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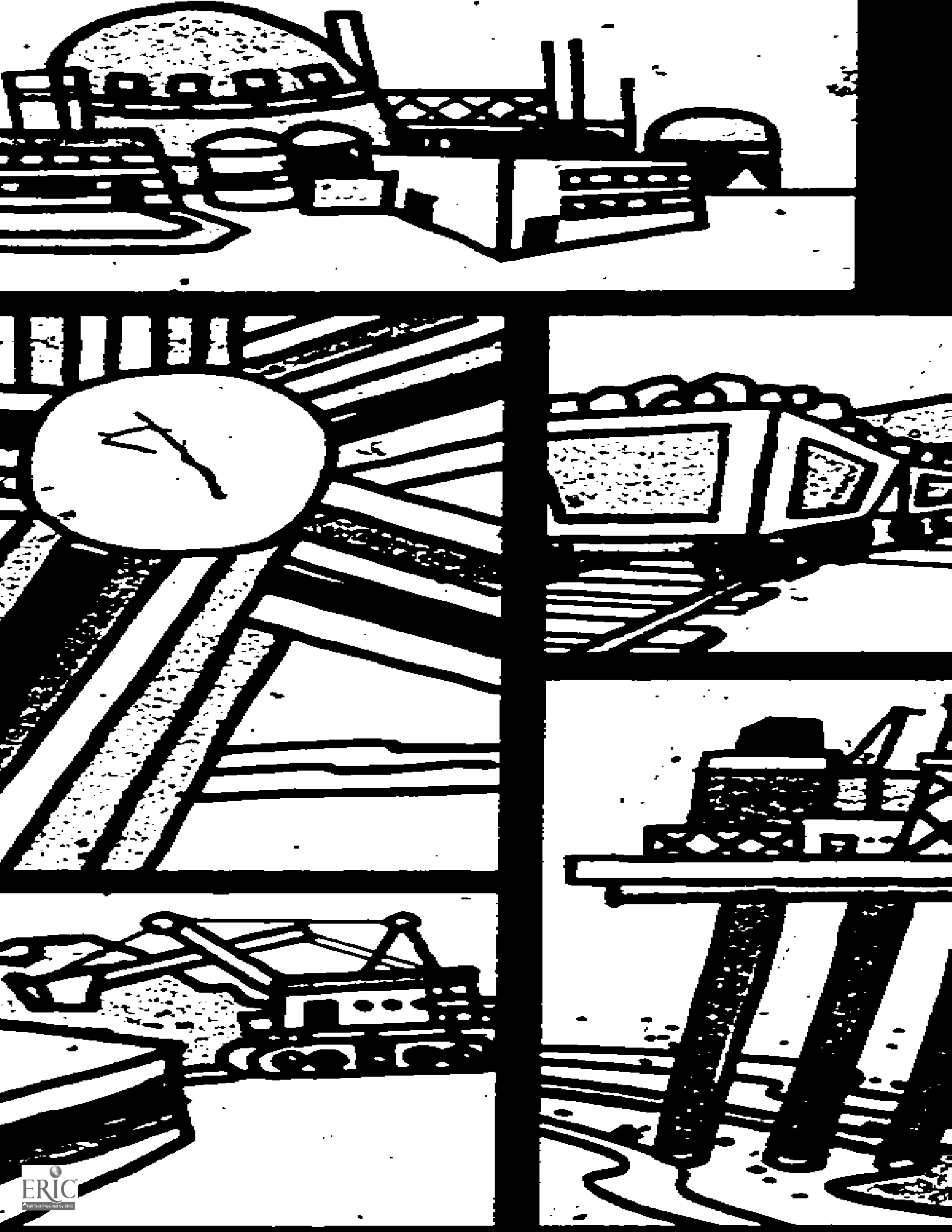
ABSTRACT

This publication is a summary of the world energy situation and its impact on the United States. A brief review of some interrelated diplomatic, commercial, and technical aspects of the energy crisis and their implications for the U.S. and its foreign policy is presented first. Next, discussions of world supplies, uses and problems with different fuels including fossil fuels, solar, wind, nuclear, and geothermal are given. The distinction is made between resources and reserves. Finally, a concluding discussion is given that indicates what direction U.S. foreign policy on energy should go. It is suggested that the U.S. should play a major role in bringing the world through the transitional period ahead. (MR)



The United States and World Energy

A DISCUSSION PAPER
DEPARTMENT OF STATE

This paper is not a statement of policy. It is an attempt to bring together, for convenient reference, some essential facts and alternative views on a major foreign policy question.

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"New" Crisis

In the winter of 1976–77, Americans were rudely reminded that all was not well on the energy front. The cold . . . the gas shortage . . . the closing down of industries. . . . Once again, energy seemed to have become a problem of national dimensions.

At the same time, mounting requirements for imported oil—nearly half the country's oil consumption—were a reminder that energy is very much an international matter;[1] and the international oil picture was not reassuring:

The CIA: *Without "greatly increased energy conservation," there will be oil shortages in the 1980's.*[2]

The President: *"Each new inventory of world oil reserves has been more disturbing than the last."*[3]

Indeed, energy is a subject with vast international ramifications—some of them quite apparent, some less so. It is evident, for example, that by importing increasing amounts of limited world oil, the United States is posing a long-term threat to the fuel security of all other oil-importing countries, including its allies. (In 1972, America's allies in the Organization for Economic Cooperation and Development were already expressing polite concern about this prospect.)[4]

Of course, the reverse is also true. And if anything happened which cut the flow of oil from the Middle East, the problem obviously would reach critical dimensions within a matter of days.

One does not have to labor the point: in a world of growing potential shortages, divisive forces lie in wait . . .

And yet, this competition for existing world energy resources also has a strangely positive side, because of the very scale of long-term demand. It could even lead to a high level of international cooperation in conservation, research, development, and discovery . . . in the sense that any contribution to the global energy supply—by anyone; anywhere—is bound to be of general benefit. Europe and North America would surely stand to gain, for example, if the considerable hydroelectric potential of the southern hemisphere were developed. And all countries would benefit, at least in the long run, if Japanese or American scientists made a major breakthrough in solar technology.

By the same token, there is a certain complementarity of interests between the industrial consuming nations and members of the Organization of Petroleum Exporting Countries (OPEC); as will be seen, the objectives of these two groups are not as far apart as many have assumed.

Since 1950, the United States has moved from being an energy exporter to being the world's leading importer. But there seems no doubt that even in the unlikely event the U.S. again be-

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[1] According to a Gallup poll published in June 1977, only 52% of Americans knew their country had to import any oil at all.

[2] *The International Energy Situation: Outlook to 1985*, Apr. 1977, p. 1.

[3] President Carter's address to the nation, White House press release, Apr. 18, 1977.

[4] *Energy Prospects to 1985*, OECD, Paris, 1974, vol. I, p. 1.

came totally *independent* in energy, its own interests—even narrowly defined—would still dictate a continuing and deep U.S. involvement in world energy affairs. For one thing, an economic crisis induced by energy shortages in one part of the world would almost surely have economic or political consequences for other areas, including North America. For another, no country can isolate itself from the mounting problems of global pollution, much of which derives from the uses of energy.

But presumably the most compelling reason for U.S. involvement in world energy affairs is the hope that this country can influence the future in vitally important ways. The ways in which countries choose and manage energy technologies can spell the difference between the survival of civilization and a series of catastrophes that would leave no nation untouched.

In attempting a fresh look at the global energy picture, this paper will briefly review some interrelated diplomatic, commercial, and technical aspects of the question, with their implications for the United States and its foreign policy.

The Turning Point

EVENTS LEADING UP TO AND FOLLOWING THE CRISIS OF 1973–74

For more than 50 years the world's oil trade has to a large extent been managed by seven major companies—the "Seven Sisters," as they are often called—five of which are American.[1] All of them are "integrated," meaning that they are equipped to do everything in the oil business: produce, refine, transport, and market.

According to some scholars, the essential pattern of the Sisters' international operations was set once and for all in 1928, when industry leaders gathered at Achnacarry Castle in the Highlands of Scotland.[2] The result was a secret agreement which began by noting that "excessive competition" had resulted in "tremendous over-production."[3] To avoid such situations in the future, the agreement provided for dividing world markets and stabilizing prices.[4]

The general concept of this agreement seemed consistent, moreover, with another important aspect of the relationship among the Sisters: their working together in common enterprises.

Managing international oil production so as to provide a stable growth in supply, as world demand increased, while avoiding any overproduction with attendant falling prices, was a complex undertaking. Among other things, it meant that the production rates of many disparate countries had to be brought into overall harmony—a delicate process sometimes requiring that certain countries be used as "eveners," i.e., that their production rates be reduced.

On the whole, from the end of World War II until the mid-1960's, "the international and domestic market control mechanisms of the oil industry achieved their objectives with exemplary precision."[5] However, in 1959 and 1960 the majors were obliged to lower oil prices somewhat, because of competition from medium-sized "independent" companies. In reaction, the producing countries—largely at the initiative of Venezuela—banded together and formed the Organization of Petroleum Exporting Countries (OPEC), in an effort to prevent future declines in price.

Then, in the mid-1960's, a wave of competition began to be felt from some independents which had managed to win concessions, alongside the majors, in Libya. The independents were selling their product on world markets at lower prices; and the majors were threatened with "the painful necessity of offsetting the Libyan expansion with corresponding reductions in the Middle East, thereby imperiling their invaluable concessions in that area."[6]

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[1] Their present names: Exxon, Gulf, Mobil, So-Cal (or Chevron), Texaco, Shell, and BP (British Petroleum). Shell is under Dutch-British management; BP is half-owned by the British Government.

[2] Anthony Sampson, *The Seven Sisters*, Viking Press, New York, 1975, p. 72.

[3] *Ibid.*, p. 73.

[4] John M. Blair, *The Control of Oil*, Pantheon Books, New York, 1976, p. 62.

[5] *Ibid.*, p. 207.

[6] *Ibid.*

Help came from an unlikely quarter: the revolutionary government of Colonel Qadhafi, which in 1970, soon after coming to power, asked the independents for a price increase of 40¢ per barrel. When this was refused, the Qadhafi government imposed cutbacks on oil production in Libya.

Libya finally did win a concession, however—a price increase of 30¢. Though the amount was not large, the oil companies feared that it could be a precedent for competing demands between Libya on the one hand and the Middle East countries on the other. To avoid being thus whipsawed, they sought to form a united front among themselves for dealing with OPEC as a whole. But over the next few years OPEC demands were to escalate from price increases to "gradual nationalisation, under the tactful slogan of 'participation' "; and the united front did not hold.[7]

When war again broke out in the Middle East in the fall of 1973, the Arab oil-producers imposed an embargo on the United States in protest against a U.S. military airlift and some $2 billion in economic assistance to Israel. Other OPEC members did not take part in the embargo, but in the end they nevertheless benefited from this period of shortages and uncertainty. By the time the embargo was lifted in March 1974, the world price of oil had quadrupled. And decisions about production and pricing which formerly had been made by the companies were now being made by the producing countries.

Meanwhile, the major oil companies had the task of applying the embargo; and in the United States opinion polls showed that "Americans blamed the companies more than the Arabs."[8] Although U.S. imports of Arab oil were almost completely cut off before the embargo ended, many Americans felt the shortage within the country was more contrived than real; and there were cries of "rip-off" when gasoline became abundant again after an increase of 40% in price. In the meantime, moreover, the major oil companies had further tarnished their public image by announcing unprecedented profits for the preceding year—due mainly to the greatly enhanced value of their inventories (although these would have to be replaced at higher prices).

