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Low-Cost, Abundant Energy: Paradise Lost?

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The United States has entered an era of profound alteration in traditional patterns and trends in the field of energy. Price relationships, rates of use, sources of supply, and, in its broadest sense, national security, all have become areas affected with uncertainty and conflict.

With supplies tight and prices rising, the changes are widespread and painful. Although the Arab oil embargo of recent months has greatly aggravated the crisis, the underlying causes lie farther back in the past and hopes of long-term remedies lie well into the future. It would be fruitless here to describe the immediate situation or report on day-to-day efforts to improve it. Events are moving so fast that any up-to-the-minute account would be out-of-date before it could be gotten into print. Instead, let us examine the fundamental trends and forces that have brought this country to its present pass and that can be expected to persist. Although no clear answer can as yet be given, there is reason at least to ask whether we are witnessing the closing of still another frontier—the end of a low-cost, reliable energy supply in the United States.

If the answer should be unfavorable, we would have plenty of company. For many years relative prices of energy have been far higher in Europe, as every tourist who has pulled up at a gas pump knows. Western Europe and, to an even greater degree, Japan are vastly more dependent on energy imports than is the United States, which even for oil produces two-thirds of its own requirements (Tables 1 and 2). Uncertainty of energy supply, both in availability at any given time and in quality of service, prevails through much of the world. Most of industrialized Europe, Japan, and in fact all but a handful of countries get along on one-half the per capita supply, or less, of what has seemed to be a necessity for Americans, although their growth rates in recent years have far exceeded that of the United States (Table 3).

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Early Signs of Trouble

Energy problems did not hit the country full-blown in 1973. There were much earlier hints of impending trouble. Among them were the refusal of numerous natural gas utilities to connect new residential customers and voltage reductions and load shedding instituted by a number of eastern electric utilities during peak load periods in each of the past two summers.

In the late fall of 1972, shortages of heating oil prompted the closing of schools and other public buildings, and farmers in the Midwest began to worry about securing enough fuel to dry wet crops and power their implements. By the summer of 1973, distillate and fuel oil and gasoline, as well as crude, were in short supply. Sunday or early weekday closings of service stations or "sold out" signs on the pumps began to make their appearance before becoming routine matters late in the year. Beyond the borders of this country there were ever more frequent confrontations between the major exporters, banded together in the Organization of Petroleum Exporting Countries (OPEC), and their customers, until the seemingly unending string of short-term revisions in long-term basic compacts reached their climax in reduction or denial of access to supplies and drastic, unilateral price boosts, with grave economic and political ramifications.

At the end of the product line, the consumer's energy bill began to rise. Long a bargain, electric utility rates, as well as petroleum product prices, have started a rapid upward climb. Predictable reactions followed. There was increasing pressure for relaxation of environmental standards and controls. Both the automobile industry and numerous municipalities pressed for deferment of automotive emission standards; utilities sought temporary waivers of stack emission controls, largely in order to enable generating facilities to burn fuel of higher sulfur content; and high government officials asked environmentalists to be "reasonable," lest a backlash develop. (How many of these pressures were bona fide responses to the energy pinch and how many were a grasping of the opportunity to resist environmentalism is a warmly debated question.) Government action began to replace voluntarism; variances in and postponement of achieving prescribed standards had come to be official late in 1973.

Surging sales of compact cars may represent the consumer's first adjustment to fears of higher prices and uncertain availability of gasoline. In the booming auto market of 1973, sales of small cars during the first half of the calendar year reportedly constituted 40 percent of sales, up from 35 percent during the same period 1 year ago. More recently the boom sagged, but the shift toward compacts was intensified.

For both the executive and the legislative branches of government, energy policy has become a major concern. It has produced a rising swell of presidential messages, public addresses, and proposals for legislation. Organization-

al regrouping has been frequent but as yet unsuccessful in the search for Administration "coordination." Long-cherished policies like import quotas have been abandoned with little opposition. The flow of government energy research funds has steadily mounted. This fiscal year they stand just short of $1 billion, mostly for nuclear reactor development, and are projected to rise to an annual $2 billion during the next 5 years, with more emphasis on nonnuclear energy sources.

The Congress, for its part, is considering a wide variety of measures to cope with energy problems. There is hardly a day on the congressional calendar that does not list hearings on one or more energy bills.

