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WESTERN ENERGY AND GROWTH



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Western Resources: Key to the Nation's Energy Future

Yvonne Levy

The United States is dedicated to a policy of independence from foreign sources of energy. Originally, the Administration envisioned Project Independence as a "crash" program to achieve the national goal of complete energy self-sufficiency by the end of the decade. Later, in recognition of the intolerable strains such a program would place on the environment and on the productive capacity of the economy, the Administration relaxed that goal to allow for a more leisurely target deadline of 1985. At that point, the nation would not be completely self-sufficient, but its oil imports would be sufficiently small—3 to 5 million barrels a day—that it would be invulnerable to disruption from oil embargoes or worldwide price increases.¹ To help achieve this goal, President Ford last January called for the nation to reduce its oil imports

by 1 million b/d by the end of 1975 and by 2 million b/d by the end of 1977.

With that as background, this article will discuss the broad trends in demand and supply which have led to the nation's growing dependence on insecure and costly foreign sources of energy, the supply strategies and conditions required to move the nation toward the goal of energy independence, and the nonfinancial constraints likely to be encountered. The question of financial constraints on development—a major topic in itself—is not considered in this analysis. Our primary emphasis is on the prospects for increased energy development in the West, which because of the abundant and varied nature of its energy-resource base, is certain to play a major role in any national effort to increase domestic energy production.

The Energy Gap

The events of late 1973—the Arab embargo and the quadrupling of oil-import prices—focused attention on the dangers inherent in the nation's growing dependence on foreign sources of energy. But that situation had been developing for over two decades, because of a growing imbalance between domestic production and consumption of energy. U.S. energy consumption increased at an annual rate of about 3.5 percent between 1950 and 1965, and the rate accelerated to 4.5 percent over the 1965-73 period. (In 1974, however, consumption dropped by 2.2 percent to 73.1 quadrillion Brit-

ish Thermal units—BTU's—under the impact of rising energy prices, the economic slowdown and conservation efforts.)² Although energy use has grown even faster in other nations of the world, U.S. per capita consumption is still six times the world average (Chart 2).

Domestic energy production, on the other hand, has lagged far behind the growth of demand. Production grew at a 3-percent annual rate between 1950 and 1973, despite a steady decline in the present decade. In this recent period, crude-oil production dropped from a peak of 9.6 million b/d to 8.8 million b/d,

while natural-gas production dipped slightly to 21.9 trillion cubic feet. Coal production, at 606 million tons last year, remains below the level of thirty years ago. Other energy sources were of minor importance. Nuclear power, although growing rapidly, supplied less than 2 percent of the nation's total energy requirements last year, while hydropower maintained its steady 4-percent share. Altogether, the U.S. produced domestically last year only 60.7 quadrillion BTU's of its total consumption of 73.1 quadrillion BTU's (Chart 1).

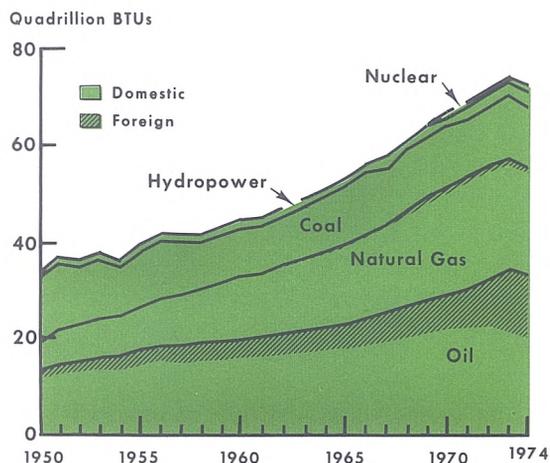
Role of foreign imports

To fill the growing gap, the United States has come to rely increasingly upon foreign imports—primarily crude oil and refined petroleum products. Over the past decade, oil imports rose from 2.3 million b/d to 6.1 million b/d. Foreign nations now supply 36 percent of the nation's total petroleum consumption and 16 percent of its total energy consumption (Chart 3).

Canada and Venezuela are still our principal suppliers, but the Middle East has recently become a key supplier, especially since domestic production has levelled off. Prior to the embargo, U.S. imports of Middle East crude and refined petroleum products amounted to about 20 percent of total oil imports and 6 percent of total petroleum consumption, and imports of products refined from Arab crude were even more important. Thus, the decline in imports during the embargo was equivalent to 14 percent of total U.S. petroleum consumption.

The impact on the economy would probably be much more serious in the event of another embargo. The U.S. could be importing as much as 23 percent of its total energy requirements by 1985 if steps are not taken to increase domestic supplies and to slow the growth of demand. Moreover, its dependence could be much greater on Middle Eastern nations, which hold 60 percent of the world's oil reserves. Aside from its national-security implications, this dependence could have serious economic consequences in the form of possible disruptions in supply, inflationary pressures and balance-of-payment difficulties.

Chart 1
U.S. Energy Consumption by Source



From coal to oil and natural gas

Another crucial change in energy patterns has been the shift away from coal and toward oil and natural gas in the past two decades.³ Coal still remains the dominant fuel for electric-power generation, an increasingly important energy user, but overall, coal now accounts for less than 20 percent of the nation's total energy requirements. Despite an upswing since 1959, coal production still has not regained the peak level reached in 1947. Coal's declining importance reflects its high sulphur content, as well as the convenience and comparative low cost of oil and gas.

Natural-gas consumption rose rapidly after World War II, as pipelines were built to transport gas from the producing regions of the Southwest to other areas of the nation. Between 1950 and 1970 natural-gas consumption rose almost four-fold—twice as fast as total energy consumption—but shortage of supplies then began to restrict consumption. Nonetheless, natural gas still accounts for 30 percent of total consumption.

Since 1954, the Federal Power Commission has regulated wellhead prices of natural gas sold in interstate commerce. Under this regulation, the FPC has held natural-gas prices at artificially low levels, stimulating consumption but at the same time discouraging producers from trying

to find new supplies. Since 1968 Americans have been consuming natural gas at about twice the rate of discovery. As a result, proven domestic reserves (including a major Alaska find) dropped from 293 trillion cubic feet in 1967 to 237 trillion cubic feet in 1974—equivalent to only 10 years' production at current rates.⁴ Serious shortages have developed, despite a doubling of imports over the 1967-74 period to almost 5 percent of total gas consumption.

The environmental movement meanwhile has helped to boost the demand for natural gas. Natural gas is the cleanest-burning fossil fuel in that it is free of sulphur and particulate matter—in contrast to “dirty” coal, the traditional fuel of power-generating plants. To meet the Federal environmental requirements, an increasing number of power plants have had to switch to natural gas and, during the past few years, due to the gas shortage, to low-sulphur fuel oil.⁵

In this situation, petroleum has proven to be pivotal in balancing the nation's energy needs. Oil consumption increased at a 5-percent annual rate during the 1960-70 period, and then accelerated to a 6-percent rate between 1970 and 1973. In that period it grew faster than total energy demand, so that oil's share of total consumption rose to 46 percent in 1973. (During the 1974 crisis, of course, oil consumption declined.) Petroleum supplies nearly all of the nation's transportation fuel, 45 percent of house-

hold and commercial usage, almost 25 percent of industrial energy, and about 13 percent of electric utilities' requirements.

Domestic petroleum production has trended downward in the face of booming demand. This decline reflects an almost uninterrupted decade-long reduction in crude-oil reserves—except for 1970, when the Alaska bonanza added 9.4 billion barrels to the nation's reserves. Proven reserves at the end of 1974 amounted to 38.8 billion barrels—the equivalent of 12 years' supply at the current production rate. Higher prices recently have stimulated increased drilling, but reserves still fell during 1974.

Resources versus reserves

The recent decline in oil and gas production can be attributed not to a scarcity of resources, but rather to inadequate economic incentives and environmental restrictions. Here a distinction must be made between resources and reserves. The nation's petroleum resource base may be thought of as the total amount of oil and gas occurring in the rocks lying within its boundaries, including the continental shelf. Resources comprise all those materials that are potentially recoverable, including those in deposits as yet undiscovered. Reserves, on the other hand, comprise that portion of the resource base that has been identified, explored and delineated with a reasonable degree of certainty, and from which a usable commodity can be extracted under existing economic and technological conditions. The occurrence of oil and gas is finite, being governed by geology, but the rate at which oil and gas resources are discovered, developed and transferred to the category of reserves is determined primarily by economics, technology, and environmental and political considerations. Proven reserves represent the underground assets (inventory) in which the petroleum industry has made specific investments.

Development activity in the U.S. industry, measured by the number of exploratory wells drilled, declined sharply after 1956 simply because the financial rewards from domestic development did not compare favorably with more attractive opportunities abroad, especially

Chart 2

U.S. Energy Consumption by Sector

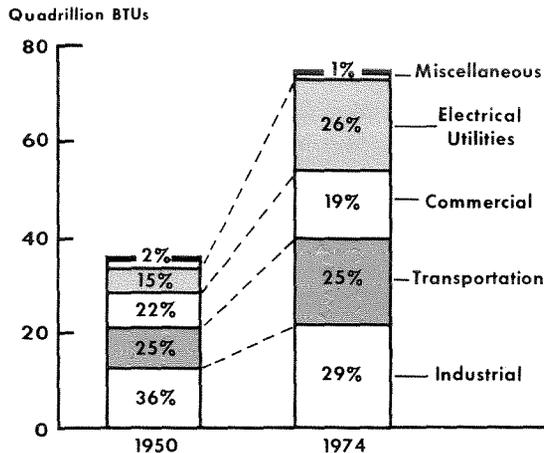
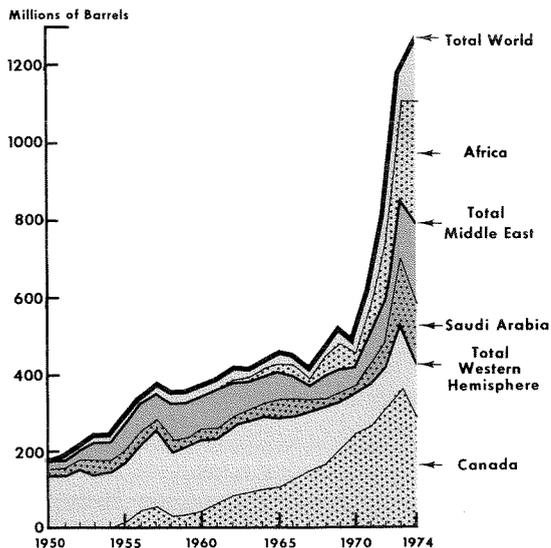


Chart 3
U.S. Crude Oil Imports



in the Persian Gulf area. In addition, domestic oil prices failed to rise as fast as costs or industrial prices in general. The price of crude almost doubled over the 1947-57 period but thereafter rose only moderately, from \$3.09 per barrel in 1957 to \$3.66 per barrel in 1973. In real terms,

oil prices declined by 18 percent. Natural-gas prices rose rapidly until the early 60's, largely because gas had been drastically underpriced when it first came into use as a by-product of oil, but the price declined 6 percent in real terms during the following decade. Environmental controls meanwhile helped to raise domestic costs, and also to curtail drilling and refinery construction.

In August 1973, Phase IV price controls were removed from "new oil"—defined as that oil in excess of a property's production rate in the corresponding month of 1972—and from a portion of "old" oil production. In January 1974, controls were lifted for petroleum liquids produced from "stripper" wells, i.e., from properties where average production per well did not exceed 10 b/d during the preceding calendar year. Prices on the remaining production ("old" oil) have remained limited to \$5.25 per barrel, while prices for "new" oil have ranged from \$12 to \$13 per barrel at wellhead, in line with the prices of foreign oils of comparable quality. If all controls are lifted in the wake of this summer's intense political maneuvering, the resultant price rise could result eventually in larger reserves and stimulate increased production.