In Europe also the major oil companies ran into stormy weather, though of a somewhat different kind. Since most of them are American-based, there was suspicion that during the embargo they had shown favoritism toward the United States. A European Commission report subsequently absolved them of this charge, however, and exoneration came also from the prestigious European, North American, and Japanese Trilateral Commission.[9] This latter body said the companies "did well in the distribution of available supplies," adding that they had not sought this onerous responsibility "and do not want it in the future."[10] (Since then the International Energy Agency (IEA) has in fact drawn up a plan which would assign

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[7] Sampson, *Sisters*, p. 230.

[8] *Ibid.*, p. 266.

[9] The Trilateral Commission was formed in 1973 by private citizens "to foster closer cooperation among these three regions on common problems." Ambassador Gerard C. Smith (former U.S. SALT negotiator) was named North American chairman.

[10] "Energy: The Imperative for a Trilateral Approach," *Triangle Paper* No. 5, 1974.

this function to governments in any future emergency.)

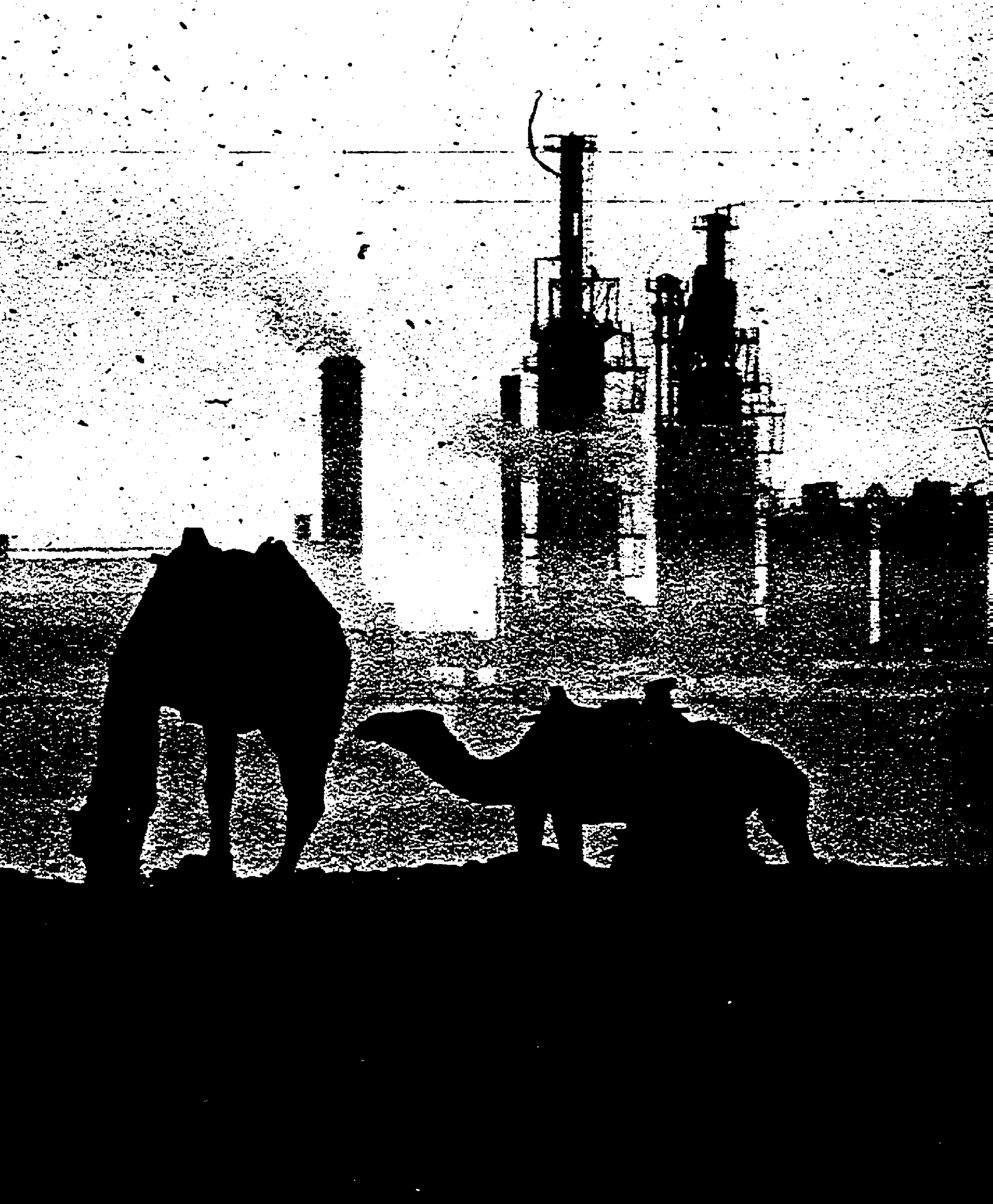
The general feelings of doubt and suspicion engendered at the time of the embargo have nevertheless persisted, at least to some degree—and not only in the United States. A report issued by the OECD in the latter part of 1976, for example—following a study of energy conservation efforts in 17 of its member-countries—noted that in most of these countries people were "skeptical that any energy problem exists." "It remains to be seen," the report concluded, how effective government conservation policies and programs could be "in such an environment."[11]

With respect to OPEC attitudes toward the companies in the wake of all these turbulent events, a book published by an OPEC official in the latter part of 1974 reflects a mixture of sentiments. On the one hand, the author takes them strongly to task for their historical role, and applauds the progressive nationalizations that were taking place. But on the other hand, the book states that the producing countries "must be aware that the share which they are getting out of their oil could not possibly be attained without the capital, the technique, and the experience of the companies."[12]

Retrospective: Many observers have viewed the history of international oil production primarily as a story of conflicting efforts among various groups—governmental or commercial—for the "control" of oil. State Department analysts feel, however, that preoccupation with this controversy in recent times tends to obscure the essential underlying trend—a dramatic shift in the global supply-and-demand situation. While consumers were still favored in the 1960's, the picture changed in the 1970's, and according to most projections, will continue changing in the same direction in the 1980's. One oil-producing country after another has approached the limits of its productive capacity, while world consumption has continued to rise.

[11] *Energy Conservation in the International Energy Agency—1976 Review,* OECD, Paris, 1976, p. 8.

[12] Abdul Amir Q. Kubbah (Acting Chief of OPEC's Information Department), *OPEC Past and Present*, Petro-Economic Research Centre, Vienna, 1974, pp. 7, 101, and 131.



Impact

SOME EFFECTS OF THE ENERGY CRISIS

The Industrial Democracies

As observed in a report of the Trilateral Commission, the events of 1973–74 "did not create the energy problem." Rather, they "revealed with merciless clarity the vulnerability of the industrial countries."[1]

In many ways the United States was a good deal less vulnerable than the others. As noted in an OECD study, the U.S. is one of the very few industrial countries "with large and diversified energy resources" (the others being Australia, Canada, Norway, and the United Kingdom).[2] Also, the very extent of energy wasted in the U.S. was seen as a kind of safety factor, since it meant that substantial energy savings could be made without curtailing production. Nevertheless, the American economy was strongly affected. As noted by one observer, the U.S. gross national product "declined by about $15 billion, 500,000 jobs were lost, and all prices increased."[3]

The collective response of the industrial countries to the events of 1973–74 was the establishment of the International Energy Agency (IEA) within the OECD. The agreement setting up this agency provided for certain protective measures such as the sharing of oil in an emergency. It also provided for cooperation in research and development (R&D) and in conservation.[4]

Over the next few years, economic activity picked up considerably in the industrial world. With all the signs of economic recovery, however, the bills for imported oil were a reminder of the serious condition which lay beneath the surface. (In the case of the U.S., oil imports for 1977 were expected to cost $41 billion—as against $4.6 billion in 1972.)[5]

In 1976 the IEA published a report on members' performance in conservation (under the somewhat awkward slogan: "A barrel saved is as useful as a barrel produced—better in many respects"). Commending member-nations for what progress had been made, the report said that "Nonetheless, significant potential still exists for reducing future energy demand in almost every country." It placed considerable emphasis on energy prices and taxes as conservation measures, and had this to say with respect to the transportation sector: "Automobile efficiency is a critical concern since autos by far are the dominant transport mode in both urban and rural use . . ." It added: "High national gasoline prices and/or taxes have promoted the manufacture and purchase of relatively efficient autos notably in Western Europe, and low gasoline prices/taxes

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[1] *Triangle Paper* No. 5, p. 9.

[2] "Energy R&D Policies in OECD Member Countries," *Energy R&D*, OECD, Paris, 1975.

[3] John M. Fowler, *Energy-Environment Source Book*, N.S.T.A., vol. 1, p. 27.

[4] For a description of the IEA and its origins, see *The United States and the Third World*, Department of State Publication 8863, July 1976, pp. 49–50.

[5] Hobart Rowen, "Needed: An Energy Program That Really Hurts," *The Washington Post*, June 1977.

have led to large inefficient autos, notably in the United States and Canada."

The drafters of the report also commented tactfully about the performance of individual countries. About the U.S. they said: "In summary, the United States rates below average among IEA nations in actual conservation results and experiences below average specific efficiencies in transportation and industry. The country has adopted a conservation programme with some strong elements, but needs much improvement in several important areas such as pricing/taxes and buildings."[6]

While the report did not say so, American per capita energy consumption rates are as much as *three times* those of Western European countries with comparable living standards. (Only the Canadians are ahead—a fact which, some months later, would lead a Canadian editorialist to remark: "We too are going to have to face the music. Jimmy Carter is playing our song.")[7]

History will perhaps take a tolerant view of America's past performance in energy consumption, given the unforeseen problems, the vast size of the country, and the extraordinary diversity and sophistication of the goods it has produced, some of which have benefited the whole world. But the present outlook of other industrial nations is probably more accurately reflected in a recent article by a West German science writer. Discussing his country's success in conservation, he commented: "West Germans also hope that President Carter triumphs in his crusade to conserve energy in the United States. For, as they see it, perhaps selfishly, that will mean more oil is available for them."[8]

Looking at another aspect of the matter, *The National Energy Plan* (released by the White House in April 1977) makes this observation: "Because the United States is the country most wasteful of energy, and because it has been increasing its demand for world oil, the United States has not been able to provide leadership to restrain the growth of world demand."

The Oil-Producing Countries

"If God so wills," according to a Persian proverb, "good will come out of evil." And according to an OPEC official, who cites this proverb, that is more or less what happened.[9] The "evil" in question was the oil companies' behavior in 1959 and 1960 in "arbitrarily and unilaterally" reducing oil prices in reaction to market conditions. The "good" that came out of it was OPEC—founded largely at Venezuelan initiative and formally launched at Baghdad in 1960. The five founding members—whose approval has been required for all subsequent membership—were: Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela.[10]

A decade later, however, OPEC members were even more discontented with the returns they were getting on their oil. At an OPEC conference in 1971, the Shah of Iran observed that "while the prices of the products of the industrial countries

[6] *Energy Conservation in the International Energy Agency—1976 Review*, OECD, Paris, 1976, pp. 7, 8, 15, and 35.

[7] *The Vancouver Sun*, Apr. 21, 1977.

[8] Gunter Haaf, "Energy-Efficient Germany," International Writers Service, reproduced in *The Washington Post*, June 20, 1977.

[9] Kubbah, *OPEC Past and Present*, p. 7.

[10] Current OPEC membership: Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela.