An animated search for the villain is under way. In a country as rich as the United States, few are willing to believe that the consumer suddenly faces shortages simply because demand has run up against a serious problem of supply. It must be someone's fault. Three convenient targets present themselves: the energy industry, the federal government, and the environmentalists. As seen by their adversaries, the first conspires, the second bungles, and the third obstructs. The first is a knave, the second a fool, and the third a dreamer. *Industry* is accused of withholding supplies—and information on their magnitude, alleged to be much greater than reported; thus it creates shortages, higher prices, and, as a bonus, is able to squeeze out independent refiners and service stations. *Government* is charged with holding down prices (or, by consumers, with not holding them down), reducing incentives, cutting subsidies, and enmeshing industry in a thicket of agencies, standards, and regulations, causing profits to decline, capital to become scarce, and initiative to evaporate. *Environmentalists* are held guilty of halting the wheels of progress, of following elitist aspirations, and of shunning the "facts of life."

Few of these accusations can be taken at face value. Neither can they all be dismissed.

It is obvious that demand has outrun supply at prices which have either been regulated or have risen only with some lag in time, so that quite likely considerably higher prices would be needed to bring about balance. The nature of the energy industry is such that, once its reserve margins of productive capacity have been exhausted, output can expand only slowly—that is, over a period of a few years rather than months. Anticipating the magnitude of future demand is thus of crucial importance, and, given the time lag between planning and operation, such estimates must be pushed substantially into the future to be useful.

Table 1. U.S. petroleum demand and imports (*3*).

Year	Domestic demand (10^3 barrel/day)	Gross import (%)
1950	6,507	13.1
1955	8,460	14.8
1960	9,661	18.8
1965	11,303	21.8
1970	14,709	23.2
1971	15,213	25.8
1972	16,367	29.0
1973	17,248	35.7

Table 2. Significance of oil imported from the Middle East and North Africa during 1972 (*1*).

Area	Imports (gross) as percent of		
	Oil imports	Consumption	
		Oil	Energy
United States	14.9	4.4	2.1
West Europe	80.4	79.5	50.6
Japan	78.9	78.6	60.5
World	67.9	38.8	18.5

Table 3. Per capita energy consumption in selected countries during 1968 and 1971 (*2*).

Area	Coal equivalent (kg) per capita		Increase (%)
	1968	1971	
United States	10,398	11,244	8.1
France	3,282	3,928	19.7
Germany	4,488	5,223	16.4
Italy	2,267	2,682	18.3
United Kingdom	4,961	5,507	11.0
West Europe	3,313	3,878	17.1
U.S.S.R.	4,050	4,535	12.0
Japan	2,519	3,267	29.7
World	1,734	1,927	11.1

Table 4. Selected data on automobiles, United States, 1960 to 1971 (*4*).

Year	Passenger cars			
	Registration ($\times 10^6$)	FIAC* (%)	Average use (mi/car)†	Fuel (mi/gallon)†
1960	61.7	6.9	9,446	14.28
1965	75.2	23.3	9,286	14.15
1968	83.6	43.3	9,448	13.91
1969	86.9	54.0	9,633	13.75
1970	89.2	60.9	9,783	13.58
1971	92.8	61.0	9,926	13.73
1972	96.9	68.6	10,184	13.49

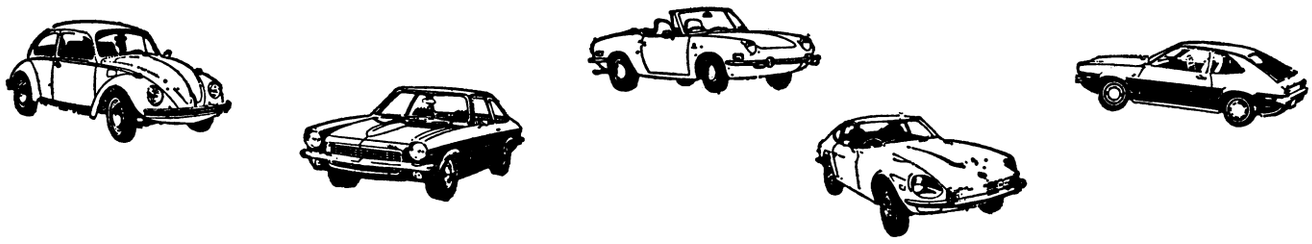
* FIAC, factory-installed air conditioning. † 1 mile = 1.6 km; 1 gallon = 3.8×10^{-3} m³.

Let us take oil demand as an example. Under 1958 limitations, approximately 12 percent of consumption was to be contributed by imports, but by 1973 imports represented closer to 36 percent (Table 2).

