization and political uncertainty is the anathema of major capital investment. We swing from strongly pro-solar to strongly pro-nuclear regimes leaving a trail of abandoned energy projects behind us. Who will invest scarce capital into new power plants, coal synthetics, unit train factories, or advanced conservation techniques when the time to bring these to fruition is often two or three times the length of one presidential term of office?

We've been taken in by this energy debate. The rancorous voices have been so loud that many of us didn't hear the major findings of the Senate Committee on Energy and Natural Resources (November, 1980):

1. Oil exports from the Persian Gulf and North Africa are not likely to rise substantially in the next 10 years.
2. Even if the present conflict between Iraq and Iran is settled quickly (note: this war rages on today), a major oil supply disruption within the next decade is likely.
3. Oil has become a political instrument in the hands of the major oil producing nations.
4. Unless there is a major shift in current policies, the next two decades could witness growing competition among the governments of the consuming nations for scarce crude supplies.
5. The Soviet Union's growing interest in the Middle East and its increasing control over Western Europe's energy supplies pose grave dangers for the Western alliance.
6. The economic slowdown in the developing countries and the huge increase in their foreign debt jeopordizes economic development and threatens to undermine the international financial system.

The clamor of the national energy debate has been so loud that some of us didn't hear that international trade in oil may be in a divergent rhythm. The past great increases in prices have resulted in sharp decreases in oil use in the industrialized nations, which in turn has frustrated the hopes of many OPEC countries. This then leads to threats by Iran to bomb Saudi Arabia if oil prices sink too slow. Because of the inherent instability of many of the OPEC countries, oil supply disruptions are possible during both rising and falling prices.

We seem to have forgotten that the depletion of oil and gas is the dominant energy risk to humans and the environment. It is time now to hear new voices that call for the end of this energy debate---this "fistfight in front of a forest fire." If we cannot at least agree on some low energy mix, some minimum program, then indeed there is much to fear.