Domestic Supply Prospects

The extent of dependence on oil imports will depend primarily on the world price of oil, which will in turn largely determine U.S. energy prices, and also upon Federal government policies to slow the growth of consumption and encourage production. In its *Project Independence Report*, the Federal Energy Administration (FEA) therefore examined consumption and production possibilities at two different price levels—\$7 and \$11 per barrel—and under two sets of assumptions: 1) Business-As-Usual, assuming a continuation of policies in effect prior to 1973 (except for those controlling prices) and 2) Accelerated Development, assuming changes in policies to further stimulate production, such as accelerated leasing of offshore lands on the Outer Continental Shelf, the opening up of Naval Petroleum Reserves for produc-

tion, and increased Federal funding for energy research and development.⁶

The FEA concluded that the long lead time involved in bringing new production on stream will forestall any increase in U.S. crude-oil production over the next few years, regardless of what the Federal government does to encourage production. Imports will thus rise in the absence of conservation strategies or direct limitation on imports. But by 1985, assuming Business-As-Usual conditions, U.S. production at a \$7 price would rise about 5 percent above current levels to 8.9 million b/d. "Lower 48" production would fall almost by half, but this would be offset by increased production from Alaska and the Outer Continental Shelf. At an \$11 price, however, domestic production would increase nearly 50 percent to 12.8 million b/d,

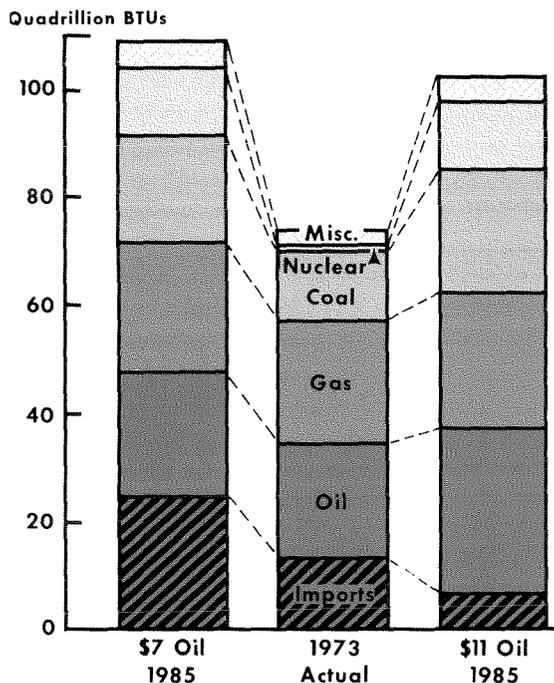
mostly because of the more widespread use of secondary- and tertiary-recovery techniques (Chart 4).

The FEA claims that, under Business-As-Usual assumptions, domestic natural-gas production by 1985 would rise 10 percent above the current level of 22.4 trillion cubic feet if the price is deregulated, but would fall by some 30 percent if the ceiling is retained. A base price of at least 80 cents per thousand cubic feet for newly discovered gas is considered necessary to elicit this 10-percent increase in output. The Federal Power Commission already has moved toward this price level by raising the ceiling price of "new" gas (gas from wells producing since January 1, 1973) in two steps to 50 cents last December. If all new gas were permitted to go to the 80-cent level, it would result in more than a doubling of the average wellhead price for "new" and "old" gas combined, or an increase of at least \$5 billion in the annual cost to consumers. Complete deregulation, which would imply prices well above 80 cents, would probably bring forth little additional output, owing to the physical limits on potentially exploitable resources and the inapplicability of secondary and tertiary recovery techniques to gas production.

Under these circumstances, coal production might double by 1985 to about 1.1 billion tons, replacing both gas and oil in many industrial and electric-utility uses. Nuclear power meanwhile could increase its share of electric power generation from 7 percent to 30 percent. Other fuels and energy sources, such as geothermal and solar power, are likely to be of only marginal importance by 1985, even under the higher (\$11) oil-price assumption.

The FEA study concludes that oil imports over the long-run will be inversely related to the level of oil prices—the higher the price, the lower the vulnerability. At an \$11-per-barrel price, imports could be reduced from a current level of around 6 million b/d to 3.3 million b/d by 1985. This decline would result from a reduced demand for energy and increased production from sources that are economically feasible

Chart 4
Sources of U.S. Energy Supply
(Business-As-Usual Assumptions)



at higher prices. However, maintenance of an \$11 price would require extremely large production cutbacks by OPEC nations. Thus, the world price might be pushed down to about \$7 per barrel—a price which could lead to imports of over 12 million b/d by 1985.

Consequently, for the nation to reduce its imports to a target level of 3-to-5 million b/d by 1985, it would have to adopt a policy of accelerated development. This would include increased offshore leasing off the Atlantic and Pacific coasts, development of Naval Petroleum Reserves, and increased Federal support for nuclear-plant construction, shale oil and synthetic-fuel production. Under this strategy, domestic oil production could rise almost to 13 million b/d at a \$7 price and to 17 million b/d at an \$11 price.

Technological and resource barriers

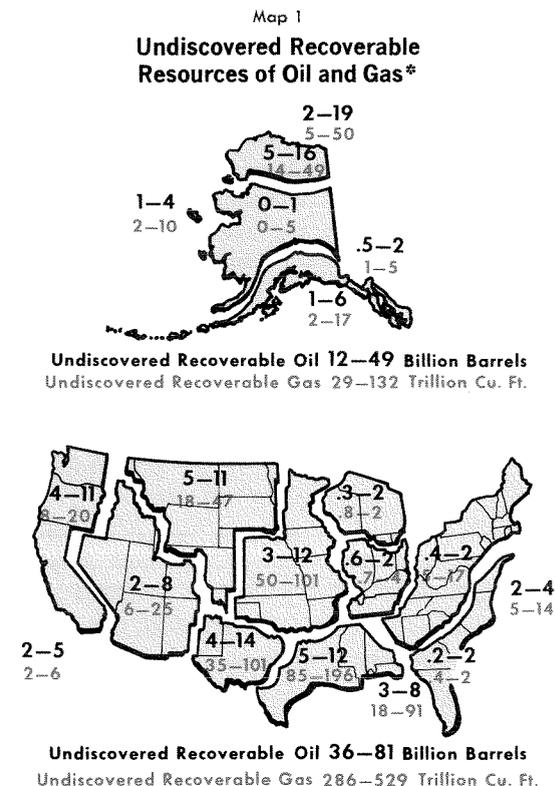
The ability to attain these levels of production will depend not only upon price but upon a wide range of other considerations as well. Indeed, recent estimates of the nation's resource base by

the U.S. Geological Survey⁷ indicate that undiscovered recoverable resources of oil and gas may be much smaller than the USGS had earlier suggested in its contribution to the *Project Independence Report*. (The adoption of more conservative estimating techniques accounts for the downward revision.) According to current estimates, undiscovered recoverable resources of oil and natural-gas liquids range between 61 billion and 149 billion barrels, and undiscovered recoverable natural-gas supplies range between 322 trillion and 655 trillion cubic feet. In both cases, the latest estimates are far below even the minimum levels estimated just a year ago. However, another 30 billion barrels of oil and 180 trillion cubic feet of gas may be recoverable from unexplored parts of known fields through the use of advanced - recovery technologies (Map 1).

Aside from the question of how much is actually recoverable, the production and processing of energy materials could be constrained by inadequate manpower, materials, water and high-technology equipment — not to mention financial resources. For example, water is essential to almost every energy process. It is required to extract raw materials from the earth, process the materials into useful fuels, generate electricity from those fuels, and dispose of waste products in an environmentally acceptable manner. Yet in the rural regions of the West, where a substantial portion of the nation's total energy resources are located, there is not only a relative scarcity of water but also a prior call on roughly 90 percent of the available supply for agricul-

Alaskan Oil and Gas

Alaska is certain to play the largest role in the current effort to increase domestic oil and gas production. Actually, the state has been an important factor in the industry for some years; in 1974 it produced 193,000 b/d of oil and 383,000 million cf/d of natural gas, with most of the output coming from the Kenai Peninsula/Cook Inlet area in the southern part of the state. By mid-1977, however, the Prudhoe Bay field on the North Slope should be producing 1.2 mil-



*Estimated range at 95-5 percent probability levels. For example, in the case of the Pacific Coast region, the chance of having undiscovered recoverable resources of crude oil of at least 4 billion barrels is 95 out of 100; however, the chance of having 11 or more billion barrels is only 5 out of 100.

tural purposes. Meanwhile, recent shortages have dramatized the potential problems that could be faced in obtaining the drilling rigs, platforms, pipe and tubing, steam-turbine generators and other equipment required to meet targeted production levels.

lion b/d—and with full development of that and neighboring fields, the pipeline should be operating at its full capacity of 2.0 million b/d by the year 1980.

The pipeline project includes the 789-mile pipeline from Prudhoe Bay on the Arctic to Valdez on the Gulf of Alaska, and in addition, a road from the Yukon River to Prudhoe Bay, seven air fields, twelve pump stations, an ocean terminal and a number of offices and related

service buildings. At this summer's peak, about 20,000 people were employed on the project. The overall cost, not including the cost of financing, is expected to top \$6 billion—more than eight times the original estimate.

Tapping Prudhoe's resources

The Federal Power Commission is currently studying two pipeline proposals to transport North Slope gas to the lower 48 states. One company proposes a \$6.7-billion project to deliver the gas to the U.S. West Coast via a combination pipeline and tanker system. An 809-mile underground pipeline would be built from Prudhoe Bay to Gravina Point, Alaska, where the gas would be liquefied for shipment by tanker to Point Conception, California. Alaskan gas would permit some West Texas supplies that are ordinarily piped to California to be shipped instead to Eastern and Midwestern markets. A second company proposes an \$8.0-billion project that would deliver gas through a 2,600-mile pipeline from Alaska and Canadian Arctic areas down the Mackenzie River Valley of Canada to Idaho and Montana. Related lines would then carry the gas to California, the Midwest, the East Coast and Eastern Canada.

Midwestern Congressmen vigorously support the Mackenzie Valley project on the grounds that it would bring more gas to their energy-deficient region. Supporters of the trans-Alaska route argue, on the other hand, that the trans-Canada route would leave the U.S. vulnerable to a potential cutoff of gas supplied by Canada. They argue further that the trans-Canadian pipeline would adversely affect the U.S. balance of payments, by causing billions of U.S. dollars to be spent in Canada to hire Canadian workers and pay Canadian taxes. The trans-Canada route appears to have the most support at the present time; however, if Petroleum Reserve No. 4 and additional reserves are developed, both transmission systems eventually may be required to handle the increased supply.

Alaska presently has proven oil reserves of 10.1 billion barrels and gas reserves of 31.1 trillion cubic feet, or about 33 and 13 percent, respectively, of the nation's total reserves. Most

of this fuel is contained in the Prudhoe Bay field, by far the largest hydrocarbon deposit in the Western hemisphere. But the state may also contain undiscovered oil resources of 12 to 49 billion barrels—roughly one-quarter of the U.S. total—and undiscovered natural gas resources of 29 to 132 trillion cubic feet—roughly one-tenth to one-quarter of the U.S. total.

On the basis of its earlier (and higher) estimates, the FEA's *Project Independence Report* suggested that Alaskan oil production could reach as much as 4.6 million b/d by 1985 at a \$7 price, and as much as 5.3 million b/d at an \$11 price. To develop that level of resources, massive new investment would be required—another 48-inch oil pipeline, both the trans-Alaska and Mackenzie Valley gas pipelines, processing facilities for both the North Slope and Outer Continental Shelf, and transportation and other facilities to support these basic systems. The required investments would be substantial even if the conservative USGS estimates of resources turn out to be correct.

Other onshore resources

Exploration and drilling activity already has accelerated on the North Slope, upper Cook Inlet basin and the little-explored Susitna basin. But if Alaska's onshore resources are to be fully exploited, a larger proportion of Federal and state lands will have to be opened for development. Only about 5 percent of the 231,887 square miles of onshore land with resource potential has been offered for lease to date. Alaska's Department of Natural Resources last November announced a schedule of oil-and-gas lease sales for the 1975-78 period. But there are some complicating factors; the Federal government recently contested state-ownership rights to the Lower Cook Inlet,⁸ and other offshore areas near the coastline could also be embroiled in jurisdictional disputes.

The Alaska state government is anxious to hold more lease sales to ease its financial problems. With the state budget running at \$500 million or more each year, and state revenues at only about \$300 million, the government is fearful it will run out of funds before North Slope

oil royalty money begins to flow into the state treasury in late 1977 or 1978. The \$900 million which the state collected in bonus money for the 1969 lease of North Slope oil fields is now two-thirds spent.