What has pushed imports up so far and so fast? One item has been the shift of electric utilities to oil, highly notable along the Atlantic Coast, and evident in the most spectacular manner in the Greater New York City area, where Consolidated Edison and Long Island Lighting relied on oil for 22 percent of their fuel input in 1960 and for nearly 80 percent in 1971. Controls imposed on emissions from plants that burn fossil fuel, the absence of a commercially viable technology for removing sufficient sulfur compounds from stack gases, and the tightness of natural gas supplies have caused utilities to shift to oil, which enables them to meet the restrictions imposed. The effect on prices is not surprising. In the Middle Atlantic region, cost to utilities of oil "as burned" rose 54 percent per barrel between 1969 and 1971, in constant dollars. Various industrial users have turned to oil and, within that category, to the less polluting, lighter distillates. This in turn has caused a tightening of oil available for heating.

At the same time, automobiles, which account for nearly 40 percent of oil consumed in this country, have become less efficient converters of gasoline into vehicle-miles. More power-consuming accessories on more cars (power steering, power brakes, air conditioners, and, more recently, emission control devices) are diverting part of the power produced from the drive shaft. These devices also have added to the car's weight, so that the same number of gallons will pull the car fewer miles, and there are more automobiles. Moreover, miles traveled per car per year have shown a moderate increase, after years of stability and despite the emergence on a rising scale of the two- and three-car family. Congestion in city streets and on highways adjacent to metropolitan areas could well have been another factor in lowering mileage per gallon (Table 4).

These factors have boosted demand for petroleum products. Gasoline de-

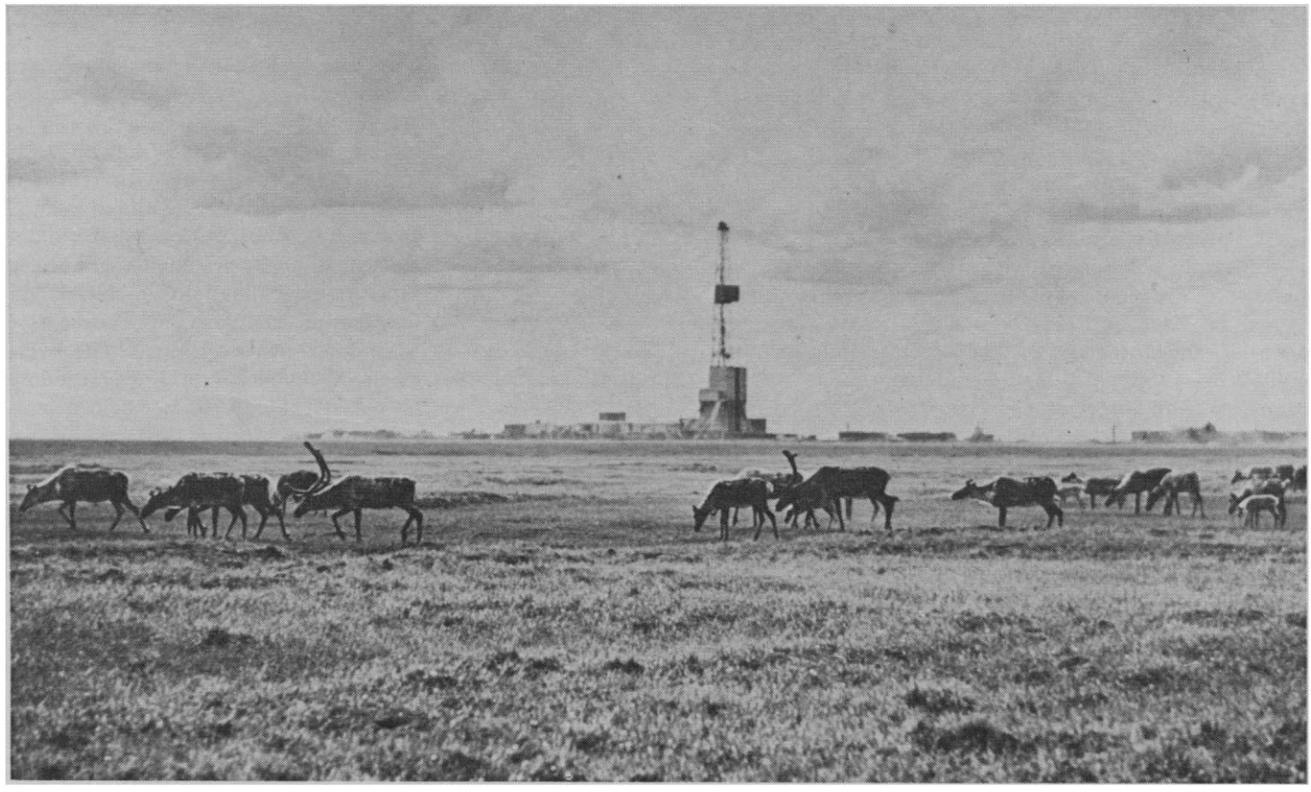


Small cars have increased in popularity.