Note: The Organization of Arab Petroleum Exporting Countries (OAPEC) consists of seven OPEC members (Algeria, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, and the United Arab Emirates) plus Bahrain, Egypt, and Syria. It was OAPEC—not OPEC—which declared the embargo in 1973.

have been progressively rising, our real income per barrel from oil has actually fallen by something like 20% [during the preceding three years]. The old saying that the rich have become richer and the poor, poorer, has indeed become a reality. . . ."[11]

By the end of 1976, OPEC countries were estimated to have accumulated financial surpluses of around $140 billion. Strong pressures for higher oil prices continued nevertheless to come from some of them—notably Iran, Venezuela, Libya, Iraq, and Algeria—while Saudi Arabia was generally regarded as the moderating influence. According to State Department officials, the reasons for these upward pressures were varied: large populations and ambitious development projects, waning oil reserves, ideological feistiness, or a combination of these.

To maximize returns from oil, the major producing countries in OPEC have now nationalized oil production or are in the process of doing so, and a number of them have sought to extend their activities "downstream"—i.e., into refining, which some have already done, or into shipping and marketing (although marketing has traditionally been the low-profit end of the oil business). There is a political advantage, of course, for the producing country which has its own tanker fleet: it then knows that the oil is reaching its intended destination and is not being diverted elsewhere. Saudi Arabia, Kuwait, and Iraq have acquired or ordered some tankers; by and large, however, there has been little buying, despite the fact that there has been a surplus of tankers since 1973 and they are relatively cheap.[12]

With the rise in oil-producing countries' revenues, the volume of their trade with the industrial world has increased vastly. In this connection, an official of the European Economic Community was quoted early in 1977 as saying that the Arab countries alone were buying more EEC exports than was the United States.[13] But U.S. trade with the oil-producing countries has risen very substantially; and the United States has attracted a high proportion of OPEC investments, especially Saudi Arabian.

With its vast oil reserves (by some estimates, one-quarter of the world's proved reserves), Saudi Arabia has enormous influence on world oil prices. And some Saudi Arabians believe they should leave more oil in the ground, for future use, and let prices rise accordingly. Instead, their country has favored price stability and maintaining oil production adequate for world needs. According to a former U.S. official, it has followed this policy "not out of altruism, but self-interest, for Saudi Arabia depends both politically and economically on a stable and growing world economy." He added that the United States and Saudi Arabia thus share "fundamental interests," including but not limited to "peace in the Middle East."[14]

On the whole, however, the events of 1973 and 1974 left a considerable distance, to say the least, between the viewpoints of industrial and OPEC countries. In fact the atmosphere of confrontation between the two groups very nearly prevented them from discussing energy in a common forum. But they finally agreed to do so, at the Conference on International Economic Cooperation, which began in Paris at the end of 1975 and ended in June 1977.

The Paris conference (CIEC) did not arrive at specific agreements on energy—it had not been expected to—

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[11] Kubbah, *OPEC Past and Present*, p. 116.

[12] *OAPEC News Bulletin*, Kuwait, May 1977, p. 5.

[13] *Ibid.*, p. 18.

[14] Richard D. Erb, "The U.S.-Saudi Relationship: Of Oil and Optimism," *The Washington Post*, M[illegible], 1977. Mr. Erb was formerly a Deputy Assistant Secretary of the Treasury.

nor were the conferees able to agree on a formula for continuing the multilateral dialogue they had begun. Nevertheless, according to U.S. officials, a considerable improvement in atmosphere had been achieved, and there was an important agreement on general principles. Commenting on this, a senior State Department official later said: "While replete with caveats, the agreement on supply puts OPEC on record as recognizing that adequate energy supplies are necessary and that oil exporters have a responsibility of meeting energy needs during the transition period that must occur while countries develop alternative sources."[15]

Non-Oil Developing Countries

"Since non-oil developing countries are relatively small users of oil, accounting for only about ten percent of annual world consumption, OPEC countries [in 1973] underestimated the importance of oil to them and tended to regard forecasts of the dire effect of oil price increases as part of the publicity campaign by industrial consumers against higher prices."[16]

Presumably, not everyone would agree with the above statement (by an American official of the OECD), and some would rather not hear about it. But there is no denying that the non-oil developing countries were much the hardest hit of all; not only did they have to pay more for their imported oil, but they suffered a serious decline in their export earnings during the ensuing world recession. They in turn had to reduce their imports and to borrow more in order to finance their development. They began to pile up indebtedness.

Arab use of "the oil weapon" in 1973–74, we are told, had at first been greeted with some enthusiasm in these non-oil countries because of the discomfort it caused the rich and powerful industrial nations. Also, leaders of these developing countries seemed receptive to the OPEC thesis that the oil price increase was "the vanguard of a new economic order" which would benefit *all* developing nations.[17] In any case, they gave OPEC full diplomatic support; and subsequently, even as their condition worsened, they continued to avoid any public criticism of the oil producers.[18]

Since the time of those events, both industrial and oil-producing nations have taken a number of steps to increase the amount of international credit available to the non-oil developing countries.[19] And while aid outlays from industrial nations have been much greater in absolute terms (and extended to a great many recipients), the oil-producing countries point out that *their* aid has been much greater in terms of donor countries' GNP [gross national product]. However, it has been very largely limited to Moslem recipients. Even with the subsequent improvement in world economic conditions, in any event, the non-oil

[15] Richard N. Cooper, Under Secretary of State for Economic Affairs, statement to Joint Economic Committee, June 21, 1977.

[16] Maurice J. Williams, "The Aid Programs of the OPEC Countries," *Foreign Affairs*, Jan. 1976. Mr. Williams is Chairman of the OECD's Development Assistance Committee.

[17] *The United States and the Third World*, Department of State Publication 8863, July 1976, pp. 4–5.

[18] The power of the oil-producing countries to punish or reward is of course considerable; and while OPEC members have consistently refused to set up a two-tier pricing system, with lower prices for developing countries, from time to time they have given concessions to selected LDC's [less developed countries]—for example, very low-interest loans, which had the effect of lowering the cost of oil imports. (A two-tier pricing system would probably be very difficult to administer, in any event, since it would require some mechanism for tracing oil to its final destination.)

[19] See Department of State *Special Report* No. 28, Dec. 1976, "U.S. Initiatives for World Development."

LDC's have continued to amass debts, though at a slower rate, and the process of adjustment will presumably be a long one.

The Paris conference (CIEC) adopted several energy-related recommendations—proposed by the industrial nations—that favored the non-oil LDC's. One of these called on the World Bank to place greater priority on lending to the LDC's for development of energy resources. In the U.S. view, this could have a significant long-term impact, especially as it would tend to stimulate an increased flow of private investment toward the same objective.

Another CIEC recommendation called for international cooperation in research and development. This will open the way to participation by both OPEC members and oil-importing LDC's in the R&D work of the International Energy Agency. (Previously, OPEC had kept the IEA at arm's length, calling it a "confrontational" organization.) And if this happens, it could result in considerably greater applications of technology in developing the energy resources of the LDC's themselves—clearly a key element in their long-term adjustment process.

The Communist Countries

While the Middle East has long been a zone of intensive East-West competition, up to now the Soviet Union has not had any need for Middle Eastern oil. On the contrary, the U.S.S.R.—now the world's leading oil producer—has seemed to have plenty of oil for domestic purposes and for export, mainly to Eastern Europe. But this seems to be changing.

To begin with, there is the matter of energy consumption. The Soviet Union and Eastern Europe now consume more than Western Europe does, although before the Second World War they used less than half as much.[20] "The growth in energy consumption in Russia over the past half a century reflects the rapid pace of industrialization and urbanization."[21] Consequently, in recent years some energy experts had begun to wonder if the Soviet Union wasn't headed for a kind of "turning point" of its own, when it would cease to be a net exporter of oil and become a net importer.

Corroboration of this trend was contained in a CIA report, released by the White House in April 1977, about the world energy situation as a whole. "In the absence of greatly increased energy conservation," the report said, "projected world demand for oil will approach productive capacity by the early 1980s and substantially exceed capacity by 1985." The authors of the report then explained that part of their "pessimism" was based on their estimate that the Soviet Union would indeed become a net importer of oil during this time.[22]

A later CIA report provided some additional insight: "Unlike the United States, which has long restricted [oil] production for reasons of conservation and profit," it said, "the USSR favors a forced draft approach. Short-term production goals are considered floors, not ceilings, and rewards are given for exceeding them, with little regard to productivity over the longer-term." One result had been "overproduction of existing wells and fields through rapid water injection and other methods," so that finally less of the oil would be recovered.

The report acknowledged "uncertainty about the size of the USSR's reserves, because of definitional problems as well as Soviet secrecy." It added: "Our best estimate is that Soviet proved reserves are 30-35 billion barrels, roughly comparable with those

[20] S. David Freeman, *Energy: The New Era*, Walker & Co., New York, 1974, p. 40.

[21] *Ibid.*

[22] *International Energy Situation: Outlook to 1985*, Apr. 1977, p. 1.

of the United States." Finally: "Although the USSR has abundant potential reserves in Arctic, East Siberian, and offshore areas, development of such reserves is at least a decade away." Therefore, the Soviet Union and Eastern Europe together may have to import some 3.5 million barrels per day by 1985.[23]

Meanwhile the Communist countries of Europe appeared to be moving ahead with plans for increased use of *nuclear* energy. As reported in a June 21, 1977, Reuters dispatch from Warsaw: "Leaders of the Communist economic grouping, Comecon, were asked at a summit here today to approve a program providing for a major boost in their nuclear energy capacity."

While there is considerable uncertainty about the oil resources of mainland China, most estimates have been fairly modest. A U.S. Geological Survey study of 1972, for example, estimated them at one-tenth those of the U.S.S.R.[24] Most of China's own industry is coal-based. It has been able to export small amounts of oil to Japan in recent years, and according to one account: "China will push its search for oil in several new areas, including potential off-shore fields in the South China Sea and perhaps the East China Sea."[25]

The CIA report on the energy situation had this to say about future prospects: "In China, the reserve and production outlook is much less favorable than it appeared a few years ago. We anticipate that growing domestic oil needs, resulting from economic growth and trouble with coal production, will reduce oil exports to a negligible level by 1985. In 1980 exports will total no more than 500,000 b/d [barrels per day]."[26]

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[23] *Prospect for Soviet Oil Production*, Apr. 1977.

[24] Richard F. Zaffarano and William B. Harper, "Petroleum," a chapter from *Mineral Facts and Problems*, 1975 ed., U.S. Department of the Interior, p. 7.

[25] Lee Lescaze, "Chinese May Inspect U.S. Oil Rigs," *The Washington Post*, May 28, 1977.

[26] *The International Energy Situation: Outlook to 1985*, Apr. 1977, p. 13.

Diplomacy and the Energy Systems

A General Caveat

Statistics about the earth's fuel deposits can be very misleading. Apart from special pleading in behalf of this or that energy system, there may be honest differences of geological opinion, or of opinion about what is or will be economically exploitable.

Other pitfalls derive from terminology. In U.S. Government usage, for example, there is a vast difference between "resources" and "reserves." "Resources" are to a large extent theoretical; they may include deposits that are merely *surmised* to exist on the basis of geologic theory. "Reserves" are much more rigidly calculated, and require some concrete evidence of the actual existence of the deposit. "Recoverable reserves" (as in the case of coal) are identified as "recoverable with current technology under present economic conditions." (The analagous term for oil is "proved reserves" or "proven reserves.")

