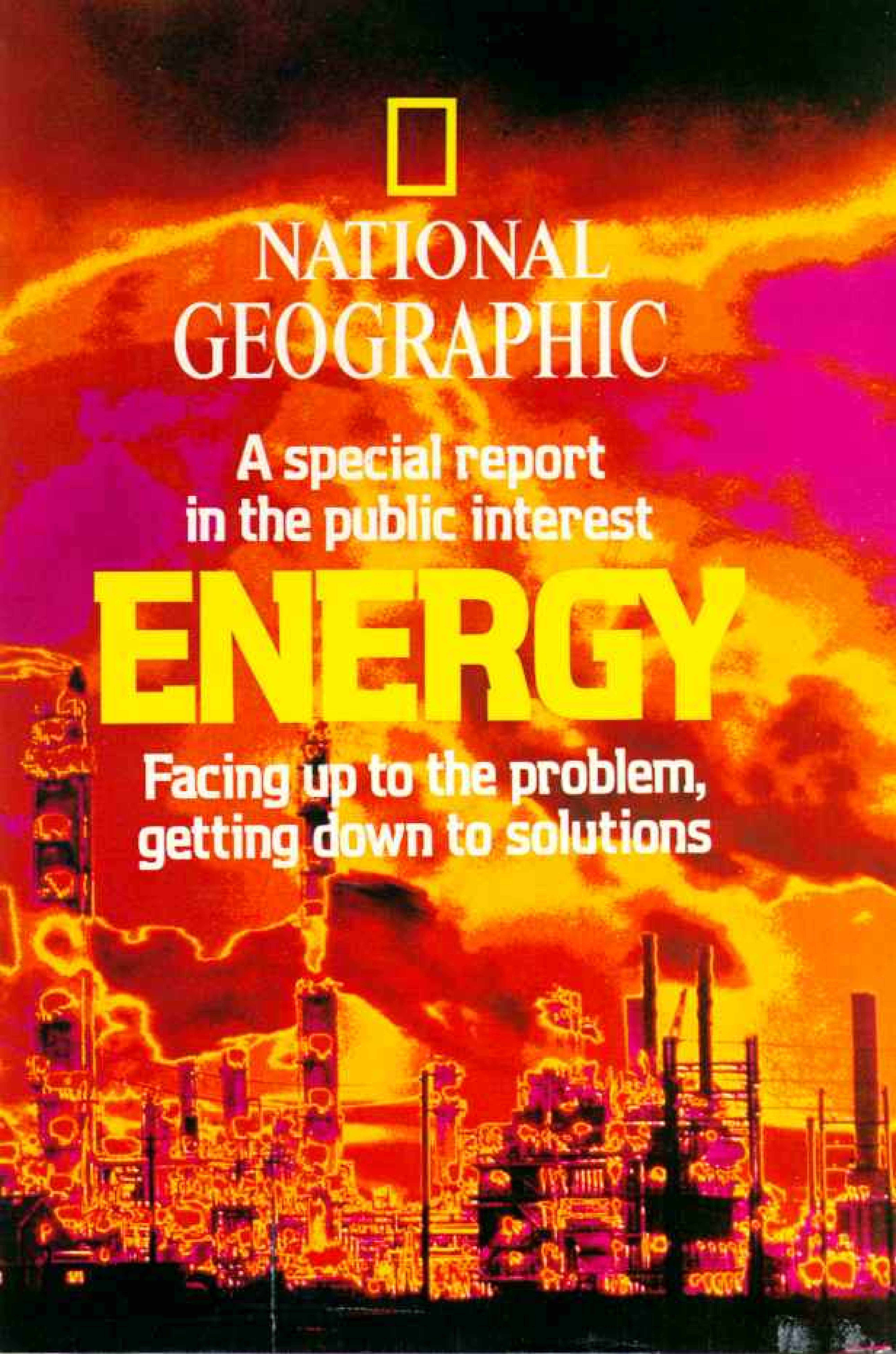


NATIONAL GEOGRAPHIC

A special report in the public interest

ENERGY

Facing up to the problem, getting down to solutions

SPECIAL REPORT NATIONAL GEOGRAPHIC FEBRUARY 1981

The unbalanced world

MORE THAN a year ago the editors of NATIONAL GEOGRAPHIC became concerned that while advocates and detractors of oil, coal, and synfuels, nuclear, solar, and wind power competed in the daily press, there were few readily available summaries of the energy situation. A large staff under Science Editor Kenneth F. Weaver has assembled such a picture in the hope that it will help inform the public.