mand rose by 2.6 percent per year from 1960 to 1965; it has risen at 4.5 percent since. From 1967 to 1972 it rose by 27 percent, or 4.9 percent per year. Consumption of residual fuel oil, the one-time Cinderella of refinery products that had risen by barely 1 percent per year from 1960 to 1965, shot up by an annual 7.2 percent over the latest 5-year span. This is the story for 1972, in percentage increases over 1971: gasoline, 6.0 percent; distillate, 8.5 percent; residual fuel oil, 10.1 percent; and total product demand, 7.3 percent.

The recent increases in consumption have no match on the domestic supply side. Through 1972 the trend of exploration activity and drilling was down, while refinery construction increased only slowly. Well completion, for example, had by the early 1970's declined to the level of 1946, after a sharply rising trend that began in 1948 and persisted through 1956 (Table 5). As a result, reserves, as defined in the industry statistics, have declined absolutely, and even more drastically as a multiple of production. The steep 1973 increase in gas drilling activities is encouraging, but too recent to evaluate as a guide to future events.

Promising new avenues of supply expansion have narrowed or closed altogether. Leading oil states like Texas and Louisiana now are lifting oil at essentially 100 percent of capacity, calculated at a rate of extraction designed to result in maximum economic recovery. Offshore drilling received a heavy setback from the Santa Barbara Channel spill. Existing wells in the area had to be throttled, and new ones could not be drilled. Moreover, the event cast a shadow over offshore drilling as a whole, a significant drag on future supply in view of the richness of the offshore fields and their rising relative role in recent years (from 4.5 percent of total crude and condensate production in 1960 to 16.4 percent in 1972) (Table 6). No less significant has been the delay of production of the northern Alaska field. Had offshore drilling and producing continued as foreseen and had North Slope oil come into operation, these two sources could have contributed about 2 million barrels per day by now—substantially more than 10 percent of demand, or more than a third of current U.S. oil imports and thus roughly the equivalent of direct and indirect imports from Middle East sources. Moreover, production of North Slope natural gas on the heels of that of oil would have



Caribou graze nonchalantly on the Arctic tundra within sight of one of the operating drilling rigs at Prudhoe Bay, Alaska. This photograph was taken during the animals' annual migration across the North Slope. [Courtesy Alyeska Pipeline Service Company, Bellevue, Washington]

eased the demand that oil make up for the natural gas shortage. (These conclusions are offered strictly from the viewpoint of energy supply, with no intention of passing judgments on objections of environmentalists to both offshore drilling and the trans-Alaska pipeline.)

The recent upturn in energy prices result not only from the failure of domestic production to expand as expected, but also from the fact that some of the costs of environmental damages are being taken into account. More such external costs will go into future concepts of "abundant, reliable, low-cost energy." Moreover, the price increases, for whatever reasons, are especially disconcerting because they follow a long period of declining *real* energy prices, which have been masked by price increases measured in current dollars. Thus a barrel of crude oil was worth $2.60 in 1948 and $3.39 in 1972, with only a slow upward trend until the very recent rise. In constant (1948) dollars, however, the 1972 price reached not $3.39 but $1.85, for a decline of about 30 percent during the quarter century. The price decline was even more pronounced in coal, whose price in constant dollars had declined by some 40 percent between the early postwar period and 1970, although it increased very sharply thereafter as a number of phenomena created a sudden shortage of coal, specifically of low-sulfur coal (here again the long slide in coal's real price must be taken into account when contemplating its subsequent rise). Only the price of natural gas had advanced in real terms, but that advance had been accomplished by the late 1950's, primarily because gas had been so drastically underpriced when it first came into use as a by-product of oil extraction. Even in 1972, its wellhead price of approximately 20 cents per million Btu (1 Btu ~ 1.06×10^3 joule) compared with 30 cents for coal (at the minemouth) and 60 cents for wellhead oil, although these differences are greatly reduced when costs of transportation to users are taken into consideration. Recent price behavior apparently marks the end of energy as one of the great postwar bargains.