Unfortunately, not everyone is so meticulous about these distinctions; and since there is no nationally or internationally uniform code of terminology, the reader simply has to be on the look-out for shades of meaning.

One more caveat: when the costs of two systems are compared, one has to be alert for hidden subsidies, such as special tax treatment or handling in government facilities.

Oil

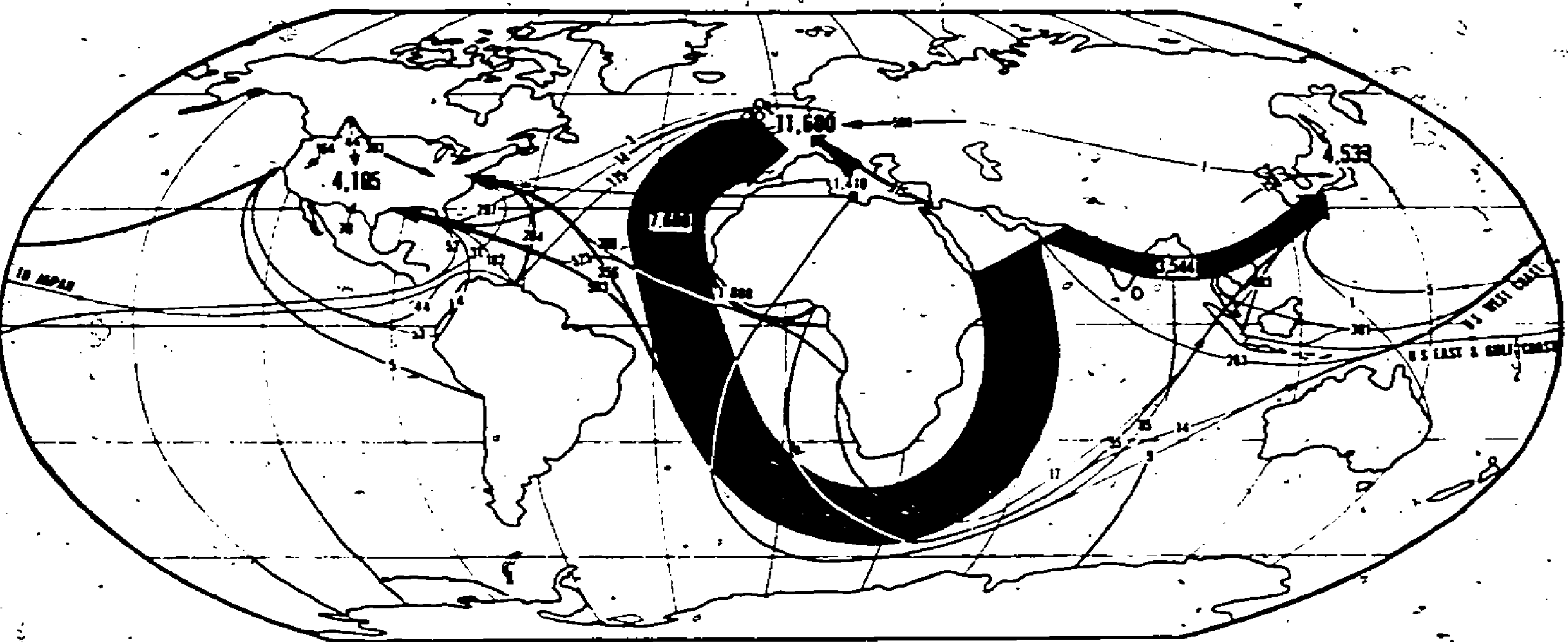
In line with the *general caveat*, it is important to note that oil reserves are generally calculated on the basis that two barrels are left in the ground for every one recovered. Many efforts have been made to improve this recovery percentage, mainly through the use of detergents or heat (steam) to step up the flow; and some believe that new recovery methods will make it possible to extract from currently "depleted" oil wells more than they originally produced. In the case of the U.S., this would be over 100 billion barrels. (Current U.S. production is about 3 billion barrels annually.) However, Energy Research and Development Agency (ERDA) officials regard this projection as highly exaggerated; they believe that with foreseeable technology and economic conditions, over the next 20 years no more than about 15 billion additional barrels can be recovered from those fields.

The Upward Curve

The economic effects of the 1973–74 price increases were stunning and worldwide; but they produced only a momentary reversal in the worldwide trend toward increased oil consumption.

By 1975, oil exports from the Middle East were cutting an enormous swath—shown on the accompanying map—and they have been going up ever since. (See the accompanying boxes on super-tankers and ocean pollution—for some side effects of this

World Crude Oil Movements To Major Consuming Areas—1975
[thousand barrels per day]



ARROWS INDICATE ORIGIN AND DESTINATION BUT NOT NECESSARILY SPECIFIC ROUTES

BUREAU OF MINES
DIVISION OF PETROLEUM AND NATURAL GAS
FEB. 1977

Super-tankers

An important issue in the transport of so much oil across the seas has been the very size of the ships involved. Noël Mostert, in his book *Supership,* draws a rather awesome picture of a present-day tanker of "only" 250,000 tons' carrying capacity. The bridge is about one-quarter of a mile from the bow, and the watch officer has to walk 150 feet from port to starboard just to see what is happening on the other side. With its engine backing down full, the ship takes about 20 minutes and three miles to stop. A *million*-ton vessel of this class, such as has been contemplated, would be accordingly more impressive: it has been likened to a 13-story building covering six city blocks.

Accidental release of oil from such a ship obviously could be a major catastrophe. And yet, neither governments nor ocean clean-up experts seem inclined to say that the super-tanker should be outlawed. It has become much the most economical mode for ocean transport of oil; and in case of accident it would not necessarily lose oil from all its tanks—i.e., it might lose no more oil than a smaller vessel.[1] Another thing about carrying oil in super-tankers: there are not so many ships involved.

[1] A few years ago there were some optimistic-sounding accounts in the press about the use of oil-eating bacteria for cleaning up spills. Unfortunately, this method appears to have been successful only in closely-confined areas, such as inside oil tanks or in small harbors. Environmental experts explain that the bacteria must constantly be fed *other* nutrients in addition to oil if they are "to be kept alert."

Ocean Pollution

The need to transport huge quantities of oil across the seas has led to some dramatic oil spills; and yet, 85-90% of oil pollution from vessels comes not from such accidents but from operational discharges, such as tank-cleaning, ballasting, and dry-docking.

A 1954 international convention prohibits such discharges within 50 miles of land, and limits it at sea. Some amendments to this convention—to enter into force in January 1978—provide further tightening of discharge limits. But the United States has been urging universal adoption of a more recent instrument—a 1973 convention—which not only reinforces these provisions but requires structural innovations—notably "segregated ballast"—in large new tankers.

The point about "segregated ballast" is this: After unloading their oil, tankers have customarily filled some of their oil tanks with water, to serve as ballast on the return trip. Then, on approaching the port where they were to take on new oil, they have washed out these tanks, pumping the oily water overboard. The 1973 convention will require not only that this oily water be kept aboard—in separate or "segregated" tanks (which incidentally reduces the ship's oil-carrying capacity by some 10-30%)—but that oil-loading ports have facilities for disposing of it on land.

In addition, President Carter in March 1977 recommended to Congress a package of both domestic and international measures. These included strong U.S. support for tighter international standards for tanker construction, operation, and inspection; and many of these proposed measures would eventually apply to foreign tankers calling at U.S. ports if the international community does not adopt sufficiently strict standards in the meantime. Among these would be a requirement for segregated ballast tanks on many more tankers (e.g., on vessels of 20,000 deadweight tons or larger) than called for by the 1973 international convention (which requires these only on vessels of 70,000 deadweight tons or above).

enormous movement of oil across the seas.) And yet, a White House report says that for the world even to maintain its current rate of consumption and keep its reserves intact, it "*would have to discover another Kuwait or Iran roughly every three years, or another Texas or Alaska roughly every six months.*" [1]

Bright Spots, But. . .

Within this somber world tableau there are some relatively bright spots, it is true—especially Mexico, which is expected to produce 5–6 million barrels per day in the 1980's (the present rate is 1.8 million). The combined output of British and Norwegian fields in the North Sea may reach some 4 million barrels a day at about the same time; and Egypt's production may reach 2 million barrels.

Indeed, for the near term British and Norwegian pospects look most enviable in the eyes of continental Europe, which has no comparable resources. The United Kingdom hopes to fill all its own oil and gas needs by 1979. Norway was already self-sufficient in 1976, and even exporting small quantities.

[1] ...e *National Energy Plan*, White House press release, Apr. 29, 1977, p. viii.

Estimated World Oil Reserves

Area	Billion Barrels
Middle East	392
Western Hemisphere (including U.S.)	96
Africa	59
North Sea-Western Europe	31
Asia-Pacific	22
Total, non-Communist countries	600
Total, Communist countries	65
World total:	665

Source: *Major Oil and Gas Fields of the Free World*, Central Intelligence Agency, June 1977.

For a time, North Sea output may stabilize European requirements for Middle East oil, so that only the United States and Japan will draw increasingly on that area. However, British experts believe their North Sea fields will be running dry in 1990's; similarly, the Norwegians seem to believe their fields will peak in the mid-80's and then fall off toward the end of the century.

Current Oil Production

(millions of barrels per day)

Soviet Union	10.4
United States	9.7
Saudi Arabia	8.9
Iran	5.9
Venezuela	2.4
Iraq	2.2
Kuwait	2.2
Nigeria	2.1
Libya	2.0
United Arab Emirates	1.9
People's Republic of China	1.7
Canada	1.6
Indonesia	1.5

Source: "Oil and Energy," *Gist* paper of May 1977, Bureau of Public Affairs, Department of State.

And so we are back to the CIA projection that, "In the absence of greatly increased energy conservation, projected world demand for oil will approach productive capacity by the early 1980s and substantially exceed capacity by 1985."[2] This would be before the North Sea had peaked; but by 1985, under the same projection, the Soviet Union and Eastern Europe would have become net importers.

Natural Gas

While the evidence is somewhat conflicting, natural gas also appears to be a rapidly diminishing resource.

The situation of the United States—which has accounted for some 40% of world gas consumption in recent years—was summed up in *The National Energy Plan* (p. 16) in these terms: (1) The "growing imbalance between America's domestic natural gas resources and its annual consumption is of particular concern . . ." and (2) "The opportunities for supplementing domestic production . . . with imports are small." (To the extent that imports come by sea, in liquefied-natural-gas tankers, there is also the problem that this is a highly explosive cargo.)

The long-term world outlook seems similarly unpromising. Natural gas now provides around one-fifth of world energy, with demand growing by about 7% annually.[3] According to U.S. Department of the Interior figures, however (see accompanying table), currently estimated reserves would last only about 50 years at the 1976 rate of production. Also natural gas appears to be very unevenly distributed: ". . . about 70 countries produced natural gas in 1975, but 4 nations (the United States, the U.S.S.R., Canada, and The Netherlands) accounted for about four-fifths of world marketed production."[4]

[2] It should be noted that the term "productive capacity" does not necessarily imply production up to the extent permitted by reserves, since a country may choose to limit its productive capacity.

[3] Gordon W. Koelling and Ronald F. Balazik, "Natural Gas," *Mineral Facts and Problems*, 1975 ed., U.S. Department of the Interior, p. 7.

[4] *Ibid.*

On the other hand, there is a considerable element of uncertainty arising from the fact that, in the past, discoveries of gas were largely incidental to the search for oil. Now, in the light of improved technology, large areas of sediments which previously were considered unfavorable for oil discovery may be worth exploring for gas.