During the year things did not improve. We still have no national energy policy. Energy prices are still inflating others. And Mr. Weaver's scenario of the consequences of a future Middle East breakdown is underscored by the present Iraqi-Iranian conflict.

Events in the United States, however, are only a part of basic changes in the fragile international order of things. Since 1945 world events have been controlled by the balance between the two superpowers, the United States and the Soviet Union, and the response of the Third World to their actions.

That pattern was broken with the emergence from the Third World of a privileged group, the relatively few oil-producing nations that hold the economic health of industrialized societies in their hands and cater to neither Moscow nor Washington.

And a Fourth World has emerged, that of the very poor, with no chance whatever to educate, house, care for, or fully employ their teeming populations. Rising energy costs have deprived them of reaching even the minimums in this century.

A World Bank official estimates that the cost of providing minimum-level nutrition, water, shelter, and energy to more than two billion people in the poor nations of the world will be a hundred billion dollars a year for the next ten years—and 40 percent of that huge cost will be for energy.

One way or another, the United States and other "have" nations, who use most of the world's energy, will devise stratagems to survive. But for much of the world, governments caught in the crunch between huge balance-of-payments deficits and sinking living standards will find it difficult to remain stable, much less prosper.

A chief problem facing the new administration in Washington is devising an energy policy that encourages American economic growth while coming to grips with the international economic balances that are being so radically altered by the pressures of energy cost and social unrest. We wish our new leaders luck in this most difficult task.

Gilbert M. Grosvenor
PRESIDENT

CONTENTS

COVER: *Tar-sands plant in Alberta; night photo by Jonathan Blair, color-enhanced by Rex A. Stucky*

AMERICA'S THIRST FOR IMPORTED OIL

Our Energy Predicament

1973 Crude oil in a fine Waterford crystal pitcher symbolized the rising price of petroleum when the GEOGRAPHIC photographed a smiling Kuwaiti for the June 1974 article that warned of imminent oil shortages.

1980 In seven years the world market price for crude had soared from $3 to more than $32 a barrel. World supplies were threatened as the war between Iraq and Iran dragged on.

1985 Conservative estimates project a price of $80 a barrel, even if peace is restored to the Persian Gulf and an uncertain stability maintained.

By KENNETH F. WEAVER
SENIOR ASSISTANT EDITOR

IT IS THE SUMMER OF 1983. Violent uprisings have shaken Saudi Arabia, and the House of Saud has fallen. For months the nation has been kept in turmoil by dissidents with strong religious and anti-Western feelings: ultraconservative Muslims of the Wahhabi sect, angered by corruption among some of the ruling princes and embittered by the erosion of family and tribal values; and disaffected foreign workers, many of them Palestinians, stirred up by radical forces in other lands.

Oil no longer flows from rich Saudi fields. Critical elements of the oil distribution system, systematically wrecked, lie in ruins. The giant terminal at Ras Tanura, which once sent half a dozen tankers a day down the Persian Gulf and out to the global oil routes, rusts silently under a scorching sun.

The free world has lost a fifth of its oil supply—some ten million barrels a day.

For a brief time the United States seemed not to feel the loss; its daily share from Saudi Arabia was less than a million and a half barrels, and there were stockpiles and a small strategic reserve to draw on. But events have destroyed any complacency. The oil glut of 1980, which cushioned the world's

EMORY KRISTOF

losses at the outbreak of the Iraqi-Iranian war, has long since evaporated. Bid up by the worst panic buying in history, prices on the spot market in Rotterdam are skyrocketing—$80, $100 a barrel (see definition in glossary of energy terms, page 23). Official prices of the oil cartel are heading for similar levels, if more slowly.

The 21-nation International Energy Agency has called on its members to fulfill an agreement signed in 1975: In the event of a major cutoff, they are to share their oil. Honoring that promise is costing the United States nearly three million barrels a day additional, for Western Europe and Japan are far more heavily hit than we are. Our total loss is now more than half the oil we were importing before the Saudi collapse. It equals more than half of all the oil consumed by our 160 million motor vehicles.

Domestically the effects are disastrous. Critical gasoline shortages have brought endless lines at filling stations, even though prices have reached painful levels. Violence frequently erupts when the pumps reach empty, and thefts from gas tanks are epidemic. The President has invoked the gasoline-rationing plan passed in 1980, but it will be months getting into operation.

Meanwhile, transportation is hamstrung; we are far short of the 110 billion gallons of motor fuel we are accustomed to burning each year. Many workers cannot get to their jobs; productivity drops. Businesses dependent on gasoline, such as shopping centers, resorts, motels, are suffering heavy losses.