Other factors have aggravated the situation. One of these is the slow pace in refinery construction, most pronounced along the East Coast, where no new refinery has been built in the last 15 years and capacity has been declining since 1961. This trend is frequently blamed on environmentalist opposition; but this cannot be the whole story if only because the slowdown antedates public environmental concern. Other factors—mostly within control of government—are: import limitations and uncertainties as to their duration and character; possibly capital tightness following the reduction in the depletion allowance; the suspension of the investment tax credit; tax advantages for location offshore; the uncertainties concerning the type of gasoline to be marketed; and the rising difficulties of obtaining low-sulfur oil, which most U.S. refineries are built to process. These factors have contributed to the failure of refining capacity to keep pace with rising demand. Actually, refining capacity has not stood still, even in the most recent past. It rose by about 4 percent annually, from 1967 to 1972, and by 1.2 percent, from 1971 to 1972. This limited expansion, however, was not nearly sufficient, and the wave of recently announced planned capacity growth cannot soon remedy this condition, even if fully implemented and supported by access to crude.

Furthermore, there have been substantial delays in the expansion of the electric power industry. Here, too, it would be wrong to hold environmentalists solely or even largely responsible. Rather the nuclear power industry has been plagued with childhood diseases, including unsuspected technical problems, poor workmanship, congested order books, strikes, and other delays not peculiar to the power equipment industry—slowness of the licensing process, multiplicity of agencies involved, and time-consuming tests in the courts. These, together with the concern of environmentalists about routine as well as accidental emission of radioactive substances, safe management of disposed material, thermal pollution of lakes and rivers, and the like, have slowed down the planned expansion of the industry.

Nor were there ready alternatives. Supplies of natural gas, the "clean fuel" par excellence, were becoming increasingly tight. Its use as boiler fuel once again was frowned upon, just as is had been some 20 years ago. Regulatory policies have played a part in perpetuating the price differential, keeping the price of gas below the level at which the market would be cleared without the "shortage" phenomenon that has emerged. Diminished regulatory control, most believe, would boost output from existing wells, while many expect, in addition, increased exploration and development.

As for coal-fired boilers, a reliable, commercial process for desulfurization has yet to be demonstrated, occasional reports to the contrary notwithstanding. Utilities have thus been reluctant to commit funds to coal-fired plants, an attitude strengthened by the judgment that problems attending nuclear generation will in time be solved and that the nuclear plant thus represents a wiser long-term investment. The overwhelming emphasis in R & D funding on nuclear energy has not helped matters. Current efforts at correcting it can bear fruit only in the years to come.

The evidence sketched above suggests no quick way out of the nation's energy bind. In looking ahead, let us reexamine some familiar problems: import dependency, possibilities of curbing domestic demand and increasing domestic supply, and environmental impacts and trade offs that might be involved.

Until November 1973, nobody doubted continuance of the shift in supplies from indigenous to foreign sources, involving principally oil and,

Table 5. Number of oil and gas wells completed in the United States, 1945 to 1972.

Year	Reference	Wells (No.)*
1945	(5)	24,666
1950	(5)	42,039
1955	(5)	55,896
1960	(5)	44,018
1965	(5)	39,510
1970	(6)	28,120
1971	(6)	25,851
1972	(7)	27,291
1973	(8)	26,592

* Excludes service wells.

Table 6. U.S. crude oil and condensate production, total and offshore (9).

Year	Production (10^3 barrels)		Offshore as % of total
	Total*	Offshore†	
1960	2,574,933	116,763	4.5
1965	2,848,514	242,652	8.5
1966	3,027,763	300,270	9.9
1967	3,215,742	368,177	11.4
1968	3,329,042	471,191	14.2
1969	3,371,751	525,832	15.6
1970	3,517,450	575,714	16.4
1971	3,453,914	614,754	17.8
1972	3,455,000	569,206	16.4

* Total U.S. crude oil and condensate. † Total offshore "state" and "federal outer continental shelf" oil and condensate.

Table 7. Percentage shares of primary energy sources in total consumption for selected countries in 1960 and 1970.

Country	Percentage shares of sources									
	Solid		Liquid		Gaseous		Hydro		Nuclear	
	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970
United States	23.9	20.5	44.1	42.7	30.3	34.8	1.7	1.7		0.3
France	56.7	26.5	34.3	62.4	3.3	6.1	5.6	4.1	0.1	0.9
Germany	76.6	39.3	21.7	53.3	0.5	5.8	1.2	1.0		0.6
Italy	17.8	7.6	55.7	77.9	13.7	9.8	12.8	4.2		0.5
United Kingdom	73.6	48.0	25.8	44.2		5.0	0.2	0.2	0.4	2.6
Europe (OECD)	61.4	29.4	32.5	59.6	1.8	6.7	4.2	3.3	0.1	1.0
Japan	54.8	23.3	36.4	71.7	1.0	1.4	7.8	3.2		0.4

to a lesser degree, natural gas. The Magnitude and duration of the shift were less easily agreed on. Nor was it asserted that there was no possibility of reversal. On the contrary, the new devotion to energy research and development was regarded as likely to provide the pivot on which the growing dependence could eventually turn around.