Finally, there is a potentially important source of methane gas—the chief constituent of natural gas—under heavy pressure in reservoirs of hot salt water beneath the Gulf of Mexico and perhaps elsewhere.[5] By some estimates, however, the price of natural gas would have to be 2–5 times what it is now in order for these deposits to be exploitable; also the heat and salinity of these deposits could pose an excessive environmental problem.

Natural Gas—
World Production And Reserves
(in billions of cubic feet)

	Marketed Production, 1976[1]	Reserves, 1975[2]
United States	19,900	228,000[3]
Canada	3,130	57,000[3]
Netherlands	3,450	65,000
Other Market Economy Countries	8,300	1,220,000
U.S.S.R.	11,220	710,000
Other Central-Economy Countries	3,500	50,000
World Total:	49,500	2,330,000

[1] Estimated.

[2] There is no international standard defining categories of natural gas reserves.

[3] Proved reserves as of Dec. 31, 1975.

Source: Adapted from "Natural Gas," by Gordon W. Koelling, *Commodity Data Summaries 1977*, U.S. Dept. of the Interior, p. 109.

[5] William M. Brown, "A Huge New Reserve of Natural Gas Comes Within Reach," *Fortune*, Oct. 1976, reviewed in *The Wilson Quarterly*, Winter 1977, p. 14.

Liquefied natural gas (LNG) storage tank under construction

Southern Connecticut Gas Compa

Shale Oil

"Some of the petroleum formed at the bottom of the seabeds did not escape as a liquid or gas but was instead bound into the clay sediment. . . ."[6] In time it became a flaky, soft rock—shale. There are vast deposits of it in the world—mainly in North America—as shown in the accompanying table.

In principle, the production of synthetic crude oil from shale "is a simple process. When the shale is crushed and heated to 480°C, raw shale oil is released."[7] But commercial production of this oil, though it has existed in some countries since the last century, has never been on a large scale. Shale has simply not been competitive when there were supplies of liquid petroleum readily available. Also, in more recent times shale recovery has been a subject of environmental controversy because of apparent requirements for extensive earth removal and for the use of large quantities of water.

Different grades of fuel oil produced from shale

A 1975 U.S. Government report nevertheless indicated that it was "reasonable to expect shale oil production capacity in the United States to reach 1.5 to 2 million barrels per day by the end of the century, and about half that amount in the rest of the world."[8]

[6] Fowler, *Energy-Environment*, vol. 2, p. 15a.

[7] William D. Metz, "Oil Shale: A Huge Resource of Low-Grade Fuel," *Energy: Use, Conservation and Supply*, A.A.A.S., Washington, D.C., 1974, p. 70.

[8] L. W. Schramm, "Shale Oil," *Mineral Facts and Problems*, 1975 ed., U.S. Department of the Interior, p. 1.

Identified Shale Oil Resources Of The World

(Billion barrels. 42 gallons per barrel)

	Oil in place: 25 to 100 gallons per ton	Oil in place: 10 to 25 gallons per ton	Recoverable paramarginal shale oil resources[1]
North America	600	1,600	80
South America	Small	800	50
Europe	70	6	30
Africa	100	Small	10
Asia	90	14	20
Australia and New Zealand	Small	1	Small
World totals (rounded)	860	2,400	190

[1] Using present technology and considering only the higher grade, more accessible portions of deposits.

Source: U.S. Geological Survey.

23

Since then there have also been moderately optimistic reports about the development of *"in situ* technology," which calls for cracking and heating of the shale rock in place underground. (Requirements for both earth removal and the use of water are thus considerably reduced.) While the verdict is not yet in, *The National Energy Plan* released by the White House in April 1977 gave encouragement to the extent of saying that "the Government should establish a pricing policy that provides adequate incentives to producers."

Outside the United States, the largest known shale deposit is in southern Brazil. There are substantial deposits, also, in the Soviet Union and in China.

Gas, as well as oil, can be produced from shale. According to the U.S. Department of the Interior, research in this field has been limited, but "efforts have been stepped up in recent years."[9]

Energy Research and Development Administration

strip mining

Coal

Again, there is a vast difference between "resources" and "recoverable reserves." With respect to coal, in U.S. official usage this latter term assumes that about half the coal in an underground mine is actually recovered, the remainder being left standing as "pillars." And some coal experts say that "in real life" a good deal less than that is recovered. (In strip mining, however, the recovery rate is about 80%.)

The accompanying table shows coal resources *and* reserves worldwide; and for convenience, the last column shows how many years the reserves would last at existing rates of production. But needless to say, this should be treated with great caution. Changes in the rates of discovery or exploitation could radically change the "reserve" figures. And although coal deposits are less difficult to assess than oil, being easier to sample, no one really knows what's down there until it is dug out.

Though coal is by far the most abundant of the world's fossil fuels, geographically it is very unevenly distributed. Also, much more information is available about coal deposits in some areas of the world than in others. (In

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[9] Ibid., p. 11.

some countries, notably the Soviet Union and China, such information may even be treated as classified.) It seems to be generally agreed, however, that the Soviet Union, the United States, and China—in that order—have a very high percentage of the world's coal *resources*, perhaps 90%—the U.S.S.R. having nearly twice those of the United States, and the U.S. having about three times those of China.

World Coal Resources/Reserves

	Total Resources (Million short tons)	Recoverable Reserves (Million short tons)	1975 Production (Thousand short tons)	Years at 1975 Production Rate
North America				
United States	3,968,300	218,400	626,200	349
Canada	117,000	5,600	23,900	234
Other	3,000	100	4,000	25
Total:	4,088,300	224,100	654,000	343
South America				
Brazil	3,600	2,000	2,800	714
Chile	4,300	100	1,600	63
Colombia	5,900	100	4,000	25
Other	22,500	200	800	250
Total:	36,300	2,400	9,200	261
Europe				
Czechoslovakia	23,600	2,700	31,000	87
France	1,600	500	24,700	20
F.R.G.	316,400	33,100	101,900	325
G.D.R.	33,100	27,900	600	46,500
Netherlands	4,100	2,000	—	—
Poland	66,800	19,600	189,000	104
U.K.	179,500	4,300	140,900	31[1]
U.S.S.R.	6,298,200	91,400	590,800	155
Other	48,500	26,200	33,300	787
Total:	6,971,800	207,700	1,112,200	140
Africa				
Republic of South Africa	48,900	11,700	77,100	152
Other	16,000	3,800	5,500	691
Total:	64,900	15,500	82,600	188
Asia				
People's Republic of China	1,102,300	88,200	518,100	170
India	91,500	11,800	95,700	123
Japan	9,500	1,000	20,900	48
Other	14,000	2,000	74,800	27
Total:	1,217,300	103,000	709,500	145
Oceania				
Australia	218,900	15,600	72,900	214
New Zealand	1,200	200	2,600	77
Total:	220,100	15,800	75,500	209
WORLD TOTAL:	12,598,700	568,500	2,643,000	194

Source: World Energy Conference, Survey of Energy Resources, 1974—updated in some instances by data from U.S. Geologic Survey and Bureau of Mines, U.S. Dept. of the Interior, 1977.

Note: A short ton is 2,000 lbs. (A metric ton is 2,204.6 lbs.)

[1] U.K. officials say they have "technically recoverable" reserves that would last 10 times this long.

As shown in the accompanying table of coal-producing nations, however, rates of current production may have little relationship to a country's total resources.

Among the industrial democracies, Australia, the United Kingdom, and the Federal Republic of Germany have the largest resources, after the U.S. The rest of Western Europe is relatively poor in coal, as is Japan. Japan imports about 40% of its coking coals (for the steel industry) from Australia, and about equal amounts from the United States. (Contrary to what is shown in the resource/reserve table, an official British publication estimates that Britain has sufficient "technically recoverable" reserves "to support the current rate of production for over 300 years. . . .")[10]

Leading Coal-Producing Nations

Country	1975" Net Tons	% of World Total
United States	626,170,000	23.5
U.S.S.R.	590,000,000	22.1
People's Republic of China" [1]	522,000,000	19.6
Poland	189,156,000	7.1
United Kingdom	141,700,000	5.3
Federal Republic of Germany	101,846,000'	3.8
Total:	2,170,872,000	81.5
World Total:	2,664,539,000	100.0

Note: Bituminous and anthracite; excludes lignite except where noted.

' estimate. " preliminary. [1] includes some lignite.

Source: U.S. Bureau of Mines. Excerpted from Tables I-4 in *International Coal 1976*, published by the National Coal Association and the Coal Exporters Association of the United States, Inc.

The Nature of Coal

Though coal was once *the* fuel of the industrial age, in recent years its use has been increasingly restricted to a few industrial processes, to generating electricity, and to making coke for the steel industry. (U.S. coal exports—about 10% of production—are mainly coking coals for Japan, Europe, and Canada, in that order. Total value approaches $3 billion annually.)

Even before environmental factors were considered important, coal lost heavily to oil and natural gas—partly because these were cleaner burning, but also because, weight for weight, they contain a good deal more energy. The loss was particularly heavy in the transport sector, since oil can be used in internal-combustion engines, which have much greater thermal efficiency than steam engines as well as a considerable weight advantage. (An exception to this rule is that the use of coal-fired plants to drive electrified railroads and trolley cars is regarded as thermodynamically very efficient; though ironically such plants are far more prevalent in Europe and Japan, which have relatively little coal, than in the United States, which has a great deal.)

For all these reasons, coal research and development efforts in recent years have included substantial programs for *gasification* and *liquefaction*. This has given rise to some concern because of the large volumes of water these processes seem to require. The concept also has been criticized on grounds of energy efficiency: "If coal is either gasified or liquefied . . . 20 to 35 percent of the energy is lost in conversion."[11] Finally, a biologist has warned that "the chemistry of coal conversion may produce powerful carcinogens."[12] U.S. and European officials dealing with these programs nevertheless seem to feel it will be possible to produce at least certain

[10] *Coal for the Future*, Department of Energy, London, 1977, pp. 19, 22.

[11] Mason Willrich, *Energy and World Politics*, Free Press, Macmillan, New York, 1975, p. 113.

[12] Barry Commoner, *The Poverty of Power*, Alfred A. Knopf, New York, 1976, p. 75.

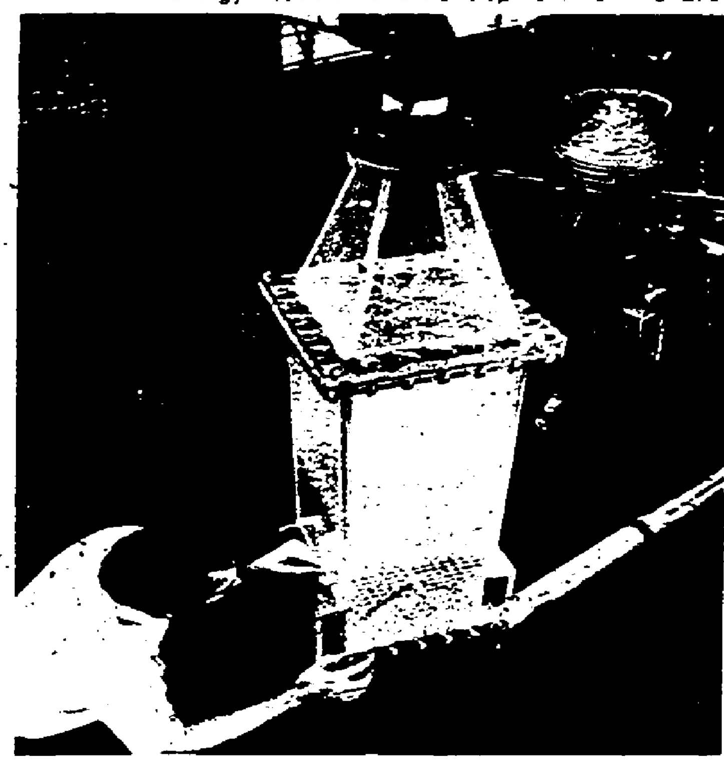
types of coal-based synthetic gas and oil, safely and economically, some time in the 1980's or 1990's.