All economic indicators are flying red flags. Unemployment has already climbed a million. The stock market drops daily. Inflation has passed 30 percent.

And all for the want of imported oil.

WHAT YOU HAVE JUST READ is, of course, an imaginary scenario. You may juggle the details, but many experts believe that something similar is almost certain to happen somewhere in the Persian Gulf within the next few years. Even as this is written, the bitter struggle between Iraq and Iran threatens to trigger all kinds of explosive disruptions in the Middle East.

Think back on the trauma of the gasoline lines following the Arab oil embargo of 1973-74 and the Iranian revolution in 1979. The losses were puny then compared to a cutoff of Saudi Arabian oil or—worse yet—all Persian Gulf oil. Yet the impact on American motorists is still a vivid and unpleasant memory. And the embargo, which lasted only six months, helped trigger the worst U. S. recession in 40 years.

The simple truth is that the United States—and most of the rest of the world—has an insatiable thirst for petroleum.

This unbridled appetite has left us vulnerably dependent on some of the most politically unstable parts of the world, bristling with ancient feuds, religious hatreds, and nationalist ambitions. Sizable amounts of our petroleum—called "hostile oil"—come from Libya and Algeria, neither of which bears any love for the United States. At any moment, as we have seen three times in less than a decade, war or revolution or political action in the oil-producing states can abruptly cut off shipments of vital importance to the West.

As London energy analyst Jonathan P. Stern sums it up: "Western vulnerability is such that any destabilizing force that even remotely threatens oil production sends massive shock waves through the industrial world. So delicate is the balance of the world oil supply that the cessation of supplies from . . . even a minor producing country for a comparatively short . . . time . . . causes major dislocations in supply and price."

HOW DID WE GET ourselves into this dangerous predicament?

The answer is clear. Of all the common fuels, oil is the most portable, the most convenient for transportation, the most versatile. It has seemed endlessly abundant. Above all, it was—until recently—cheap. Only a decade ago crude oil sold for less than two dollars a barrel.

And so we became addicted to oil. We built a way of life around it. Our love affair with the automobile has been possible because of it. Last year just under half of our energy needs were provided by oil.

But since late in 1947, when the United States became a net importer of oil, our own production has not been enough to sustain this life-style. Over the years, as demand increased, the imbalance has grown steadily worse. *(Continued on page 16)*

An American energy chronology

1758—*First recorded commercial shipment of American coal (32 tons from Virginia to New York).*

1825—*First natural gas extracted in the United States lights streetlamps in Fredonia, New York. For decades natural gas is regarded as a flammable nuisance. It does not become a practical industrial fuel until the end of the 1920s.*

1859—*Oil strike at Titusville, Pennsylvania, starts U. S. oil industry, but petroleum does not become the primary U. S. energy source for nearly a century.*

1879—*Electric streetlamps replace gaslights along Broadway in New York City.*

1885—*Coal surpasses wood as the main U. S. energy source.*

1913—*Ford assembly-line production brings car prices in reach of millions.*

1947—*U. S. changes from a net exporter to an importer of oil.*

1950—*Oil surpasses coal as main U. S. energy source.*

1957—*First sale of nuclear-generated electricity.*

1970—*U. S. oil production peaks.*

1971—*Federal price controls placed on petroleum.*

1973—*U. S. natural-gas production peaks.*

Arab nations embargo oil exports to the United States for six months.

1974—*World crude oil prices quadruple between October 1973 and March 1974.*

1975—*Congress passes Energy Policy and Conservation Act, which further regulates prices for domestic oil and provides for the Strategic Petroleum Reserve, automobile fuel-efficiency standards, and a variety of conservation measures.*

1977—*Department of Energy established; Solar Energy Research Institute formed.*

1978—*Iranian revolution causes slowdown of Iranian oil production and halts exports for three months.*

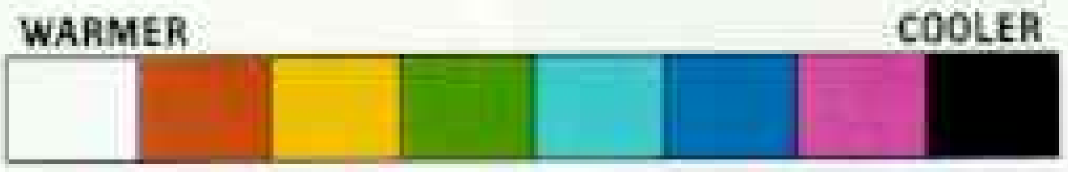
1979—*In Pennsylvania the Three Mile Island nuclear accident brings about a moratorium on nuclear-power-plant licensing.*

World oil prices double as a result of panic buying induced by the Iranian cutoff. Domestic crude oil averages $14.27 a barrel. Imported crude oil averages $21.67 a barrel.