As for Federal land, Congress is still debating whether Naval Petroleum Reserve No. 4 (North Slope) should be opened to oil drilling by private companies. The Navy is currently drilling several test wells and has retained a contractor to do some exploratory work, but some experts argue that the best way to develop the reserve would be to lease tracts within the reserve to private industry. It could take at least ten years to explore, develop and construct delivery systems from NPR-4, and the cost could be well over the \$15 to \$20 billion required for Prudhoe Bay. However, the 3,500-square-mile reserve is geologically similar to Prudhoe Bay, and similar economic benefits could flow from its development in coming decades.

Meanwhile, Congress recently passed legislation authorizing large-scale civilian oil production from the Elk Hills Naval Petroleum Reserve near Taft, California, for the creation of a national strategic stockpile. Only jurisdictional problems remain to be resolved before exploitation of this field is begun.

Offshore resources

Offshore drilling for oil and gas in the Federally owned Outer Continental Shelf offers the greatest potential for significantly increasing U.S. oil and gas production by 1985. But exploitation of these areas, including not only the already lucrative Gulf of Mexico but also the untapped waters off the Gulf of Alaska and the Atlantic Coast, will be circumscribed by environmental and other difficulties. Development of the Outer Continental Shelf was made possible by 1953 legislation authorizing the Federal Government to lease tracts lying more than three miles off the coast. Production in 1974,

although below the 1971 peak, comprised 11 and 14 percent respectively of the nation's total output of oil and gas. This was in addition to the production from state-owned land within the three-mile limit.

Nonetheless, only about 10 million of the 80 million acres in the Outer Continental Shelf have been offered for lease since 1953. To help meet its Project Independence goals, the Administration in late 1974 announced an accelerated schedule of lease sales for the 1975-78 period. Sales in 1975 alone may not reach the total 10 million acres scheduled, but will be considerably higher than in prior years and will include frontier areas in the Gulf of Alaska and possibly the Atlantic. According to USGS estimates, the Gulf of Alaska may contain 1 to 6 billion barrels of oil and 2 to 17 trillion cubic feet of natural gas, and other promising areas include the Beaufort, Bering and Chukchi Seas and the Outer Bristol Basin.

The planned leasing of new offshore areas has generated heavy criticism from environmentalists. Indeed, the President's Council on Environmental Quality this spring warned of grave problems from drilling, especially in the Gulf of Alaska. The Council foresaw a high probability of oil spills and wrecked drilling operations because of severe storms, earthquakes and tidal waves, in an area where conditions are "more severe than the industry has yet experienced anywhere in the world." Many conservationists also forecast heavy damage to animal life, since the Gulf is rich in fish, birds and marine animals. Despite these objections, a sale of Gulf of Alaska leases may occur in December of this year. Action is even more likely here than off the Atlantic Coast, where intense concern about drilling has risen because of the highly populated nature of the region, and where the states and the Federal government are locked in a jurisdictional struggle over title to the continental shelf.

California Oil and Gas

In California, hopes for reversing a four-year decline in oil and gas production also rest upon the development of the Outer Continental Shelf.

Onshore, the most prolific oil-producing province in the state—and in relation to size, probably in the world—is the relatively small, semi-

arid Los Angeles basin. But since this is a densely populated area with very high land values, the area available for oil development is greatly restricted.

The productivity of existing wells may be increased, however, through the use of advanced-recovery techniques that boost the amount that can be produced from each reservoir above what could be obtained by the use of natural forces alone. California firms have had some success with a technique known as water flooding, and spurred on by the high price of oil, they are now utilizing a tertiary-recovery process called steam flooding. With the help of these and even more advanced techniques, U.S. (and California) reserves might possibly double in size.

California's offshore areas have long been an important source of energy for the nation and of revenues for the state. The first offshore wells in the world were drilled in 1896 as an extension to Santa Barbara's Summerland oil field. By 1974, there were 23 oil or gas fields off California's coast, and their production accounted for 27 percent of California's total output.

Drilling for new oil and gas wells on state-owned tidelands virtually ceased after the 1969 blow-out in the (Federal) Don Cuadros field in the Santa Barbara Channel. That action caused the State Lands Commission to place a moratorium on drilling in state tidelands, and the ban remained in place for almost five years. Even now, approval for drilling is granted only

on a lease-for-lease basis.

The U.S. Department of the Interior plans a lease auction this October of about 1.6 million acres on California's Outer Continental Shelf. This area, extending from three to sixty miles off the Southern California coast, is believed to contain as much as 5 billion barrels of crude oil and more than 6 trillion cubic feet of natural gas in formations extending as much as 5,000 feet beneath the sea. Oil industry officials claim that these riches can safely be tapped, since advanced offshore technology could minimize the danger of oil spills and other disasters. But environmentalists argue that the drilling will entail increased risk because of the depth of the formations, and will also lead to other environmentally harmful consequences, such as the construction of extensive transportation, refining and distribution facilities. The Department of Transportation apparently agrees that there are environmental dangers, as it recently announced that probably only half of the 1.6 million acres scheduled for leasing in October would actually be offered. State officials are critical of the present system of leases and royalties, which would return to the Federal government only about 15 percent of the oil's present value—about \$21.6 billion over the 50 to 60 year life of the California fields. In their view, the Federal government should retain title to the oil and permit the companies to extract it for a fee, instead of selling leases and receiving production royalties.

Western Coal

The U.S. is the Persian Gulf of coal with more than one-fifth of the world's reserves locked up in its crust, and coal accordingly is counted on to play a major role in reducing the nation's dependence on uncertain Middle Eastern sources of oil. According to FEA estimates, coal production could reach 1.1 billion tons per year by 1985—almost double the present level—even without any help from higher coal prices. Nearly all of the industry's production will be consumed in the generation of electricity and in steel making. The West is expected to supply most of the increase because Western

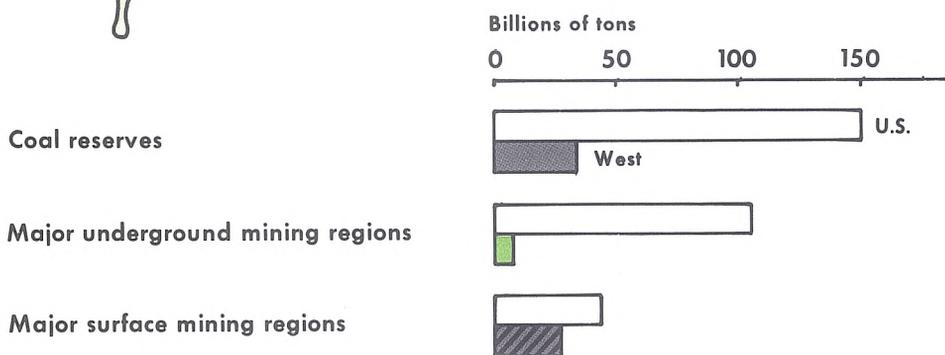
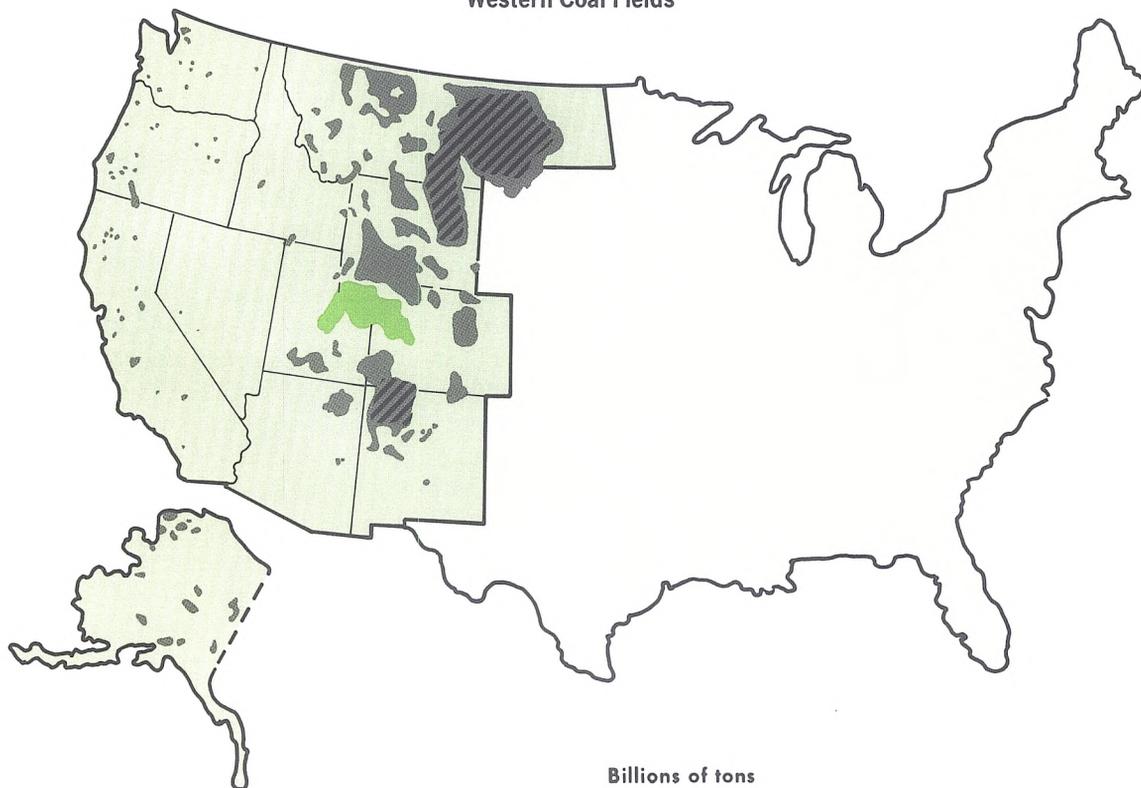
coal is a clean low-sulphur product which is capable of being mined by low-cost surface-mining techniques (Map 2).

The nation's total coal resources have been conservatively estimated at about 3.2 trillion tons, about half of which has been mapped.⁹ These resources, measured in terms of heat content, amount to about three-quarters of the nation's ultimately recoverable fossil fuels. Only about 150 billion tons are recoverable under current technological and economic conditions—but even this amount would provide over two centuries' supply at current consumption rates.

The Western states contain one-fifth of these enormous recoverable reserves of coal. Utah has almost 7 billion tons of reserves, mineable through underground techniques, while the states of Montana, Wyoming, New Mexico and North Dakota contain about 26 billion tons of strippable reserves. These Western reserves comprise four-fifths of the nation's low-sulphur deposits and more than one-half of the total reserves mineable through surface methods. Until

recent years, the West's subbituminous deposits occasioned little interest, because they have a lower BTU content than Eastern coal and are expensively far from Eastern markets. But utilities, faced with new clear-air legislation, are now buying substantial amounts of this coal because of its very low sulphur content. Western coal production thus has grown phenomenally in the last few years, although the region still accounts for only 10 percent of total U.S. production.

Map 2
Western Coal Fields



Problems of surface mining

Surface mining—the dominant mode of production in the West—has a number of advantages over underground mining. Productivity in underground mines dropped 29 percent between 1969 and 1973, under the impact of labor troubles and (particularly) new safety legislation, and output and costs were affected commensurately. In this situation, the industry has turned increasingly to surface mining, which now accounts for one-half of the nation's total output, compared with less than one-third in 1960. Strip mining requires less manpower and capital than underground mining, and is also safer and more productive—but it can also be environmentally disastrous.

Strip mining involves removing the earth cover, or "overburden" from a seam of coal lying relatively near the surface, then scooping up the fuel and carrying it away. In the process, streams can be diverted or fouled with poisonous minerals, drainage patterns upset and huge mountains of rubble created. In the arid West, where strip mining is in its infancy, surface vegetation may not grow back for years or even decades. In the meantime the land is vulnerable to constant erosion by wind and water, and becomes unsightly and worthless for agriculture or recreational purposes.

Congress recently sustained a Presidential veto on a bill that would have established stringent Federal controls on strip mining, far more restrictive than state standards presently in effect. In a sense, the legislators were expressing a preference for energy independence over the goal of environmental protection. The legislation would have required all companies engaged in strip mining to protect water sources from pollution and to return strip-mined lands to whatever condition they were in prior to mining. To pay for land reclamation, a tax would have been imposed on each ton of coal mined.