Especially in view of the energy "loss" through conversion, referred to above, it seems likely, in any event, that the safe burning of coal in unconverted form will continue to be the main concern for some time to come. Safe burning involves solutions to the problems of:

- **Soot** (particulates): Great progress has been made in eliminating this visible pollution through the use of electrostatic precipitators. The problem is not completely solved, however, since the efficiency of these falls off considerably when low-sulfur coal is burned.
- **Sulfur dioxide**, produced when coal is burned, "is an especially pernicious pollutant, for it tends to interfere with the self-protective mechanisms in the lungs. . . ."[13] Some sulfur can be removed by washing the coal before it is burned, but not all. Consequently, "scrubbers," for removing sulfur dioxide after burning, have been installed at some plants, with varying degrees of success.
- **Nitrogen oxides**, another pollutant, can be reduced through use of a technology called "fluidized-bed combustion," in which small chunks of coal are mixed with particles of limestone, "aerated from below to produce a bubbling, fluid-like mass."[14] This method also removes sulfur, and has great thermal efficiency, but has not yet been adapted for large-scale use. First developed in the U.K., this technology has been supported by both U.S. and British Governments, and is the subject of a multilateral (IEA) agreement in which the Federal Republic of Germany also participates.

There are reports that coal exhausts may also contain harmful amounts of other toxic substances, including some that are radioactive, and we will presumably hear more about these as research progresses.[15] Finally, some scientists fear that added carbon dioxide from coal burning may raise the atmospheric temperature to a harmful extent. This view was reinforced in a recent National Academy of Sciences report. There are others, however, who feel that this tendency would correct itself; and still others who "are concerned about an opposite trend, a cooling of the earth as particulate matter builds up in the air to shield the sun. And in fact there has been a slight cooling in recent years."[16]

Energy Research and Development Administration



Model of a fluidized bed system

[13] "Clean Energy from Coal Technology," Office of Coal Research, U.S. Department of the Interior, 1974, p. 22.

[14] *Ibid.*

[15] Thomas O'Toole, "Coal Held More Hazardous Than A-Plants," *The Washington Post*, June 8, 1977.

[16] Freeman, *Energy: The New Era*, p. 50.

Note: It is apparent that much remains to be learned about the effects of various chemicals on the earth's atmosphere. Scientists point out that this is one important reason for studying the atmospheres of other planets which have different chemical make-ups.

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here is no dilemma today,"
nt Carter observed in an April
olicy statement, that is "more
to resolve than that connected
e use of nuclear power. Many
es," he said, "see nuclear
as the only real opportunity, at
this century, to reduce the
ence of their economic well-
n foreign oil. . . . The U.S., by
t, has a major domestic energy
—coal—but its use is not with-
alties, and our plans also call
use of nuclear power as a
n our energy production."[17]

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Uranium World Production And Reserves

(short tons)

	Production		Reserves
	1975	1976	(@ $30 per lb.)
United States	11,600	13,500	640,000
Australia	—	500	430,000
Canada	4,631	7,600	225,000
France	2,228	2,200	71,000
Gabon	1,209	1,200	26,000
Niger	1,820	2,000	65,000
South Africa, Republic of and Territory of South-West Africa	3,096	3,200	359,000
Sweden	—	—	390,000
Other Market Economy Countries	[r]450	450	243,000
Central Economy Countries	NA	NA	Moderate
World Total	[r,5]25,034	[5]30,650	2,400,000

[r] Estimate.
[5] Excludes centrally-planned-economy countries.
NA Not Available.
Source: Commodity Data Summaries 1977, U.S. Department of the Interior, p. 183.

duce *highly* enriched uranium, suitable for making nuclear bombs.

Another sensitive stage in the fuel cycle involves reprocessing, during which the spent fuel from a reactor is broken down into waste materials and reusable materials. Among the latter is plutonium, a highly toxic man-made substance, and this too can be used for making nuclear bombs. In fact, making a bomb with plutonium is considerably easier than making it with highly enriched uranium. In any event, India's detonation of a nuclear device—made from plutonium—was a clear signal that the global spread of nuclear technology might place a nuclear weapons capability within the reach of many nations.

While the potential dangers of widespread enrichment *or* reprocessing are quite apparent, for a number of years it was widely assumed, in the United States and elsewhere, that plutonium would eventually have to be used as a supplementary fuel for nuclear power reactors. The idea was that by adding plutonium to the fuel, one could reduce the need for new uranium by some 20%. (This is called "plutonium recycle.") And later, when *der* reactors came into use—actually breeding more plutonium than they consumed—the fuel supply could be stretched some 40 to 50 times.

Increased oil prices, in 1974, and a concurrent rise in uranium prices (as a result of cartel action, in the view of some), further reinforced the assumption that reprocessing would become necessary. This was especially true in countries which do not have extensive fossil fuel *or* uranium deposits, such as the United States has. Apart from the hope of gaining energy independence, moreover, some governments have favored reprocessing as a way to reduce the long-term environmental risks of storing nuclear wastes—that is, by reducing the amount of storage space required.

The United States has nevertheless been re-examining this assumed need for reprocessing in light of the dangers which are inherent in it and has called for a pause before nations move prematurely into a plutonium technology which may never be necessary or even economic. As pointed out by a senior U.S. nuclear affairs official, "Current estimates show that any such economic advantage would be marginal at most. Such recycle does not provide independence and there are other potential ways of stretching uranium resources. There is also evidence that waste disposal problems could be exacerbated, rather than alleviated, by reprocessing." He added: "The question is whether we have come too far down the plutonium road or whether there is still time for a second look. Our conclusion is that we do have time to examine fuel cycle alternatives that minimize proliferation and physical protection risks."[18]

An intensive search, in the U.S. and elsewhere, for new technical ways to reduce the dangers of proliferation has thus been added to other strategies for dealing with the problem. These other strategies include strong support for the International Atomic Energy Agency and its program of international safeguards on peaceful nuclear programs, together with an effort, led by the U.S., among suppliers of nuclear materials to exercise restraint in the transfer of sensitive facilities and technologies. And underpinning all such efforts is the Nuclear Non-Proliferation Treaty—the principal legal and political barrier to proliferation—which has been ratified by 100 countries.

Forgoing or deferring plutonium recycle and the commercial use of breeder reactors presupposes, of course, that an adequate supply of uranium fuel will be available. In this connection, there are already some 20 countries with nuclear reactor programs; on the other hand, the number of reactors projected for the year 2000 is far less than it was a few years ago (350 in the U.S., for example, compared to a projection of 1,200 five years ago). Moreover, U.S. officials have called for a high-priority effort to reassess the world's uranium resources; and the Carter Administration has called for new facilities which would enable the United States to provide an assured supply of low-enriched uranium fuel to countries that need it and follow non-proliferation policies.

As part of a program of incentives for nations that forgo enrichment and reprocessing, the United States also contemplates giving technical assistance for improving spent fuel storage and for the development of *non*-nuclear energy resources.

Finally, President Carter has called for an international nuclear fuel cycle evaluation, a concerted new effort by experts from many countries to examine various options, relative to the fuel cycle, which might reduce the possibility of proliferation. A number of possible ways to achieve this have already been discussed in scientific and technical circles. State Department officials say that early reactions to the evaluation proposal have been positive. The study may be launched in the near future, and presumably would last several years.

(In July 1977 President Carter named Ambassador Gerard C. Smith, former U.S. SALT negotiator, as U.S. Special Representative in Charge of Non-Proliferation Matters and U.S. Representative to the International Atomic Energy Agency.)

Note on Fusion

The final disposal of nuclear wastes has of course been a particularly vexing problem in nuclear fission. As noted by the chairman of a National Academy of Sciences committee, "No single aspect of nuclear power has excited so persistent a public concern. . . ."[19] This, together with the realization that uranium is a depletable resource, has added to hopes that nuclear fission may one day be supplanted by fusion, with the advantages of greater reactor safety, fewer envi-

[18] Joseph S. Nye, Jr., Deputy to the Under Secretary of State for Security Assistance, Science, and Technology, address before the Houston Rotary, Houston, Tex., June 30, 1977.

[19] Harvey Brooks, chairman of a committee on nuclear power. Quoted by Luther J. Carter in "...oactive Wastes: Some Urgent Unfinished Business," *Science*, Feb. 18, 1977.

ronmental problems, and a virtually limitless supply of fuel from sea water. But while the United States, the United Kingdom, Japan, and the Soviet Union especially have sponsored extensive fusion research since the 1950's, the goal of a commercial fusion reactor still seems to lie at least several decades away. And once the scientific obstacles are overcome, we are told, a "nightmarish problem facing the engineers is to perfect a fusion reactor than can withstand the internal bombardment from the very high-speed particles the fusion reactor will emit."[20] Another sobering consideration is that a fusion reactor could apparently be used as a short-cut for converting natural uranium into plutonium, or thorium into U–233 (another nuclear explosive).

Photovoltaic cells

Department of Defense

Solar

As noted by a French pioneer of solar energy, the power of the sun is so great that our efforts to use it have tended to make sense either theoretically *or* practically, but not both at the same time. For example, the most widespread use in modern times has been for heating water—a thoroughly practical undertaking, but one which theoretically is almost derisory, since it involves using a source which is at 6,000° C to heat a liquid to less than 100°C! On the other hand, the almost boundless potential of the sun to do many other kinds of work for us is theoretically within our grasp, but still eludes us in practical, commercial terms.[21]

Many would hold that this is simply due to a late start; and there is no denying that there *was* a late start in dealing with this energy other than in traditional ways. In the United States, for instance, "As late as 1973, Federal expenditures for the development of practical uses of solar energy amounted to less than one percent of the total energy-research budget."[22] And the situation was similar in other industrial countries. Writing in 1974, an American energy expert noted that each of the major consuming nations was pur-

[20] Freeman, *Energy: The New Era*, p. 281.

[21] Professor Pierre Auger, address before the Conference on Solar Energy, Paris, July 1973.

[22] Commoner, *Poverty of Power*, p. 122.

suing independent research aimed at enlarging the supply of cleaner energy. "But amazingly," he said, "they are all devoted largely to atomic energy and essentially duplicate one another." The "neglect of solar energy research and development," he observed, was "a common feature of the international picture."[23]

Nor did *industry* seem much interested in solar energy—in part, perhaps, because sunlight is free (although it is said that a few years ago a Southern California utility approached the Federal Power Commission "to ask if it could secure rights to sunlight in that state").[24] An energy expert in the academic field noted, in any case, that industry projections of energy futures tended to omit solar from their calculations;[25] and indeed, as late as October 1976, an industry projection showing probable U.S. energy sources in the year 1990 still had no input whatever from solar.