Concern over import dependency is not new. In its most conventional form it rests on considerations of national security. What degree of dependency, and therefore vulnerability, is tolerable, and what alternatives exist for ensuring adequate security in the face of growing dependency?

Such concern has gradually extended its scope. In the future, security is likely to be more broadly conceived as reliance on a minimum flow of energy materials to feed the economy as a whole, not just the defense machinery or the economy in times of war. Among the large issues at stake here are: (i) the impact on the nation's foreign trade and payments balance and (ii) the effect on U.S. foreign policy in a world where competition for fuel easily becomes a major disruptive influence among friends and a potent determinant of the formation and strength of new alliances.

Relations with OPEC countries located in the Middle East and along the southern shore of the Mediterranean have, for many years, been heavily affected by energy questions, but that was principally through the medium of security for Western Europe and the role of U.S. companies as operators in that part of the world. Henceforth, the far more direct impact of the oil (and gas) supply to the U.S. market and the impairment, if not the loss, of American ability to help Western Europe and Japan overcome sudden supply difficulties by reaching into current U.S. production will take on new importance and urgency, brought into sharp focus through recent U.S.-sponsored efforts at cooperation among consumer countries, and the difficulties associated with them. At the same time, how and with what effects the exporting nations will use their growing oil revenues, assuming that large exports will take place even if not at rates desired by many potential customers, is an altogether new, and so far unanswered, question.

Of equal novelty is the idea that the U.S.S.R. might become a large-scale supplier of energy, in this instance natural gas, to the United States. Here security considerations of a different kind are bound to generate debate. Finally, rethinking the security concept will become necessary in the wake of recent evidence that Canada is reluctant to remain an unquestioned reserve pool for U.S. needs. The customary assumption that U.S. dependence on foreign supplies is acceptable as long as such supplies are located within strategically easy reach, could come in for review, modification, and perhaps abandonment.

From a purely economic viewpoint, the trend toward obtaining a growing share of energy supplies from abroad should not give rise to great concern. It is a familiar stage in the cycle of development and foreign trade. However, U.S. demand pressure coincides not only with precarious foreign trade and payments circumstances, but with similar pressures in the rest of the industrialized world. Moreover, the 1960's have witnessed a radical swing in both Western Europe and Japan to oil as the primary energy source (Table 7). Thus, plans for "sharing" were looked at askance by Europe and Japan even before the Middle East war. Now there is less to share and less willingness to do so. As a result, the world's oil producers find themselves in an unprecedentedly strong bargaining position, which has enabled them to convert the supply bind into spectacular price and revenue increases. Even if trade relations should become more normal, such revenue increases will have affected the economics of expanding production (why sell now if prices will continue to rise?) and reduced motivation to collect more revenue (what is to be done with the snowballing billions of dollars?). Thus, even sustained price increases may not bring a satisfactory expansion of crude oil supply from some foreign sources. High prices and moderate exports, if the cartel holds, could be an attractive alternative.

Boosting Efficiency and Output

One way to reduce dependency on imports (or, for that matter, relieve pressure on domestic supply) is to use energy more efficiently. Some results might come quickly, such as more car pooling and maximum use of available mass transit facilities. Higher gasoline prices, rationing, or a combination of both can assure reduction in consumption. Price increases alone can be expected to slow down demand, although our scant knowledge of price elasticities of energy as a whole and of its components suggests more about the direction of change than about its likely magnitude. We know that consumers purchase energy in driblets. This diminishes the demand-reducing effect of price increases. More potent deterrents, such as progressive taxes on energy-consuming durables, especially automobiles, have been discussed but have not as yet been put into operation. Increased capabilities for mass transportation, buildings that minimize heating and cooling requirements and other modifications of major living arrangements tend to have long incubation periods. Nonetheless, marginal adjustments are taking place even now, such

as reductions in airplane cruising speeds, the buyers' shift to compact cars and increased use of buses and commuter lines. The effectiveness of admonitions to reduce driving speeds on highways, on the other hand, has quickly given way to mandatory reductions in official speed limits. However, gradual, socially motivated changes in behavior are not to be discounted. Setting the thermostat a few degrees higher in summer and lower in winter, or doing with less illumination in offices and at home could well be contagious responses to social pressure.