The bill's supporters argued that coal-company profits would be more than sufficient to cover reclamation costs, in view of the sharp upsurge in coal prices generated by the oil crisis. Their arguments failed, however, in the face of

industry claims that reclamation requirements would not only reduce output severely but would also raise costs as much as \$5 to \$6 a ton, giving consumers much higher electricity bills. Another major consideration in the veto was the argument that urgently needed coal development could be stymied by certain provisions of the bill, permitting ordinary citizens as well as surface owners to file suit against mining firms.

Despite this defeat, environmentalists are continuing to press for restrictions on strip mining. In Wyoming, environmental groups have won a temporary injunction against further strip mining in the Powder River Basin. The state of Montana has joined a farmers' and ranchers' lawsuit against the U.S. Bureau of Reclamation for giving away valuable water rights to coal developers.

Problems of water availability

Indeed, problems of water availability—particularly in the Missouri and Upper Colorado River Basins—are likely to pose even more of a stumbling block to coal development than environmental pressures.¹⁰ Water requirements are especially heavy for the reclamation of land, the transportation of coal through slurry lines, the conversion of coal to synthetic gas, and the cooling of thermal-electric plants. Even now, water demands for revegetation pose serious problems, particularly in the Four Corners area of Arizona, New Mexico, Utah and Colorado.

Most of the coal produced at Western mines moves by train, or train-barge-train combinations to major consumers. However, these systems may not be able to handle the greatly increased coal flows expected in the future. Industry planners thus are proposing slurry pipelines, a low-cost subsurface system for transporting pulverized coal with water to power-plant sites. Slurry pipelines have been used for many years in the East, and a 273-mile line also extends from the Black Mesa coal mine in northeastern Arizona to the Mohave power plant in southern Nevada.¹¹ One proposed 1,000-mile pipeline would carry 25 million tons of coal a year from a site near Gillette, Wyoming to White Bluffs,

Arkansas. At \$750 million, this line would be both the longest and the most expensive slurry line ever constructed. But environmentalists claim that the project would require 15,000 acre-feet of water a year—enough to supply a city of 10,000 people. Indeed, it would deplete much of the large underground reservoir that lies beneath the near-barren plains of Montana, Wyoming and the Dakotas.

Water availability could also prove to be a stumbling block in the construction of the coal-gasification and coal-liquefaction plants which are expected to help expand the nation's energy supply in the 1980's.¹² The first plant to be constructed in the U.S. using the new Lurgi gasification process—a plant located near Farmington, New Mexico—already is running behind schedule because of a conflict over water. This plant would require more than 10,000 acre-feet per year for providing the necessary hydrogen for the gasification process. But the Navajo Indians

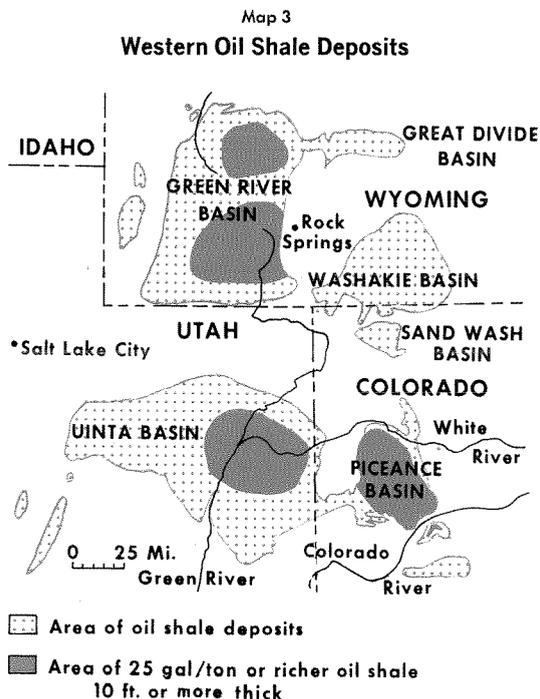
in this area claim that the water requirements of this plant would place an extra burden on Colorado River supplies which have already been overallocated by the state of New Mexico. Coal liquefaction, which is at an earlier stage of development; promises to be an even heavier user of water than coal gasification. A typical plant producing 100,000 b/d of oil could require 20,000 acre-feet of water a year.

Many Rocky Mountain officials and private citizens are also adverse to large-scale coal development because it could change the essentially rural character of their communities. Unbridled growth could occur as thousands of new residents stream into the area to enter the surface-mining and gasification industries, and the result could be the usual urban problems of pollution, congestion and higher taxes. Achieving the right balance between economic growth and environmental quality will require careful planning in regard to land use and water use.

Western Shale Oil

The large oil-bearing shale deposits in the Green River Formation of Colorado, Wyoming and Utah could produce as much as one million b/d of oil by 1985 if oil prices remain close to \$11 per barrel and if water and environmental constraints can be overcome. On the other hand, if the world oil price drops to \$7 per barrel and if water remains a problem, production could be limited to 250,000 b/d (Map 3).¹³

Oil shale is a laminated marlstone rock which contains a solid tarlike organic material called kerogen, formed from the remains of animals and plants which settled as deposits on the floors of freshwater lakes millions of years ago. The Green River deposits may contain some 1,800 billion barrels of oil—more than four times the amount of crude oil discovered to date in the United States. However, only about 130 billion barrels—6 percent of the total—are worthwhile exploiting at the \$7 to \$11 price of oil. These are the deposits which are found in seams 30 or more feet thick and which contain more than



30 gallons of oil per ton of rock.¹⁴ Pilot-plant studies have shown the feasibility of recovering shale oil (kerogen) from the mined rock and converting it to a synthetic crude low in nitrogen. With the technology established, a full-scale production plant is scheduled to be in operation in the late 1970's.

However, the availability of water could be a severely limiting factor to oil-shale development. Water is needed to cool the hot kerogen vapors from the retort or kiln, and even more to dispose of the dry spent shale after it has been crushed and roasted, especially when compacting and stabilizing the disposal pile. By some estimates, shale mining and processing would require almost three barrels of water for each barrel of oil produced. (For two shale tracts in Utah and two in Colorado already leased by the Federal government, 111,000 acre-feet of water may be required annually for shale production.) Upper Colorado River water supplies may be able to support production of one million b/d at the maximum, but a larger industry would require transfer of water rights from agriculture and other users.

Disposal problems

Disposal of spent shale poses an immense problem. Producing one million b/d of synthetic crude oil, while not large in terms of the nation's overall energy needs, would require the mining of over 500 million tons of rock per year. This amount is almost equal to the entire 1974 production of the U.S. coal-mining industry. The

disposal problem is complicated by the fact that heated shale expands to as much as half again its original volume. The spent shale and its highly alkaline runoff require special disposal arrangements that boost costs substantially. In addition, special air-pollution control equipment is needed to control the emissions created in the production of synthetic crude from kerogen.

The same criticisms that apply to the surface mining of coal are equally applicable to the mining of oil shale. Also, underground mining would be more feasible than surface mining in Colorado's Piceance Basin, where a substantial rock cover overlays the shale. But this method would present the usual disposal problem and would also result in the loss of 50 to 60 percent of the resource because of the shale pillars left inside the mine for roof support.

Because of the limitations of surface processing, considerable research is underway to develop methods for extracting the kerogen in situ, that is, underground. Cavities would be mined inside the shale layers by traditional mining techniques; the shale would be crushed by explosives and heated to product oil, which would then be pumped above ground. In-situ extraction would require much less water than surface extraction, would create fewer environmental problems, and would cost less than other methods because of the reduced need for mining and above-ground equipment. Following a 1973 pilot test, experimentation is continuing on this promising approach.

Uranium

Up until recently, Federal government sources had estimated that U.S. nuclear-generating capacity would grow from 7 to 30 percent of the nation's total electrical-generating capacity by 1985. In view of the industry's many difficulties, this estimate appears to be high but still attainable. The industry's strong prospects are based upon its ability to replace oil and gas in electrical generation, freeing those scarce fuels for other uses to which they are uniquely suited, i.e., as petrochemical feedstocks and

household and transportation fuels. Growth of any significance for nuclear power would require an enormous increase in uranium mine and milling capacity, as well as an accelerated program of exploration to add to present reserves in New Mexico, Wyoming, Colorado and Utah.

Nuclear growth

After thirty years of checkered history, nuclear powerplants are finally becoming a major factor in the nation's power picture. By the end

of this year, about 60 thermal (fission) reactors will be in operation with an electrical generating capacity of 43,000 megawatts—and a decade from now, the number may grow to 213 reactors with a rated capacity of 208,000 megawatts.¹⁵ These 213 plants will need more than 30,000 tons of uranium oxide (U_3O_8) annually—more than double the present capacity of the U.S. uranium mining industry. In addition, each new plant will require about 500 tons of U_3O_8 for its initial fuel load.¹⁶

The industry's planned growth actually has been scaled down considerably in recent years. In the last half of 1974 alone, construction was deferred on 94 plants and 14 plants were cancelled completely. These cutbacks were caused in part by the utilities' present financial difficulties and their anticipation of a slowdown in the growth of future electrical demand.

The slowdown in nuclear growth may also reflect the lengthy delays encountered in licensing and construction of nuclear plants, which may take as much as eight years' time. Each construction application must include a safety-analysis report and an environmental-impact statement, and these reports must be reviewed by authorities such as the Energy Research and Development Administration and publicized at open hearings. Moreover, construction is often delayed by necessary design changes and adherence to strict quality control.

Resources and enrichment capacity

According to ERDA estimates, proven reserves of uranium oxide range between 200,000 tons at a cost of \$8 per pound to 420,000 tons at \$15 per pound—and at the latter price, another 1.5 billion tons of undiscovered resources may also become available.¹⁷ The vast bulk of the reserves are found in New Mexico and Wyoming.

On the basis of presently scheduled growth in nuclear generating capacity, the nation may need a cumulative total of 325,000 tons of uranium oxide by 1985.¹⁸ Prices have recently risen sharply above the prior level of \$6.50 per pound, an increase which should help to gen-

erate the supply necessary to meet that demand.

Another essential factor in nuclear - power growth will be the development of adequate enrichment capacity, capable of separating the fissionable U^{235} isotope from nonfissionable material to provide a more potent mixture of the element. Present enrichment services, which supply all of the foreign and domestic commercial demand, are provided by the Government-owned, privately operated plants at Oak Ridge, Tennessee; Portsmouth, Ohio and Paducah, Kentucky. The capacity of these plants is now being expanded by 60 percent to meet the needs of the generating plants already in operation or in the planning stage, but 8 to 10 additional enrichment plants may be required to meet nuclear generating needs by the turn of the century. In this situation, the Administration has recently proposed legislation to support the creation of a private-sector uranium enrichment industry.

Environmental and other problems

The exploitation of uranium resources creates the same type of problems associated with other Rocky Mountain energy resources, plus some unique problems of its own. Mine production is split about evenly between underground and open-pit mines. The latter involves the removal of vegetative cover and the creation of overburden and waste rock, which reduces the suitability of the area for wildlife, grazing and outdoor recreation. Underground mining meanwhile involves substantial accumulation of waste rock in dump areas. In addition, milling produces considerable amounts of low-level radioactive tailing, which are unsuitable for use as fill material where human exposure might result.

Nuclear - power plants, unlike fossil - fuel plants, do not produce particulates and sulphur oxides, and hence do not generate severe air-pollution problems. However, they do generate waste heat and radioactive emissions and wastes, and thus must be strictly controlled to protect against disastrous health consequences. Because of these dangers and the potential for nuclear accidents and theft, the Federal government has tightened standards guiding the con-

struction and operation of nuclear plants, but many doubts still persist about the adequacy of these safeguards.

The proposed breeder reactor would create less thermal pollution and would be a more efficient user of uranium than the conventional light-water nuclear power plant. Its greater efficiency is based on its projected ability to utilize more than 50 percent of the uranium input in the production process, in contrast to the 0.3 percent utilized in the present light-water

reactor technology. But it would also produce more plutonium—a poisonous and explosive material—and thus would present even greater safety hazards than the present type of reactor. The Federal government has been financing the operation of a 450-megawatt demonstration reactor in Tennessee, but spending on this project has recently been curtailed because of cost and safety factors, eliminating the possibility of bringing the breeder into commercial operation within the next decade.