Since then, we are told, the "cottage industry" of solar energy has been "invaded by corporate giants with plenty of hard cash." Similarly, the Federal Government "has stepped up its support of solar research by more than a hundred-fold since 1972, appropriating $290 million for it this year. . . ."[26] Indeed, the Carter Administration has stated that "America's hope for long-term economic growth beyond the year 2000" rests on this and other forms of "renewable and virtually inexhaustible sources of energy," adding: "The Government will promote aggressively the development of renewable resources."[27]

The U.S. solar energy program, in fact, is now "many times larger than the combined programs of the rest of the world."[28] Moreover, it is

Sandia Labs

Concentrated sunlight from 7[illegible] heliostats melts steel

perhaps fair to say that this represents a difference in outlook, not just in allocation of resources. Europeans and Japanese, with energy limits pressing in upon them in a more immediate way, are perhaps more inclined to concentrate on the remedy they see as closest to hand—nuclear energy—and to consider solar energy as somewhat visionary. Similarly, they seem more inclined to view the future in terms of a technology they have already experimented with—fusion—even though the results have been far from conclusive. Finally, they tend to believe that solar energy can make only marginal contributions in northerly climates.

As a consequence, the United States is carrying a very large share of the burden in the advancement of solar energy. Most of the activity in

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[23] Freeman, *Energy: The New Era*, p. 134.

[24] Allen L. Hammond, "Individual Self-Sufficiency in Energy," *Energy: Use, Conservation and Supply*, A.A.A.S., 1974, p. 34.

[25] Fowler, *Energy-Environment*, vol 2, p. 59.

[26] *Newsweek*, May 16, 1977, p. 94.

[27] Fact sheet on the national energy program, White House press release, Apr. 20, 1977.

[28] *Summary of International Activities in the Division of Solar Energy*, ERDA report, Apr. 1976, p. 1.

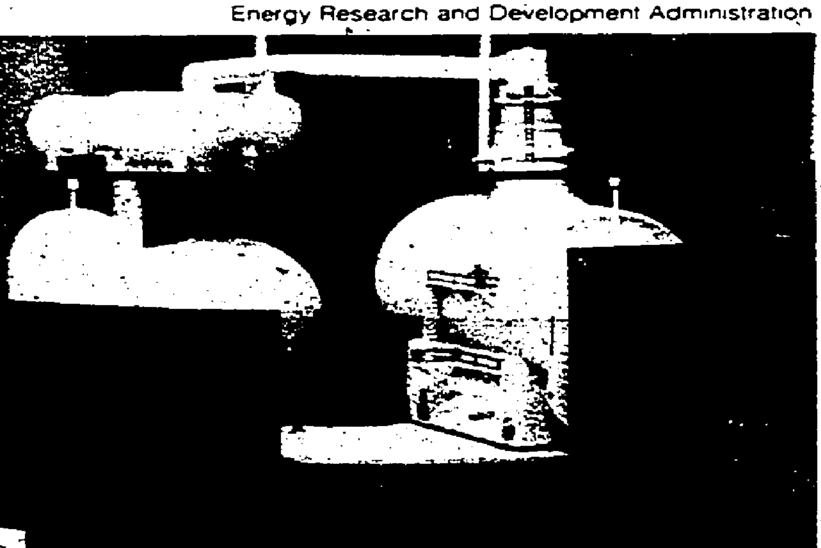
this field is still at the level of research, development, and demonstration, however, and the U.S. is a party to several international R&D agreements which it believes are clearly of mutual benefit.

It is only relatively true that one needs a sunny climate to make use of solar energy. In a very sunny climate, the average daily solar radiation falling on one acre of ground is equivalent in energy content to about 20 barrels of oil. The average for the continental United States obviously is much less; but still, it is substantial—about 11 barrels.[29] And of course this means an average of 11 barrels every day. It doesn't run out. Similarly, in most other inhabited parts of the world, substantial use can be made of energy from the sun.

Sandia Labs

Vertical-axis wind turbine

Energy Research and Development Administration



Model of an ocean thermal power system

The U.S. Energy Research and Development Administration lists three basic approaches to the use of solar energy (or solar-*derived* energy, as in wind and waves):

1. **Direct thermal applications.** This includes:
   - Heating water (through the use of solar collectors).
   - Heating and cooling buildings.
   - Generating hot water and steam for process applications in industry and agriculture.
2. **Solar electric applications.** This includes:
   - Wind turbines (windmills).
   - Hydroelectric power. (These are "solar" in that they are dependent on the weather system, which is driven by the sun.)
   - Ocean thermal power systems (based on the differences of temperature between sun-warmed surface water and cold deep water).
   - Central receiver installations, wherein a boiler is mounted on a central tower and heated by multiple-reflected images of the sun which are continuously "steered" toward it by hundreds, or even thousands, of ground-mounted mirror-heliostats. This method can produce sufficiently high-temperature steam in the receiver-boiler to drive turbines for generating electricity.
   - Photovoltaic cells (photocells), for converting solar energy directly into electricity.

Note: Both central receiver and photocell-type installations could be used not only on the ground but also in

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[29] Lloyd O. Herwig and Herbert C. Yim, *Report on United States International Cooperation in Solar Energy Technology Development*, delivered at Winnipeg, Canada, Aug. 1976.

solar power stations in space. In the latter case, the system would convert solar energy into electricity and then into *microwaves* for transmission to earth. It would thus provide a continuous source of power, day or night, regardless of weather.

3. **Fuels from biomass**. This involves making liquid, gaseous, or solid fuels from organic waste materials and from organic feedstocks (crops) grown on land or in water.

The world has had a good deal more experience, of course, in actually using the first and last of the above approaches. ERDA officials point out, however, that the feasibility of each solar electric technology listed above has been demonstrated, though these applications generally remain too costly to compete with existing systems. According to ERDA, "Wind power is the closest to economic viability."[30]

At the same time, there appears to have been some successful experimentation in Scotland with a device for using wave power to generate electricity.[31] And as for storing electricity, one method reportedly being pursued by Japanese scientists is using the electricity to produce hydrogen, which can then be stored as a gas.[32]

The United States has bilateral arrangements for solar R&D with France, Japan, Spain, the Soviet Union, and several other countries. ERDA reports have cited French expertise in high-intensity "solar furnace" technology, for instance, and Japanese experience with water heater design as examples of ways in which U.S. technology has benefited from such bilateral exchanges.

To make maximum use of staff time and travel funds, however, ERDA officials say they have placed major emphasis on multilateral international efforts, especially under the auspices of the International Energy Agency. The IEA's principal solar projects thus far have related to heating and cooling, but have also encompassed the design of a small solar-thermal power plant. The construction of this plant as a cooperative venture is now under discussion. Under the chairmanship of designated "lead countries" (Denmark, Germany, Japan, Sweden, and the United States), five international groups have been working together on heating and cooling system designs, development of components, testing of solar collectors, developing instrumentation, and compiling meteorological information.

The IEA is also developing five additional solar energy projects, relating to: ocean thermal gradients, wave power, small solar power systems, wind power, and biomass conversion.

Geothermal

As we dig through the earth's crust toward the molten rock beneath—believed to be heated mainly by radioactivity—the temperature generally rises only very gradually: about 1°C every 100 feet, or 48°C every mile. But in some places there are concentrations of hot water or steam—sometimes very hot, dry steam—quite near the earth's surface. This water or steam can be used for a large variety of industrial, commercial, and agricultural purposes, depending mainly on its temperature. (In some cases, however, its usefulness may be diminished by pollutants that are corrosive or difficult to dispose of. Very hot steam or water can be used for generating electricity.)

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30 Lloyd O. Herwig, "Review of the Solar Energy Program of the United States Energy Research and Development Administration," address before the World Electrotechnical Congress, Moscow, June 1977.

31 "Dawn of the Solar Age," Nova #412, produced for television by the BBC and WGBH [illegible]n, first transmitted Apr. 13, 1977.

New Zealand Information Services

Geothermal field in New Zealand

Although potential geothermal resources exist throughout the world, the highest temperature resources are said to be located in "Central and South America, in Turkey, East Africa, in almost all the countries around the Mediterranean, in the Far East, along the 'Circle of Fire' of volcanic action surrounding the Pacific, and in the Soviet Union."[33] But while oil wells have been drilled for a century, the rather similar efforts needed to tap geothermal energy have been very modest and largely of recent date—except in Italy, at Larderello, where the first steam well was drilled in 1904 and has been used ever since for generating electricity.

According to an American study, "New Zealand was the second country to capitalize on geothermal resources. . . ." Then, "domestic and industrial heating by geothermal heat was initiated in Iceland in 1925, and over 100,000 residents now live in houses heated in this manner." Based on "encouraging progress in these countries, exploration and development programs were initiated in Burma, Chile, Colombia, El Salvador, Ethiopia, Guatemala, Japan, Kenya, Mexico, Nicaragua, Turkey, the Soviet Union, and the United States."[34]

The best known geothermal field in the United States is The Geysers in California, initially developed in the 1920's, which like Larderello is used for generating electricity. Other geothermal fields of varying temperatures are now being assessed in many parts of the U.S., including Alaska and Hawaii.

Thus far, only New Zealand and Iceland have made geothermal applications "a principal energy technology."[35] It is reported, however, that "there are over 50 countries active or interested in geothermal exploration

[33] Freeman, *Energy: The New Era*, p. 260.

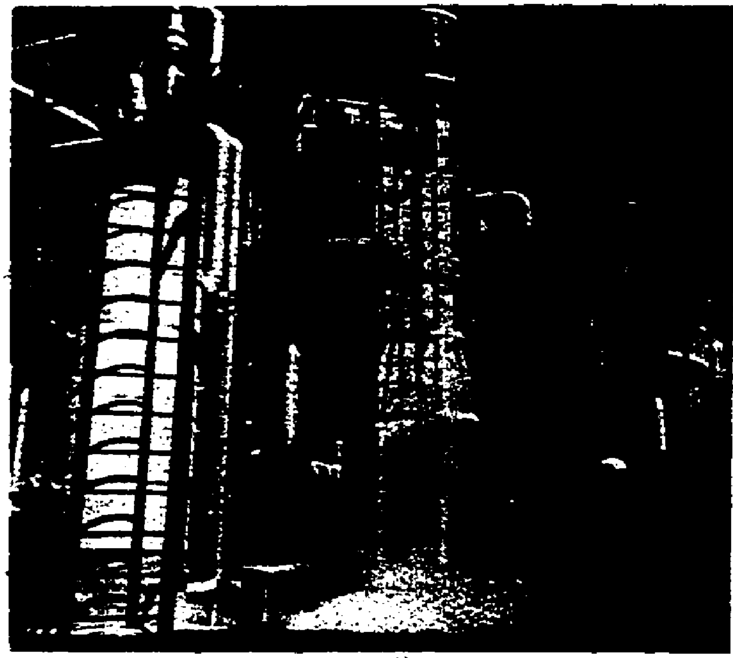
[34] *Geothermal Energy*, Informatics, Inc., Rockville, Md., Nov. 1975, p. 3.

[35] *Present Status and Future Prospects for Nonelectrical Uses of Geothermal Resources*, J. H. Howard, NATO CCMS Report No. 40, ms. date Oct. 3, 1975.

and development."[36] The United Nations has held several symposia in this field, and the U.N. Development Program has assisted several less developed countries with exploration.

The U.S. Government's interagency program—coordinated by ERDA—seeks to encourage "commercial development of geothermal energy resources for both electric and non-electric applications" in the United States "by means of demonstration projects and loan guaranties."[37] It also handles participation by the United States in multilateral R&D agreements under the International Energy Agency and NATO, and bilateral agreements with Iceland, Italy, Japan, Mexico, and New Zealand.