In designing policies and programs to increase the contribution of domestic sources, careful attention should be given to the relative costs for the economy as a whole. Attainment of a greater degree of self-sufficiency could be self-defeating if it imposed excessive burdens on the rest of the economy. Although the nation has lived with almost total import dependence for materials like nickel, manganese, chromium, and bauxite, and has carried on only modest research to probe potential domestic sources or new substitutes, one cannot realistically expect a similar attitude when the phenomenon shows up in basic energy materials.

In exploring avenues for expansion of domestic sources, it is well to distinguish between short- and long-run means, with the next decade considered as the short term. In the latter context, resumption of oil and gas leasing of offshore sources, under appropriate environmental safeguards and guided by the lessons of past accidents and their consequences, comes immediately to mind. So does the completion in one way or another of the effort that will bring Alaskan oil and gas to the West Coast or the Midwest (or both).

Often neglected in the search for new zones of production are advances in the art of finding and recovering oil and gas. In recent years, we have witnessed a decline in exploration and drilling and little progress in bringing a larger proportion of discovered oil to the surface. Much of the liveliness of research in the mid- and late-1950's, when new recovery methods were engineered and tried and hopes were high for bringing 50 percent and more of oil in place to the wellhead, seems to have gone.

Since U.S. coal reserves are measured in hundreds of years, even at rising annual rates of consumption, achievement of a "clean-burning" coal is of utmost importance. Technology has lagged in developing a process that would make such coal less costly than desulfurized oil or natural gas. Success is well within the focus of the short term as here defined, although not an instant remedy as is sometimes casually assumed.

Hand in hand with greater emphasis on technologies that promise short-term gains go incentives and policies designed to make the search for and use of such innovations attractive to producers. Whether there should be a more relaxed—and perhaps even positive—attitude toward price increases that reflect changing supply and demand relationships and must thus be distinguished from "inflationary" factors proper; whether, and what kinds of, special tax treatment, credit, allowances, and the like are indicated; whether there should be, as in the case of natural gas, less public regulation; whether and how federal funds are to be used to supplement private efforts —these are just a few of the questions that will be in the forefront of discussion.

In the Distance: True Innovation

Truly new energy sources or conversion methods to replace those approaches now narrowed or closed altogether by environmental problems are apparently not just around the corner. There is little dissent from the judgment that coal conversion to either gaseous or liquid form will not make much of a contribution before the early or mid-1980's. Moreover, should drastically higher prices elicit a correspondingly drastic supply response from oil and gas producers, the early need for producing liquefied or gasified coal would greatly diminish.

The technique of extracting oil from bituminous sands is now well advanced, though the largest operation, begun in 1967 in Canada, is yet to break even financially. No sand zones comparable to those of Alberta have been identified for early development in the United States. Expansion will come in Canada, if at all, and its benefit for the U.S. energy economy will at best be indirect.

Such indicators as rising crude oil prices, ongoing lease sales of rich shale oil land by the Department of Interior for construction of prototype shale oil plants, and various economic studies suggest that the start of a shale oil industry could be in the offing. Similar indications in the past, however, have come to nothing. Moreover, there are still unresolved environmental issues concerning the development of oil shale. A cautiously optimistic view appears warranted at present. In the long run, lack of processing water may limit the size of a Rocky Mountains shale oil industry.

Any impact on the nation's total energy supply by most remaining technologies is probably even further in the future, not excepting advanced nuclear reactors—specifically, the breeder. Given the time it has taken nonbreeding reactors to come into their own and that even "shelf-item" reactors now have a lead time of 8 years or more, as well as the fact that a breeder prototype is only now beginning to be engineered and put in place, a significant contribution within the next 15 to 20 years is excluded. The timetable for the emergence of commercially effective power derived from fusion is likely to take us into the next century. Nor is success a foregone conclusion. This does not, of course, say anything about either the timing, magnitude, or provenance of research and development funds. Uncertainty of eventual success and a long lead time are merely two factors to be considered in setting priorities; others are the likely impact of success and the capacity of the research community effectively to digest rising funds at each stage of work.

Both geothermal and solar energy are properly considered "new sources," since their present use is spotty; geothermal production now takes place under unusual circumstances, and solar energy is produced on a more or less experimental basis. Though these two approaches are technically feasible today, they are likely to be important supplemental sources only in the more distant future. Greater attention to the untapped potential of the earth's inner heat has already given life to a wholly new concept of exploiting it: the sinking of deep shafts, possibly blasting the holes with nuclear devices, and utilizing the heat of the rock masses to turn injected water into steam, to be raised and used in conventional generation. As a new technology, it is not likely to have an early payoff equaling that of shale, tar, or coal conversion, but, if commercially viable, it should come into play

during this century. In several respects it is more attractive than traditional geothermal energy.