Hydro, Geothermal and Solar Energy

Hydro, geothermal and solar resources may contribute very little to the nation's energy requirements by 1985, although geothermal and solar could become important energy sources by the year 2000, now that the Federal government is directing a large-scale research-and-development effort towards their development. Hydroelectric power production has almost doubled since 1950. But despite the huge dams built on the Columbia and the Colorado, and despite the utilization of the Niagara River and the far-flung Tennessee Valley system, hydro now supplies less than 4 percent of the nation's total energy requirements.

Moreover, hydropower's market share could slip still further by 1985. Only about one-third of the nation's hydroelectric potential has been harnessed, but most of the good sites for dam construction have already been developed. As a result, most of the growth in capacity will come from the expansion of existing installations, for the purpose of supplementing the output of large fossil-fueled and nuclear-steam-electric generating units. The Pacific Northwest, for example, is beginning to shift from almost complete reliance on hydroelectric generation to a mixed system of both hydroelectric and thermal-electric generation. Under present plans, more than 10,000 megawatts of new capacity will come on line in the Pacific Northwest between 1978 and 1985. But only about 3,700 mw of that total will be hydroelectric generating capacity; the rest will be made up of

3,700 mw of nuclear capacity and 1,700 mw of coal-fired power.¹⁹

Geothermal potential

The West has vast potential geothermal resources, consisting of a whole spectrum of heat sources stored within the earth. The West contains about 1.83 million acres of land with known geothermal resources, and another 99 million acres with "prospective value" for geothermal steam.²⁰

Yet, despite this vast potential, there is only one commercial geothermal powerplant in the nation, at The Geysers, California. Completed in 1960, the plant has an annual generating capacity of 502,000 kilowatts, with capacity scheduled to reach 900,000 kilowatts by 1978 and an ultimate level of 2 million kilowatts by around 1990. The fields at The Geysers are dry steam, the easiest type of geothermal energy to develop—but unfortunately also the rarest.

Other more abundant and widely distributed forms, such as hot brines and dry rocks, present difficult problems. Power generation from hot brines creates serious pollution and environmental problems, and in addition requires a great technological effort. For example, the briny water (and steam) produced by exploratory wells in California's Imperial Valley is highly corrosive, containing as much as 25-percent dissolved minerals compared to 3-percent in seawater. Continuous removal of water from reservoirs also can lead to subsidence, as has

occurred at some Mexican sites. Also, the technology for extracting heat from dry rocks is even less advanced than for other sources. Finally, the large-scale use of geothermal energy would require increased leasing of Federal lands, which make up more than one-half of the West's total geothermal resource acreage.

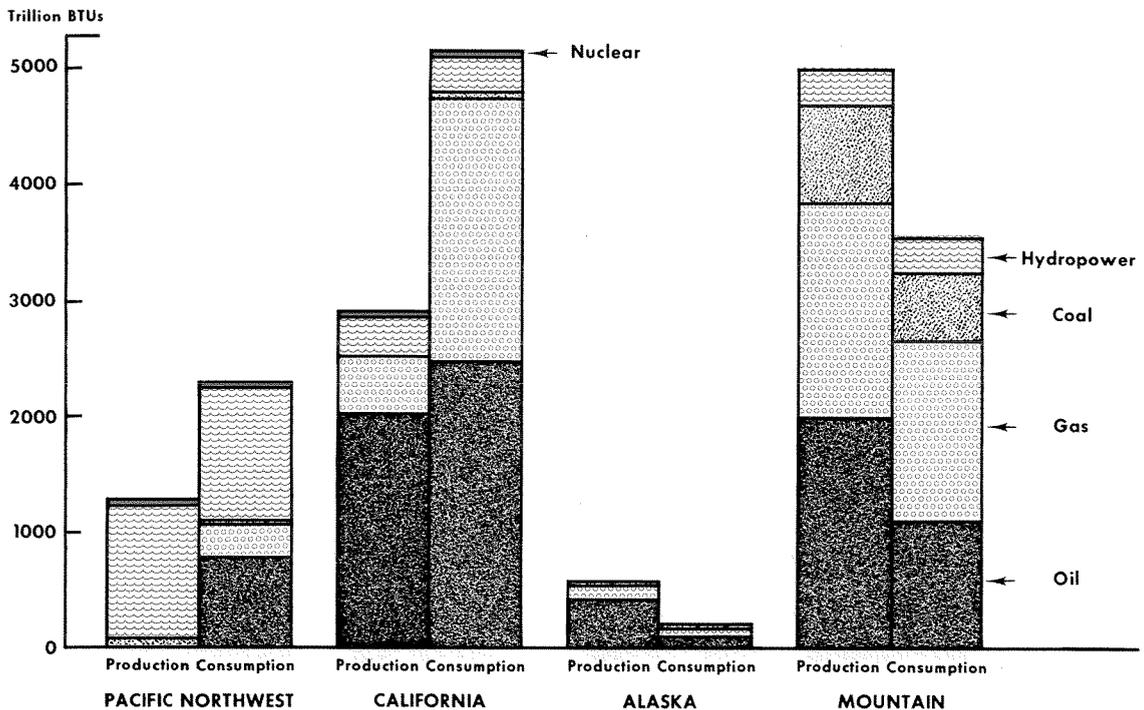
Solar energy potential

Solar radiation is the world's most abundant renewable energy resource. Its practical application is obstructed, however, by numerous engineering and economic roadblocks. The general trend in energy engineering is toward ever higher temperatures and energy densities, limited only by the capabilities of the confining materials. But solar is a diffuse and intermittent form of energy that must be collected over large areas with bulky and complicated equipment. Fortunately for the West, some of the highest intensity solar regions are located in New Mexico, Arizona, Nevada and California.

Heating and cooling of buildings with solar energy is now possible on a small scale. There are now about 175 solar-heated homes in the United States, completed or under construction. The typical system uses rooftop collectors to gather the sun's energy. The heat from the collector is transferred to a liquid—often water—that is circulated through the building or else stored in some fashion.

Harnessing solar heat to generate electricity is a more difficult challenge. Some engineers believe that small generating units located near the point of consumption provide the best way of utilizing such an inherently diffuse resource; others propose the use of large, centralized solar-thermal plants with present-day turbines; still others favor photovoltaic conversion, the solar-cell system which powered this nation's space probes. But even with lavish Governmental subsidies, it may be decades before solar energy accounts for any appreciable portion of the nation's energy needs.

Chart 5
Western Energy Patterns



The West—Producer and Consumer

The nation is becoming increasingly reliant on Western coal resources. Western production of coal more than doubled between 1970 and 1974, rising from 5 to 10 percent of the national total. This shift reflects the stringent pollution controls imposed on electric utilities and their growing preference for low-sulphur Western coal, produced especially in the Mountain states.

Crude-oil production in the West has trended downward during the past four years, dropping to slightly less than one-quarter of the national total. California, the nation's third largest producer, experienced a greater-than-national 13-percent decline. Oil-and-gas drilling activity practically ceased on state-owned offshore lands after the 1969 Santa Barbara blowout, first because of a state ban and later (after the moratorium was lifted) by environmentalists' protests. Leasing of Outer Continental Shelf acreage by the Federal government has been affected by similar problems; for instance, a scheduled 1.6-million acre sale off the Southern California coast has recently met with strong opposition. California's difficulties with offshore drilling are only part of the problem, however, since production has fallen in other states as well.

Natural-gas production in the West has followed a roughly similar pattern, since it is often found in association with petroleum. Between 1970 and 1974, gas production dropped from 2.4 to 2.3 trillion cubic feet, or from 11 to 10 percent of total U.S. production. The West has

come to depend heavily on imports from other states and nations, because it produces far less gas than it consumes.

California presently depends on out-of-state sources for more than 57 percent of its energy requirements. It gets about 78 percent of its natural gas from the Southwestern states and Canada, plus about 18 percent of its oil from the Mountain states, Alaska and foreign sources. In addition, it imports some of its electricity from coal-fired plants in the Southwest and hydroelectric plants in the Pacific Northwest. Altogether, more than 24 percent of its total energy needs are supplied by uncertain foreign sources, and Canadian natural-gas supplies may become even more uncertain as that nation acts to meet its own internal requirements.

The Pacific Northwest contains hydroelectric and coal resources, but it is in a precarious position with regard to its future supplies of oil and natural gas. Its oil supplies are imported from Canada, Alaska, California and various other foreign countries, while its natural-gas supplies come principally from Canada and to a lesser extent from the Mountain states. With 40 percent of the nation's total developed hydroelectric capacity, the Northwest is now able to satisfy all of its own electrical requirements from hydro-power and to have some left over for export. But in the future, it will become increasingly dependent on coal and nuclear power for its electricity (Chart 5).

FOOTNOTES

1. Federal Energy Administration, *Project Independence Report* (Washington, D.C.: U.S. Government Printing Office, November 1974). The background material utilized in the preparation of the final report appears in thirty-one Task Force Reports and Transcripts of Public Hearings, published by FEA and listed in Appendix AVIII of the *Project Independence Report*, page 335.

2. By "energy" consumption or use, we refer to combined resource inputs (coal, oil, natural gas, hydro and nuclear electricity) expressed in a common calorific measure (Btu's), irrespective of whether such resources are ultimately utilized in the forms of fuels and power or as raw materials (e.g. in the chemical industry). For hydro and nuclear, the Btu equivalent of the electricity generated is computed on the basis of primary energy inputs at fossil-

fueled generating stations at prevailing rates of efficiency. In practice, about 95 percent of energy resource inputs go to fuels and power use. A Btu—the common standard of measurement to which all forms of fuels and power sources can be converted—is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. The approximate Btu equivalents of common fuels and power sources are as follows:

	Btu
Crude oil, 1 barrel	= 5,800,000
Natural gas, 1 cubic foot	= 1,032
Coal, 1 ton	= 25,000,000
Nuclear power, 1 kilowatt-hour	= 10,660
Hydropower, 1 kilowatt-hour	= 10,389

Energy production and consumption statistics for the

years 1950 to 1974 in original units of measurement and Btu equivalents are from the following publications: Walter G. Dupree, Jr. and James A. West, *United States Energy Through the Year 2000* (Washington, D.C.: U.S. Department of the Interior, December 1972), Appendix B. U. S. Department of the Interior, Bureau of Mines, "Energy Use in 1974" (and in 1975), *News Release*, March 13, 1974 and April 3, 1975. These data, as well as state production figures for individual fossil fuels, are also published on an annual basis by the Bureau of Mines in its *Minerals Yearbook*.

3. For a detailed discussion of historical energy consumption and supply patterns see, Hans H. Landsberg and Sam H. Schurr, *Energy in The United States, Sources, Uses and Policy Issues, A Resources for The Future Study* (New York: Random House, 1968), pp. 9-63. Joel Darmstadter, "Energy Consumption: Trends and Patterns," *Energy, Economic Growth, and The Environment*, ed. by Sam H. Schurr (Baltimore: The Johns Hopkins University Press), pp. 155-189. Ford Foundation Energy Policy Project, *Exploring Energy Choices, A Preliminary Report* (Washington, D.C.: The Ford Foundation, 1974), pp. 1-9.

4. Reserves of crude oil and natural gas are from: American Gas Association, American Petroleum Institute, Canadian Petroleum Association, *Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1974*. Detailed statistics on the physical and financial operations of the natural gas and petroleum industries, including exploration and drilling, may be found in the following: American Gas Association, *Gas Facts, A Statistical Record of the Gas Utility Industry*, published annually; American Petroleum Institute, *Petroleum Facts and Figures*, published biennially.

5. The shortage of that fuel in turn, led the Federal Energy Administration, in late June of 1975, to order 25 utilities to switch back to coal at 74 power plants throughout the nation. At the same time, the FEA directed 41 companies building new fossil-fuel power plants to make certain that the plants have coal-burning capacity. Plants receiving the orders were required to submit plans to the Environmental Protection Agency which could then order the installation of additional pollution control equipment if necessary.