San Diego Gas and Electric Company



Experimental geothermal facility, Imperial Valley, California

ERDA officials point out that the geothermal "technology in current use is largely adapted from that of the oil industry and is often not well suited to the very different geologic environments of geothermal resources."[38] Also, "exploration methods are deficient, so that exploratory drilling is too often unsuccessful."[39] For these and other reasons, geothermal developments, worldwide, have been advancing only at a modest pace. This seems to apply especially to electrical uses—despite some striking exceptions like El Salvador, which is already generating 40% of its electricity from geothermal energy.[40]

According to one projection, in 1980 "the geothermal power component of world output will remain at less than 1 percent of total generating capacity."[41]

With improvements in technology, however, some specialists believe there could be rapid increases in both electrical and non-electrical uses. Indeed there are those who, for the very long term, would accord geothermal energy a place ahead of almost all other sources. A British energy expert, when asked what he believed were the most promising future directions, replied: "Inside the earth and inside matter" (i.e., in a more advanced knowledge of the composition of matter and its close relationship with energy).

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[36] *Geothermal Energy*, p. 481.

[37] *First Annual Report*, Geothermal Energy Research, Development, and Demonstration Program, ERDA, Washington, D.C., Apr. 1977, p. S–5.

[38] *Ibid.*, p. S–3.

[39] *Ibid.*, p. S–4.

[40] "A Visit to Ahuachapan," UNITAR (U.N. Institute for Training and Research) release, vol. II, no. 1, Feb. 1977.

[41] *Geothermal Energy*, p. 482.

Conclusions

The Oil Supply

We are still very much in the oil age and will surely remain so for some years to come, even with increased use of coal and the accelerated development of other energy sources. Ultimately, we will have to derive the main part of our energy from such other sources, but the transition will be a lengthly one. In the meantime we must at least maintain our present degree of access to oil if our complicated, energy-based society is to avoid severe economic shocks.

Large increases in domestic oil production seem clearly ruled out, apart from the contribution of Alaska; and a substantial part of our foreign sources are located in the Middle East, an area of high political tension and risk. A basic objective of our foreign policy has been and must be to bring about peace and security in that area; but regardless of what success we may have in such efforts, the fact remains that oil located abroad is not under our control. We cannot rely on its being invariably available in quantities which will insure that its price is one we can afford to pay.

Our vulnerability in this respect, combined with the impact which the cost of imported oil is having on our balance of trade, makes it all the more essential that we act now to minimize the hardships which lie ahead, by drastically curtailing our waste of oil-based energy. Other industrial countries have far outshone the United States in conservation efforts; and it does not detract from their achievement that their success has been due largely to current or past *costs* of energy (one example, the price of gasoline, is shown opposite) rather than to farsighted planning based on perceptions of a real global problem.

Gasoline Prices In Some Industrial Countries
(paid by consumers at the pump, mid-1977)

	Regular	Premium	Diesel
France	$1.67	$1.80	$1.09
Germany	$1.41	$1.50	$1.40
Italy	$2.05	$2.13	$0.66
Japan	$1.67	$1.85	$0.88
United Kingdom	$1.19	$1.22	$1.20
United States	$0.62	$0.68	$0.57

The United States will surely be subject to increasing pressures from other oil-importing countries as real shortages begin to be felt; for when that time comes, what one country does about heating its homes, for example, may have a direct bearing on what another country must use to run its factories. Moreover, as noted in *The National Energy Plan* (p. 20), because of its own actions the United States thus far "has not been able to provide leadership to restrain the growth of world demand."

(In connection with oil conservation it is perhaps worth recalling that in a CBS News/*New York Times* poll taken just after President Carter's energy speech of April 18, 1977, a majority (54%) placed "a lot of blame" for the energy crisis on "waste by consumers," as well as on "Middle East oil producers" (47%) and domestic oil companies (42%): State Department analysts noted that "The public's willingness to accept primary responsibility for the energy crisis marks a reversal of opinion. . . . Until recently, less than one-fifth of the public attributed 'major blame' to themselves as consumers."[1])

Hand-in-hand with steps to maintain the supply of oil and to stop wasting it, there must be continued efforts to deal with the economic and financial aspects of the oil trade, such as efforts to prevent a wave of protectionism by countries with excessive oil debts.

Finally, the ocean must be protected against massive oil spills and dumping of oil, just as the atmosphere must be protected from increasing pollution as more coal is burned.

Per Capita Use Of Energy In Industrial Countries	Per Capita GNP (1975)	Per Capita Use of Energy (Equivalent in metric tons of coal) (1974)
United States	$7020	12.9
United Kingdom	4160	5.4
West Germany	6820	5.7
France	6470	4.3

Source: *Handbook of Economic Statistics*, ER 76-10481, Central Intelligence Agency, Sept. 1976.

Transition/Technologies

Since nuclear energy will be called on to play an increasing role—either intermediate or long-term, depending on one's point of view—preventing the spread of nuclear explosive capabilities to more countries or the seizure or manufacture of nuclear explosives by terrorist groups will be a constant preoccupation. And the degree to which the world shifts from uranium to plutonium as a fuel will presumably have a good deal to do with the level of risk. The disposal of nuclear wastes also will be a subject of growing concern, unless finally some adequate and economically acceptable technology is devised to deal with this problem.[2]

The United States has enunciated policies on the subject of nuclear proliferation with greater comprehensiveness and clarity than any other country. These are referred to in the section on nuclear energy; suffice it to say here that unceasing efforts will be needed to carry them out.

One of the "incentives" the U.S. has offered as part of a long-term non-proliferation strategy is "cooperation and assistance in the development of *non*-nuclear energy resources" (emphasis added).[3] In this connection, perhaps the most signal service which could be rendered for non-proliferation would be the development of indigenous energy resources and technologies which simply make nuclear power non-competitive with other options.

As we have noted, the United States is by no means the only country with an imaginative energy R&D program. However, as pointed out in an OECD report, "only the United States supports a systematic research effort on all energy sources."[4] Thus other countries will doubtless be looking to the United States for important tech-

[1] Department of State Airgram A-2229, May 24, 1977, to U.S. diplomatic and consular posts.

[2] One solution proposed would be to send the high-level wastes aloft via space shuttle and then fire them into the sun. According to Professor René H. Miller, President of the American Institute of Aeronautics and Astronautics, about 50 flights per year would suffice to remove high-level wastes from U.S. reactors on a continuing basis and would cost about 2% of what consumers pay for electricity. The same service could be sold to other countries. In case of launch failure, Prof. Miller says, properly designed crash-proof canisters would prevent a spill even if parachutes also failed.

U.S. officials have nevertheless expressed some skepticism about this proposal. For one thing, the separation of high-level from other wastes requires reprocessing (see p. 27). For another, they doubt the idea would gain public acceptance, regardless of assurances about safety.

[3] Nye, Houston, Tex., June 30, 1977.

[4] "Energy R&D Policies in OECD Member Countries," *Energy R&D*, OECD, Paris, 1975.

nological developments, perhaps especially in the field of "renewable and essentially inexhaustible sources of energy," as called for in *The National Energy Plan* (p. 23). (An approximate breakdown of the U.S. R&D program is shown in the accompanying figure.)

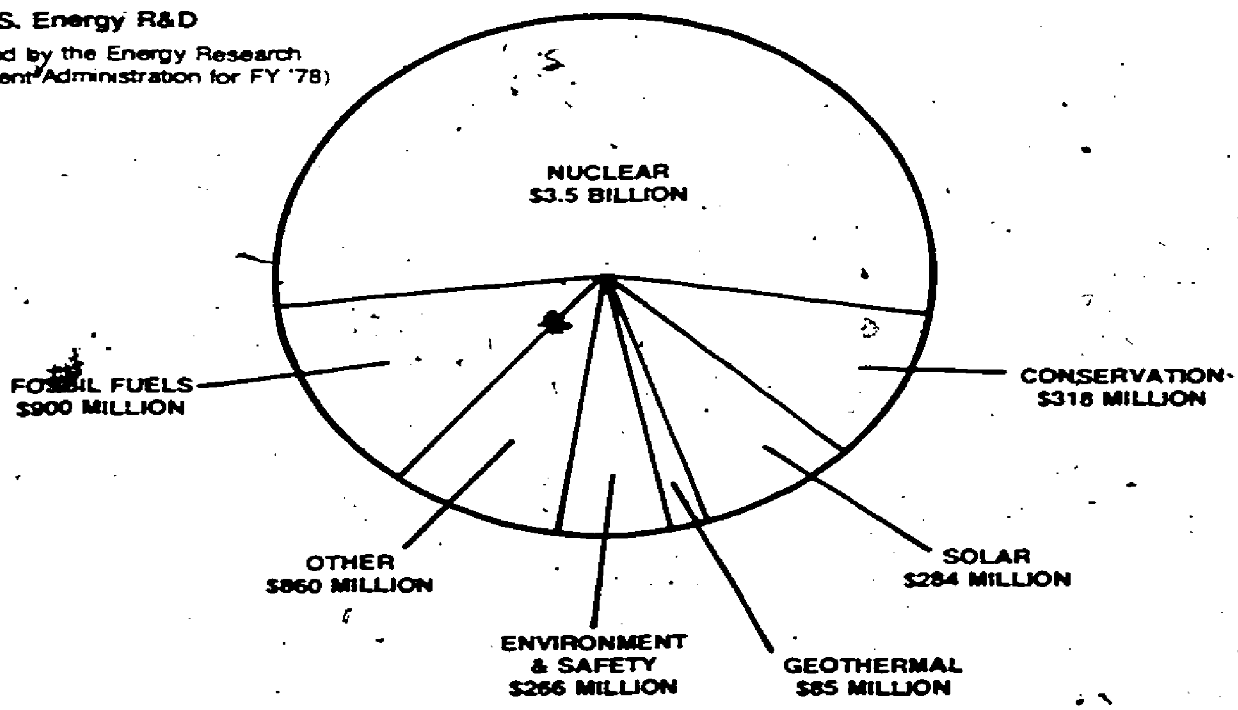
Cooperation

In any situation of potential shortage there are of course possibilities for dangerous competition. But as noted earlier, the international competition for world energy resources also has "a strangely positive side." The long-term demand for energy is so great, and the economic and political linkage between nations so strong, that as a practical matter competition may very well give way to cooperation. In an unprecedented manner, the nation-states are almost obliged to wish each other well; i.e., for essentially selfish reasons.

In any event, State Department officials who have dealt with multilateral energy problems and negotiations over the past year and a half feel that there has been a considerable improvement in the general relationships between industrial nations and the other two groups of countries involved: the oil-producing countries and the non-oil LDC's. The oil producers on the whole have seemed to evolve a greater feeling of responsibility regarding the supply of oil, just as some of them have acquired more of a stake, through their investments, in the economies of the industrial nations. And both industrial and oil-producing countries, at the recent negotiations in Paris, took steps to improve the lot of the non-oil developing countries—committing an additional $1 billion of official development assistance to them and calling on the World Bank to place greater priority on lending to them for the development of energy resources. Finally, as the Paris conference (CIEC) ended, there seemed to be enhanced prospects for cooperation among *all three* groups of countries in energy R&D. This would be a new departure, and could be politically important—acknowledging a greater mutuality of interests—as well as technically useful in stimulating new energy R&D activity in many parts of the globe.

Because of its technological preeminence as well as its general position, the United States obviously has a leading role to play in bringing the world through the period of transition that lies ahead; and other governments have expressed satisfaction that the U.S. appears to be preparing itself for this role.

U.S. Energy R&D
(as requested by the Energy Research and Development Administration for FY '78)



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