For good reason, solar energy has drawn increasing attention. At least on a global basis, its use would essentially free us of the thermal discharge penalty. It would thus get around atmospheric and climate problems and obviate limitations of energy use as an ultimate "limit to growth." Present prospects, however, are far behind the expectations aroused by popular writers. Even the more feasible applications of solar energy for heating and cooling residential and other structures would require major changes in building design, practices, and associated institutions. If adopted, it would gain importance slowly with the accretion of new housing to the existing stock, and probably not without a determined governmental drive to assure a mass market. As for electric power from solar energy, the conversion efficiency of the various devices so far designed is still exceedingly low and economic feasibility is correspondingly remote. To sum up, expansion of domestic capability in the near future will depend principally on (i) establishing effective incentives for exploration and discovery of oil and gas resources as yet unidentified, and for more complete recovery of those known and developed; (ii) bringing into operation, with acceptable environmental safeguards, Alaskan and offshore resources, and whatever other occurrences might be revealed; and (iii) expanding the use of coal as coal within acceptable limits of environmental impact.

Beyond lies resort to oil shale; to tar sands, provided Canada is willing to export; to coal conversion; to the breeder reactor; and eventually to geothermal, solar, and fusion energy. Not all of these are technically proven technologies, nor will demonstrated feasibility necessarily lead to utilization. A strong and quick response of oil and gas producers could slow down the emergence of coal conversion and shale oil production. Successful shale oil extraction might push coal conversion into the background, or vice versa. Thus, which items will be picked from the offered menu is as yet uncertain.

Reconciling Conflicting Values

Because environmental concern and action are so highly visible, it is easy to exaggerate their constraining impact in the current energy situation. For example, a nuclear power plant's schedule delayed by careless manufacturing methods is much less dramatic than court action by an advocate group. Yet available data suggest that fewer delays are caused by advocate groups than by technological and engineering problems. Again, automobile emission control devices tend to be blamed for higher gasoline consumption and, therefore, for shortages, when body weight, air conditioning and other add-ons, speed, and congestion are greater reducers of efficiency.

This is not to say that legislation during the 1960's, the administrative machinery now in place at the federal, state, and local levels, and the intervention of the courts have not significantly slowed the execution of energy-producing facilities; in this sense, the energy scene is probably the segment of the economy most heavily affected by environmental policies and considerations. Safeguards, risk-reducers, delays, and stopgap solutions add to cost. How far to carry these trade offs is a matter of legitimate disagreement. Value judgments prevail, the more so as even the underlying data regarding damage attributable to environmental impacts are often in controversy. The effect of the resulting cost and price (or rate) increases on income distribution and on competitiveness of given industries or activities, in both domestic and foreign markets, is calculable up to a point, but what to do about them is a political decision. Questions abound. How safe is safe, and how costly is costly?

Frequently, the advice given in these matters is to act "prudently," or to "preserve the maximum number of options." How does society conform to the prescription? And how does it choose among options? The choice is hard enough when only technological alternatives are at issue: coal versus nuclear energy, supertankers versus pipelines, or power parks versus plant dispersal. But comparison must also be made between benefits that accrue because of abstention from action and the cost of shortfalls that might result —between this generation and the next, between this country and others.

In a much broader framework and over the long run, the two big questions are (i) how we can agree on the point up to which we wish to trade additional, or lower-cost, energy for environmental quality and (ii) in what proportion various groups in society will share the costs that inevitably flow from trade-off decisions, no matter where along the line they are made.

Low-cost energy has been an integral part of American economic history; but European experience suggests that not greatly lower levels of per capita income can be reached with much lower per capita energy consumption. One can contemplate with equanimity a prolonged period during which U.S. energy costs will be higher, utilization more efficient, and consumption patterns somewhat different, all without a profound sacrifice of welfare, although surely with temporarily painful adjustments and crisislike phenomena. Possibly such a period may be followed once again by one of low-cost and abundant energy, if and when the technologies of either nuclear fusion or solar energy have been solved. Environmentally attractive and basically unconstrained by "fuel availability," solar energy would eliminate even the problem of excessive discharges of heat to the atmosphere; fusion might ease it. What new technological and environmental problems we might encounter we do not yet know; but experience has taught us to expect them. The first priority is to manage the energy problems now crowding in, and likely to be with us for some years at least, in ways that will not impede long-term solutions and will give due recognition to the necessity of reconciling other aspirations of society with provision of abundant energy.

References and Notes

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