6. The \$7 and \$11 world oil prices refer to prices in constant 1973 dollars. The supply response at \$7 and \$11 world oil prices presumably also assumes that both "old" and "new" oil produced in the United States sells at that price. A number of national energy forecasts have been published in recent years. Most of these relied on extrapolations of past behavior of energy markets or judgmental factors, however, and did not take explicit account of the response of energy demand and supply to price changes. For two of the most notable of these "judgmental" forecasts see: National Petroleum Council, *U.S. Energy Outlook, A Report of the National Petroleum Council's Committee on U.S. Energy Outlook* (Washington, D.C.: National Petroleum Council, December 1972). Ford Foundation Energy Policy Project, *A Time To Choose America's Energy Future* (Cambridge: Ballinger Publishing Company, 1974). For the most notable econometric forecast aside from the *Project Independence Report* see: M. I. T. Energy Laboratory Policy Study Group, *Energy Self-Sufficiency, An Economic Evaluation* (Washington, D.C.: American Enterprise Institute for Public Policy Research, November 1974). M. I. T. researchers, in forecasting to the year 1980, found domestic supplies to be generally more responsive to higher prices than the FEA.

7. Betty M. Miller, et. al., *Geological Estimates of Undiscovered Recoverable Oil and Gas Resources of the United*

States, Geological Survey Circular 725 (Washington, D.C.: U.S. Department of the Interior, Geological Survey, 1975). All oil and natural gas resource estimates used in this article were taken from this Circular. Contrary to previous estimates which utilized prior data on hand, these estimates were made by carefully evaluating a large amount of new geological and geophysical information gathered on more than 100 different provinces by over 70 specialists within the Survey and by applying a variety of resource appraisal techniques to each potential petroleum province. Due to the thoroughness of this process and the elimination of highly speculative resources lying outside the 5 percent probability range, these figures are much smaller than earlier estimates by the Survey.

8. The Supreme Court upheld the Federal Government claims to leasing rights to lands beneath lower Cook Inlet on the basis that the property in question is part of the "high seas" and not the kind of "inland waters" over which states were granted title under the 1953 Submerged Lands Act. See, "Land Off Alaska Belongs to U.S., Top Court Rules," *Wall Street Journal*, June 24, 1975, page 2.

9. Paul Averitt, *Coal Resources of the United States, January 1, 1967*, Geological Survey Bulletin 1275 (Washington, D.C.: U.S. Department of the Interior, Geological Survey, 1969). Also, National Petroleum Council, Committee on U.S. Energy Outlook, *U.S. Energy Outlook: Coal Availability* (Washington, D.C.: National Petroleum Council, 1973).

10. George H. Davis and Leonard A. Wood, *Water Demands For Expanding Energy Development*, Geological Survey Circular 703 (Washington, D.C.: U.S. Department of the Interior, Geological Survey, 1974). National Petroleum Council, *U.S. Energy Outlook: Water Availability* (Washington, D.C.: National Petroleum Council, 1973).

11. For a discussion of coal transportation problems and synthetic fuel technologies see, National Academy of Engineering, Task Force on Energy, *U.S. Energy Prospects: An Engineering Viewpoint* (Washington, D.C.: National Academy of Engineering, 1974), pp. 36-48.

12. K. C. Vyas and W. W. Bodle, "Coal and Oil-Shale Conversion Looks Better," *Oil and Gas Journal*, Vol. 73, Number 12 (March 24, 1975), pp. 45-54.

13. Federal Energy Administration, *Project Independence Report*, page 132.

14. National Petroleum Council, *U.S. Energy Outlook*, page 208.

15. Federal Energy Administration, National Energy Information Center, "Nuclear Power," *Monthly Energy Review* (April, 1975), page 5.

16. Douglas M. Johnson, "Uranium Fuel Prices," *The Conference Board Record*, XII, Number 1 (January, 1976), page 52.

17. Energy Research and Development Administration, *Statistical Data of the Uranium Industry* (Grand Junction: Grand Junction Office, January 1, 1975).

18. Federal Energy Administration, *Project Independence Report*, page 113. Data adjusted for changes in scheduled capacity.

19. Pacific Northwest River Basins Commission, Power Planning Committee, *Review of Power Planning in the Pacific Northwest, Calendar Year 1973* (Vancouver: Pacific Northwest River Basins Commission, 1974), page 3.

20. L. H. Godwin, et. al., *Classification of Public Lands Valuable for Geothermal Resources*, Geological Survey Circular 647 (Washington, D.C.: U.S. Department of the Interior, Geological Survey, 1971).

Western Manufacturing Production

Joan Walsh

As an aid to regional economic analysis, this bank's research staff has developed in recent years a manufacturing-production index for the nine-state San Francisco Federal Reserve District. (The district is composed of Alaska, most of Arizona, California, Hawaii, Idaho, Nevada, Oregon, Utah and Washington.) This article summarizes the broad trends revealed by the index, as revised recently to incorporate 1972 Census data.

The foundation of this regional-manufacturing series is provided by Census Bureau data on value added by manufactures. By 1972, the West had grown to account for 12.6 percent of all manufacturing value added. Eight industries—centered around aerospace, food processing, forest products and metals—accounted for 72 percent of the West's value added in 1972. (The same industries accounted for 60 percent of the national total.) Because of the relatively strong performance of these key industries—except food processing—manufacturing production in the West increased at a 5.4-percent annual rate between 1964 and 1974, compared with a 4.3-percent rate of gain nationwide (see table and charts).

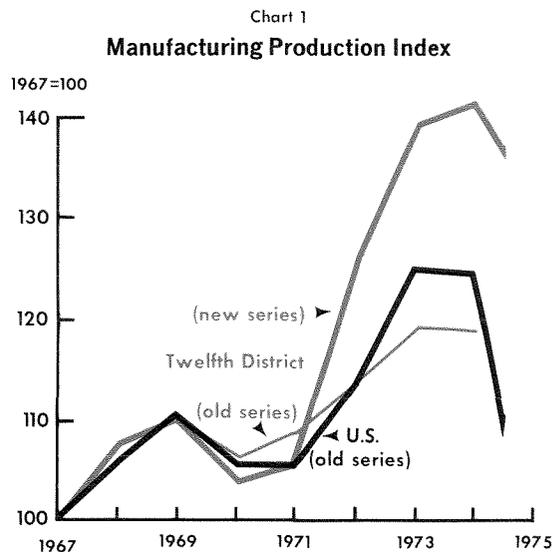
Series revision

Monthly indexes have been calculated for total manufacturing and 19 two-digit Standard Industrial Classification (SIC) codes, and are available in seasonally adjusted form with 1967 as the base year. The series cover the period June 1963 to date, and are published in the bi-monthly *Western Economic Indicators*. A technical paper presenting details of the index con-

struction is available on request from the bank's Research and Public Information Department.

The indexes shown here differ in several important respects from those previously published in *Western Economic Indicators*. The methodology has been simplified and value-added data from the 1972 Census of Manufacturers have been incorporated. Comparisons with U.S. production series are shown, but they are somewhat imprecise because 1972 Census data are not yet included in the national series; judging from the effect of revision on the regional series, the national series might show a significant increase in the early 1970's.

Other changes have been caused by the 1972 revision of the SIC manual. In most cases, the reclassification did not alter coverage at the two-digit industry level, except for the elimination of SIC 19 (ordnance and accessories) and its redistribution among SIC codes 34, 37 and 38. That shift caused value added in SIC 38



(instruments and related products) to double between 1971 and 1972, but other industries were relatively unaffected.

Industry highlights

Transportation equipment (SIC 37)—This industry accounts for 18.8 percent of the region's value added, compared with an 11.2-percent share nationwide. Growth was much stronger in the West than elsewhere in the nation over the past decade. Aircraft production has dominated the regional industry, accounting for more than four-fifths of the total, or twice its relative share in the national industry. The auto strikes of 1964 and 1970 thus did not affect the regional series as much as the national series. On the other hand, post-1969 cutbacks

in defense spending and reductions in commercial-aircraft orders showed up in a precipitate drop in Western production. The oil embargo and ensuing recession showed up in both the regional and national statistics, with especially sharp declines in early 1974 and early 1975—in both autos and aircraft—being followed by a more recent upturn.

Food and kindred products (SIC 20)—This industry accounts for 13.4 percent of the region's value added, compared with a 10.2 percent share nationwide. Production increased at a moderate pace between 1964 and 1974. Movements in the index reflect the regional importance of canned, cured and frozen food products, which account for almost one-third of the Western total—twice their national share. West-

MANUFACTURING VALUE ADDED AND PRODUCTION INDEX

SIC Code	Industry	Value Added (1972)				Annual Growth (1964-74)	
		West		U.S.		West	U.S.
		\$ Millions	Percent Distrib.	\$ Millions	Percent Distrib.	Percent	Percent
19	Ordnance and accessories	—	—	4,858	1.4	—	—
20	Food and kindred products	5,863	13.4	35,399	10.2	3.1	3.5
21	Tobacco products	—	—	2,704	0.8	—	—
22	Textiles	265	0.6	11,366	3.2	9.7	3.4
23	Apparel	1,106	2.5	13,197	3.8	6.3	1.1
24	Lumber and wood products	3,970	8.9	7,861	2.3	4.5	2.8
25	Furniture and fixtures	732	1.7	6,012	1.7	5.6	4.0
26	Paper and allied products	1,587	3.6	13,181	3.8	4.6	4.5
27	Printing and publishing	2,273	5.2	19,250	5.5	5.2	2.9
28	Chemicals and allied products	2,238	5.1	33,081	9.5	6.5	7.6
29	Petroleum and coal products	915	2.1	5,841	1.7	2.2	3.2
30	Rubber and plastic products	1,049	2.4	11,013	3.2	13.2	8.2
31	Leather and products	54	0.1	2,971	0.8	-4.0	-2.6
32	Stone, clay and glass products	1,572	3.6	12,092	3.5	3.3	2.7
33	Primary metals products	2,009	4.6	23,405	6.7	2.8	2.5
34	Fabricated metal products	2,754	6.3	24,047	6.9	5.6	4.6
35	Nonelectrical machinery	3,495	8.0	36,114	10.4	6.8	5.8
36	Electrical machinery	3,818	8.7	30,455	8.8	4.6	5.6
37	Transportation equipment	8,280	18.8	39,131	11.2	6.5	2.0
38	Instruments and products	1,238	2.8	9,510	2.7	15.9	7.3
39	Miscellaneous manufacturing	688	1.6	6,558	1.9	7.4	5.6
	Manufacturing total	43,906	100.0	348,048	100.0	5.4	4.3

Note: Growth trends not strictly comparable because U.S. index has not yet been updated to include 1972 Census data.

ern output rose along with the national industry over most of the past decade, but the different structure of the regional industry has strongly affected the series in certain periods, such as 1970-72. In that period Western fruit and vegetable processors suffered supply losses because of poor weather, while producers elsewhere in the nation benefited from very heavy demand for their most important commodities (grains and meat products). More recently, Western food-processing output has outpaced the nation because of the strong increase in Northwest grain production and the heavy liquidation of cattle supplies. Incidentally, erratic movements in the index sometimes have arisen because of strikes but also because of changes in the timing of the harvest.

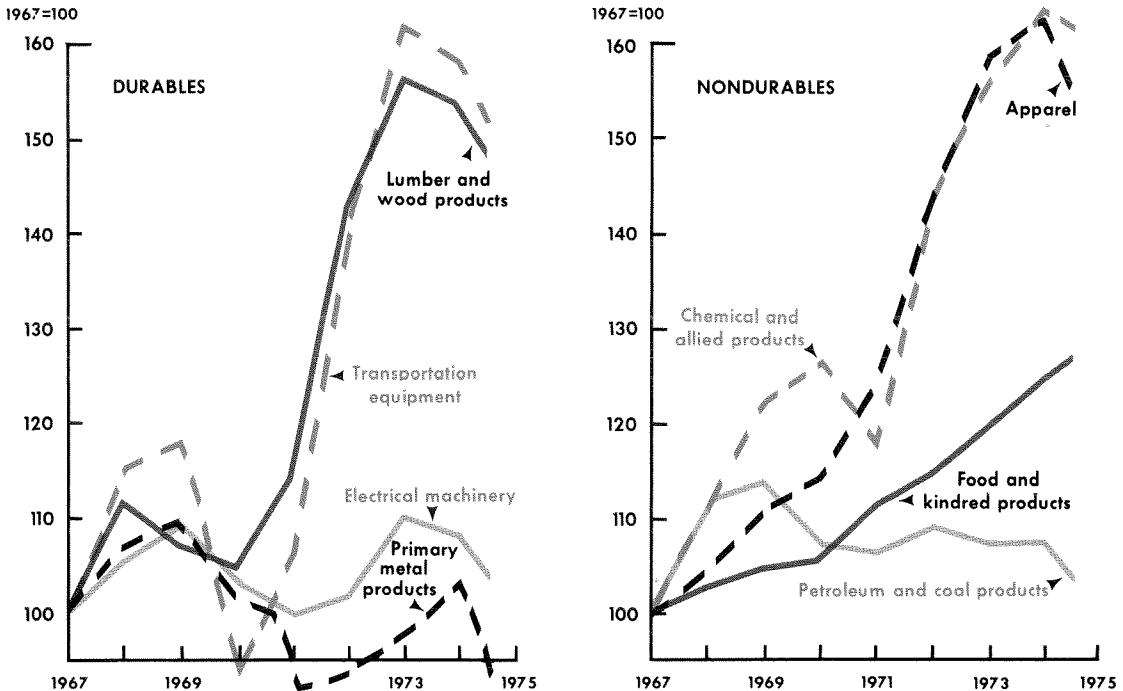
Lumber and wood products (SIC 24); paper and products (SIC 26)—These two forest-product industries together account for 12.5 percent of the region's value added, compared with a 6.1-percent share nationwide. Production increased moderately over the past decade,

and was somewhat stronger in the West than elsewhere, at least in the lumber industry. The lumber series has been affected by erratic movements attributable to labor disputes and weather problems, but above all by periodic booms and slumps in national housing demand, most notably in the past two years. (In early 1975, however, the regional series showed a healthy rebound which was not reflected in the national figures.) The paper series has been affected by similar erratic movements and also by national business-cycle fluctuations. Western production fell steeply in late 1974 and early 1975—although not so steeply as elsewhere—and in recent months an upturn has occurred in corrugated-box production, a useful leading indicator of general business activity.

Primary metals (SIC 33); fabricated metal products (SIC 34)—These two industries together account for 10.9 percent of the region's value added, compared with a 13.6-percent share nationwide. Primary-metal output grew slowly everywhere over the past decade, while

Chart 2

Western Manufacturing Production Index



fabricated-metals production rose strongly, especially in the West. Western primary production has been concentrated in the smelting and refining of nonferrous metals, with the region accounting for almost two-thirds of the nation's copper output and about one-fourth of total aluminum output. Steel production has been much less important here than elsewhere, and steel-strike activity has failed to affect the regional index as much as the national series. But both the regional and national indexes have been strongly affected over the past year by the severe cyclical declines in auto and construction demand. The substantial long-term growth in the regional segment of the fabricated-metals industry meanwhile has stemmed from the West's concentration in markets with strong long-term growth records, such as structural products and metal cans, and its relative unimportance in one severely depressed market, metal stampings for the auto industry.

Electrical machinery (SIC 36)—This industry accounts for 8.7 percent of the region's value added, compared with a comparable 8.8-percent

share nationwide. The industry grew moderately in the West over the past decade, but at a more rapid pace elsewhere, with a prolonged decline in the Western-oriented space program helping to account for the differential. The regional industry is concentrated in communications equipment, electronic components and electrical-testing equipment, while the industry elsewhere is centered around production of household appliances and radio and TV sets. The recession decline has been severe both regionally and nationally.

Nonelectrical industry (SIC 35)—This industry accounts for 8.0 percent of the region's value added, compared with a 10.4-percent share nationally. The industry grew vigorously over the past decade, especially in the West. Much of this performance was due to a substantial rise in regional production of office machines and electronic computing equipment, which compared with the more diverse product mix of the national industry. Output has shown wide cyclical fluctuations, most notably in the still continuing business downturn.

Erratum

In the article "International Money and International Inflation: 1958-1973" by Edward S. Shaw in the Spring 1975 issue equation 7 should read:

$$(7) \quad t^u = \frac{t}{s_u} - \frac{s_0(t^0)}{s_u}$$

Also, the third sentence in the last full paragraph on page 7 should read: Given (t) and the international pattern of demand for real money, (m_s^u) is determined partly by the portfolio choices of foreign monetary authorities.

California — End of Growth?

William Burke

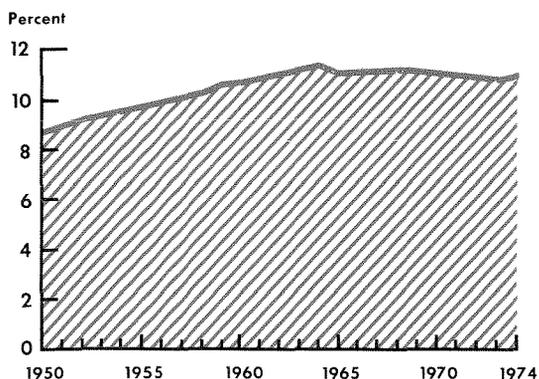
California is the nation's trend-setter, and its shift to a pattern of slower growth in recent years thus has important implications for the broader national economy as well as for its own future. True enough, the state's economy generated \$125 billion in personal income in 1974, or about one-ninth of the national total. (In terms of income, California by itself would easily rank among the world's ten largest nation-states.) But the growth which brought California to its present eminence has created a treadmill effect, which results in serious adjustment problems whenever the treadmill slows down. In even the mildest business recession, unemployment soars and other signs of stress appear. In 1971, for example, the jobless rate averaged 8.8 percent—greater by half than the national rate—and in the first half of 1975 it reached a record 9.7 percent.

For more than a century, rapid economic growth has been the hallmark of the California experience, and the economy frequently appears rudderless in periods such as the present, when there is no new growth sector on the horizon. The state's history has usually been written in terms of successive boom periods, based upon such leading sectors as gold, wheat, food processing, oil, the military, and (perennially) land development. The rapid expansion of the aerospace-electronics industry in the past quarter-century has been only the latest in a long series of booms transforming the California landscape. However, busts have been just as much a part of California history as booms, and the major question of the 1970's concerns the state's ability to weather both a cyclical recession and the maturing of the key aerospace-electronics sector.

Any economy of California's present size, with its heavy consumer, business, and public-works demand, is better able to sustain long-range economic growth in the face of cyclical downturns than a smaller area would be. But the state's economy has diversity as well as size in its favor. California's aerospace-related activities account for 19 percent of the nation's income from that source, but at the same time they account for only about 5½ percent of the state's total income. California's farmers lead the nation with 10½ percent of U.S. farm income, but they account directly for less than 3 percent of the state's total income. Similarly, California's builders lead the nation with 9 percent of U.S. construction income, but they account for only 4 percent of the state's total income. California thus boasts a welcome diversity that normally cushions downturns occurring in any one sector and thereby provides a strong underpinning for well-balanced growth.

As a reflection of its earlier troubles, California entered the recent recession with a much higher jobless rate than the rest of the nation. However, the recession itself was not so steep in California, largely because it is less dependent than the nation on autos and other cyclical industries. Civilian employment elsewhere in the nation dropped at a 6.2-percent annual rate between the September 1974 high and the March 1975 low, while California employment dropped at a 2.6-percent rate during this period. Thus, the margin between California's jobless rate and the fast-rising national rate narrowed to one percentage point in the first half of 1975, compared to a spread of 1½ to 2 percentage points during the several preceding years.

Chart 1
California Share of U.S. Personal Income



Nonetheless, this recession period aside, California has declined in importance relative to the rest of the nation over the past decade. In the preceding decade (1954-64), California's share of the nation's personal income jumped from 9.5 percent to 11.4 percent, but then the state began to lag, so that its share of total income then fell to 10.9 percent in 1974 (Chart 1). The

relative decline was less noticeable in real terms, because consumer prices rose more slowly in California than in the nation over this past decade. However, the contrast was quite striking in relation to what went before. Real personal income increased nationwide by 48.6 percent between 1954 and 1964, and by almost the same amount (46.0 percent) between 1964 and 1974, but California's real growth declined from 70.4 percent in 1954-64 to 44.4 percent in the 1964-74 period.

California's relative performance over the past decade can be measured by analyzing, for each income category, three separate sources of growth—national growth, industry mix, and regional share (see table).¹ The "national growth" effect can be calculated by assuming that California had precisely the same structural mix of income sources as the nation possessed at the outset of the period, and that each of those sectors then grew at the same rate in California as in the nation. The "industry mix" effect reflects the relative importance in the West of national fast-growing (or slow-growing) income sources.

CALIFORNIA REAL PERSONAL INCOME—
EFFECT OF GROWTH FACTORS (1964-74)
(Billions of 1974 dollars)

Source of Income	Personal Income 1964	Growth Factors			Personal Income 1974
		National Growth	Industry Mix	Regional Share	
Agriculture	2.43	1.12	-0.26	0.04	3.32
Aerospace manufacturing	6.57	3.02	-1.78	-0.97	6.86
Other manufacturing	10.61	4.88	-1.76	0.80	14.54
Mining	0.42	0.19	-0.09	-0.05	0.47
Construction	4.91	2.26	-0.07	-2.01	5.09
Trade	12.44	5.72	-1.63	-0.35	16.18
Finance	3.95	1.82	-0.02	-0.40	5.36
Transportation and utilities	4.60	2.12	-0.29	0.62	7.04
Professional and social services	5.41	2.49	2.05	0.05	10.00
Other services	5.79	2.66	-1.16	-0.30	7.00
Federal government	5.04	2.32	-0.55	0.30	7.10
State-local government	7.48	3.44	2.51	-0.72	12.72
Property income	12.48	5.74	-0.11	0.57	18.68
Transfer payments	6.76	3.11	5.92	0.57	16.36
Total personal income	86.84				125.38

Note: Total includes items not shown separately. Rows do not necessarily add across because of rounding.

The "regional share" effect reflects the growth of individual California income sources in relation to their national counterparts.

California's 1964-74 increase in real income was based almost entirely upon its similarity to national income patterns (national-growth effect). In contrast to earlier periods of rapid growth, its income structure was weighted more toward slow-growing than fast-growing sources of national income growth (industry-mix effect). Indeed, only 3 of its 14 income categories recorded positive growth from this source—professional and social services, state-local government, and (above all) transfer payments, such as social-security benefits and unemployment insurance. Much of the weakness in this respect stemmed from the importance in the California economy of such national slow-growers as aerospace manufacturing, other manufac-

turing and trade. More particularly, and in even greater contrast to earlier periods of rapid growth, most of California's individual industries lagged behind their national counterparts (regional-share effect). The slowdown was especially noticeable for such traditional fast growers as construction, aerospace manufacturing, and state-local government.

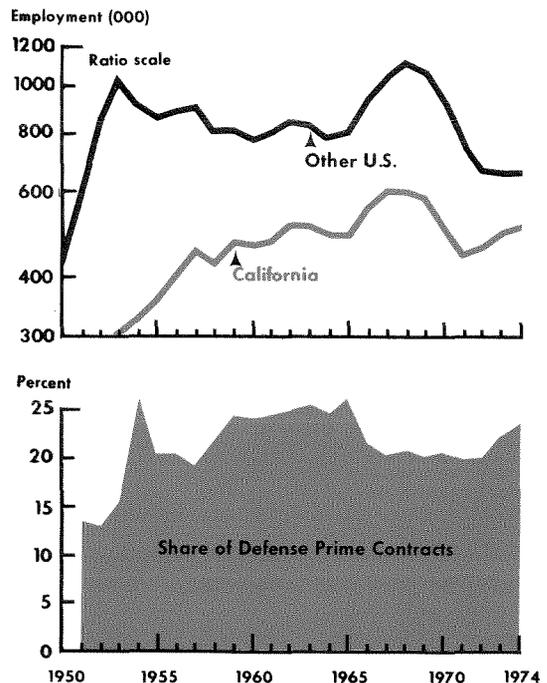
As these income shifts indicate, the state faces serious problems, not least of them being the continuous reshaping of earlier growth sectors along more modest lines. Another basic problem concerns the ability of the state and its people to adjust their planning to a state of affairs where the possibility—or even the desirability—of rapid growth can no longer go unquestioned. After a century of equating rapid growth with virtue, Californians may find it difficult to make the necessary adjustments.

Crucial Role of Aerospace

The state's problems are exemplified by the bellwether aerospace-electronics industry. At its peak in 1967-68, the industry employed more than 600,000 workers, under the stimulus of the Vietnam war, the space race, the commercial-aircraft boom, and the consumer-electronics boom. Then each of these sources of demand weakened, throwing 180,000 people out of work and leading to a state-wide slump even before the onset of the 1970 national recession. Recovery from the slump began around mid-1971, helped along by the Congressional rescue of Lockheed and its L-1011 transport project with a \$250-million loan. (At the same time, Congress let Boeing's supersonic transport project die, and for a prolonged period Seattle became even more depressed than Southern California.) The strengthening of military and (later) commercial business provided support for a rebound, but by the onset of the next recession only about one-third of the lost jobs had been recovered (Chart 2).

California's aerospace industry has been based from the very beginning upon heavy injections of federal money. In 1974, defense and

Chart 2
Aerospace: Employment & California Contract Share



space-agency contract awards reached a new peak of \$8.9 billion—23 percent of the national total—and thereby helped offset the developing weakness in commercial-aircraft and civilian-electronics business. Only one major new project has gotten underway in recent years—the space-shuttle project—but awards for ongoing aircraft and missile contracts have risen sharply since 1971, and thereby have contributed to the industry recovery. The state's economy thus relies heavily upon political decisions made in Washington about the product-mix of the national aerospace industry. Aerospace systems in the 1960's and 1970's have been grouped in six major functional categories—bombers, fighters, transports (and associated commercial products), missile systems, anti-missile systems and space systems. The 24 major aerospace systems which have been developed in this period have come from one or another of the industry's nine major production lines, three of which are in California.²

In the past, each phasing-out of a major government contract generally has coincided with the phasing-in of a new one, with the contract for the new system being awarded two to three years before the scheduled termination of the old system. But since the national industry markets only a half-dozen major products, logic might dictate that only a half-dozen production lines be kept in operation, especially since most of the major systems are due to come to the end of their production runs within the next several years. On the other hand, past experience suggests that government contracts will be found to keep most if not all of the present production lines in continued operation. Despite the recent upturn in military and space spending, individual firms could remain on rather skimpy rations, at least by past standards, as the available

federal funds are distributed on a fairly even basis among all present producers.

One alternative would be to concentrate more attention on the commercial-aircraft business, especially in view of the worldwide popularity of American jets, which have become even more popular in recent years because of the bargain-basement prices caused by the several devaluations of the dollar. However, the commercial market has long been dominated by a few Douglas and (especially) Boeing models, and new entrants into the market have had relatively little success. Moreover, a general slowdown in commercial orders now seems inevitable, partly because of the recession-affected traffic and earnings reports of the major airlines, and also because of the cutbacks in scheduled flights necessitated by the soaring price of jet fuel.

Another alternative for the industry would be to diversify into non-aerospace business, a solution which has led to many troubles in the past. In the severe postwar slump of the late-1940's, many producers turned to making such products as aluminum canoes, but these products sank without a trace in the vast and unfamiliar consumer marketplace. In more recent times, the electronics segment of the industry has developed a number of successful new products for the business and consumer markets, but this sector is today engaged in one of its periodic shake-outs. Several aerospace firms have attempted to break into the surface-transportation field by providing equipment for the Bay Area Rapid Transit system, but their work on that project has been marred by prolonged scheduling delays, substantial cost overruns and other features typical of aerospace production at its worst. This experience led David Packard, former Deputy Secretary of Defense, to conclude, "The industry does not yet know how to build complex reliable equipment at reasonable cost."³

Contribution of the Knowledge Industry

The problems of California's aerospace industry will be solved not just by the infusion of more federal money, but also by the continued health of the "knowledge" industry, with which

it has long maintained a symbiotic relationship. The fortunes of the highly technical aerospace sector, with its reliance on the continued development of advanced and sophisticated products,

have been closely tied for decades to the breakthroughs achieved in university laboratories and research centers. The industry has found an especially fertile field in California, which advertises four of the top dozen or so graduate schools in the nation. These schools attract large numbers of top-flight students, and thus a disproportionately large share of the nation's new scientists and engineers.

California's dominance in aerospace has come about because of the continued excellence of these educational and research facilities—facilities which have originated a circular development process whereby research contracts generate production contracts, which make possible stronger research staffs, which generate new research contracts, and so on. (The key resource, skilled scientific manpower, also has been attracted by the state's highly touted sun, sea and sky, despite all the deterioration in this respect in recent decades.) In the last analysis, California's economic growth depends heavily on investment in education, or human capital. This type of investment helps explain the observed discrepancy between the nation's rate of economic output and the much smaller rate of increase in measurable inputs of labor, capital and resources. Indeed, many economists argue generally that the greatest contribution to growth is made by increased education and related advancements in knowledge.⁴

Yet, California and the nation have recently shown that they are no longer willing to invest ever-increasing sums in the knowledge industry. One major cause has been the decline in federal

funding of projects which had expanded rapidly during the Great Society and the Vietnam war. Other factors have included public dissatisfaction with both the war and the antiwar movement—especially in Berkeley, the cradle of the college revolution—and the reaction against the post-Sputnik glorification of science. In addition, many California voters tend to believe that the state's higher-education system involves a redistribution of income from poorer families to higher-income families, as a result of the state's somewhat regressive tax structure as well as the substantial state support of prestigious institutions where higher-income students are mostly concentrated.

Federal support for the nation's higher-education establishment, after increasing five-fold in the 1960's, began to slow down even before the end of the decade. For example, the number of federally-supported first-year graduate fellowships dropped 62 percent nationwide between 1968 and 1972. In California, despite continued increases in dollars spent on education, the university system's instructional budget per full-time student dropped 20 percent in real terms between 1967 and 1972. The University of California has sharply trimmed its expansion plans, partly because of funding problems, but also because of enrollment problems caused by the rapid rise in instructional fees, the cresting of the college-age population, and the post-Vietnam disinterest in college life. The optimistic plans of the 1960's, which envisioned a number of major teaching and research facilities scattered around the state, have now been shelved.

Other Symptoms of Deceleration

The scaling-down of the aerospace-knowledge industry complex is only one symptom of the deceleration in California's characteristic pattern of rapid growth. More basically, the rate of population growth has sharply declined, in terms of both births and in-migration. (Nonetheless, California has added more people than any other state except Florida since the beginning of this decade.) The natural increase in

1974 totalled only 117,000—less than in 1950, when the state's population was only about half as large as today's 20.7 million total. Young California families, like their counterparts elsewhere, thus appear to have voted for zero population growth, by reducing average family size below the 2.1-child level necessary to sustain long-term population growth.

The cause is difficult to pinpoint, but it may

have something to do with relative feelings of affluence among young families. The postwar baby boom can be explained by the ability of young adults in that time period to achieve incomes quite high in relation to their Depression-era expectations. But today, the large numbers of young adults scrambling for jobs in the marketplace have had great trouble meeting the economic goals they formed in the affluent postwar period. They are less willing to have children, and with the universal spread of effective means of birth control, they are more successful than their predecessors in actually limiting family size. Whatever the cause, the phenomenon means a sharp compression of those California markets specializing in children's goods and services, including elementary education, and it also means the growing presence in the labor market of large numbers of young women who formerly would have been involved in child-care rather than job-seeking.

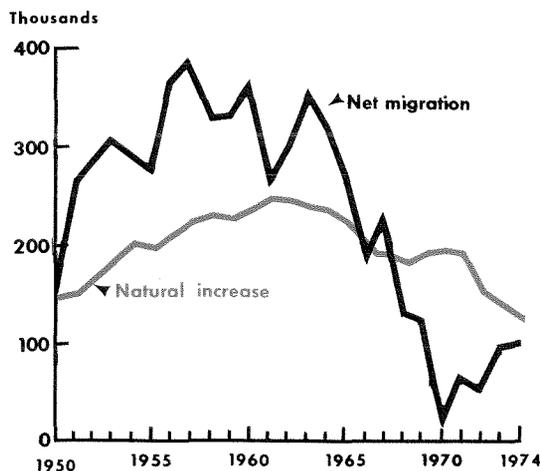
Even more strikingly, migration-based growth practically disappeared in the early 1970's. For decades, migrants had accounted for about three-fifths of the state's population growth, with the net inflow rising at times to as much as 1,000 a day. The migrant flow has always included a disproportionate number of productive adults, whose home states (and nations) have

borne the burden of raising and educating them. This growth factor in particular is now missing (Chart 3).

To a certain extent, the recent decline should have been expected because of the close relationship between migration and job opportunities in the aerospace-knowledge industry complex. Migration has always declined during recession periods, but not nearly so much as in the 1970's. Even during the sharp 1958 recession, net migration reached 325,000 for the year. In contrast, the net increase was only 16,000 in the much shallower 1970 recession, and it averaged only 71,000 annually during the 1971-73 recovery. Part of the explanation lies in the abortive nature of the recovery, which was considerably weaker in California than elsewhere because of the continued weakness of the aerospace industry; thus, the unemployment rate in 1973 averaged 7.0 percent in California as against 4.7 percent in the rest of the nation. But there are other explanatory factors as well. A California Poll taken in 1971 indicated that almost one-third of the population would leave the state if given the chance, not simply because of the lack of job opportunities but also because of problems of pollution and overpopulation.

After a century of obsession with economic growth, many Californians have become disenchanted with the pace and nature of their earlier growth. For example, in 1972 California's electorate—over the opposition of major business and labor groups—imposed a moratorium on all building along the coastline from Oregon to the Mexican border. The measure was designed to protect the entire 1,200-mile coastline from uncontrolled development by setting up regulatory commissions to grant or withhold building permits for any projects planned within 1,000 yards of the ocean. This vote followed hard on the heels of a California Supreme Court decision requiring environmental-impact statements to be filed with building-permit requests on all private construction projects involving a "significant" environmental impact. Another political factor to be faced in June 1976 is the "nuclear safeguards" initiative. By voting af-

Chart 3
Sources of Population Change



firmatively, California's electorate could empower the legislature to impose extremely rigid safety and insurance requirements over all commercial-power reactors, and thus could heavily influence the future of the nation's utility industry.

For that matter, California is peculiarly disadvantaged by the energy crisis, because it obtains 89 percent of its energy needs from the scarcest fuels, petroleum and natural gas, compared with a 78-percent dependence for the nation as a whole. (Of course, it has large oil resources offshore, but those reserves remain unexploited because of public fears of another Santa Barbara oil spill.)⁵ In addition, California's consumption is concentrated in the least essential uses, such as private auto transportation, which accounts for almost one-fourth of all energy consumed in the state. California's heavy dependence on the automobile, and the long distances traveled within the state, thus make her especially vulnerable to the energy crisis. Suburban home construction, suburban commercial development, auto retailing, resort activities, and many other elements of the life-style which Californians have built around the private auto thus would be seriously affected in the event of a deepening crisis.

California's economic salvation depends upon

the problem-solving capabilities of the state's justly famed, albeit recently besieged, knowledge industry. University training in the sciences, and especially the application of scientific advances to the development of new industries and the solution of old problems, should play an important role in the strengthening of the state's economy. In the case of the aerospace industry, California's universities trained large numbers of highly-skilled scientists and technicians; the research centers concentrated around those universities attracted other highly-trained workers; and the foundation was laid for the state's dominance of this crucial new industry. The impetus from the aerospace sector of course has weakened in recent years, but the prime mover—education and research—stands ready to provide the spark of life to new industries as yet unborn.

FOOTNOTES

1. Edgar S. Dunn, "A Statistical and Analytical Technique for Regional Analysis," *1960 Papers and Proceedings of the Regional Science Association*.
2. James R. Kurth, "Why We Buy the Weapons We Do," *Foreign Policy*, Summer 1973.
3. David Packard, "Should the Aerospace Industry Reorient to Changing Priorities?" *Business Economics*, May 1973, p. 48.
4. Edward F. Denison, *The Sources of Economic Growth in the United States*. New York: Committee for Economic Development, 1962.
5. See Yvonne Levy's article in this issue of the *Review*.