1980—*At the December meeting of the Organization of Petroleum Exporting Countries, Saudi Arabia sets $32 a barrel as its base price for crude-oil exports.*

Iraqi-Iranian war begins; oil shipments from both countries are interrupted.

AN INFRARED LOOK AT PERSONAL INSULATION



WITHOUT fur or feathers, and with little fat, man protects himself through shelter, artificial heating or cooling, and, most basically, through clothing. Models wearing a sampler of seasonal attire (**far right**) appear as spectral figures in a thermogram (**below**), an image revealing differences in infrared heat radiated from their clothing and exposed skin. White is warmest, such as the recently run motorcycle engine. Red, yellow, green, blue, and magenta form a descending temperature scale spanning about 15°F, while black represents all lower temperatures. Almost the entire scale is seen on the

NEXT PAGE FOLDS OUT ▶

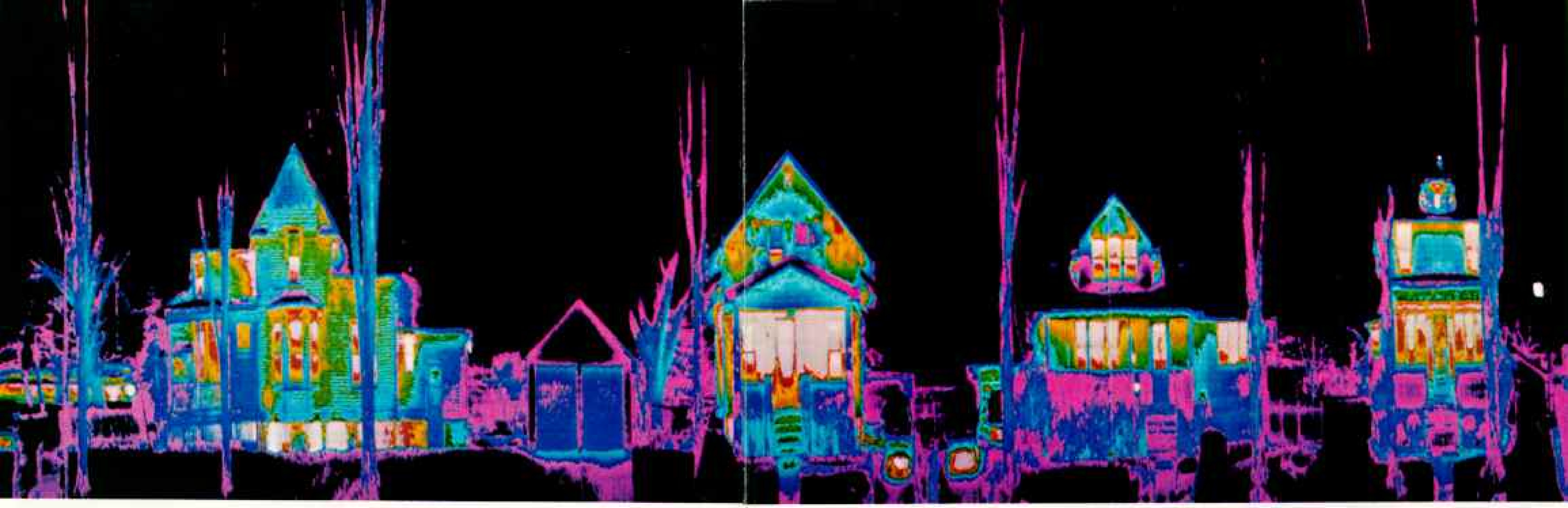
bikini-clad woman. Warm white spots appear on her underarm and neck. Only the bikini blocks radiation from her torso. Temperatures cool along her arm to dark blue fingertips, far from her heart and the body's heat engine. Summer clothing worn by her partner masks heat loss, except where it pulls against his chest and thighs.

Layered clothing on the three center figures shows heat-loss prevention. A down vest protects as well as the businessman's jacket and vest. Green and yellow on the motorcycle rider's neck reveal decreased insulation where her turtleneck emerges from her wool sweater.

Thermal underwear on the woman at right reduces heat loss, but contrasts sharply with the near-total retention signaled by the dark blues and black of her neighbor's parka, insulated pants and boots, and wool cap. On all the models, hands and faces show temperature variations due both to the models' clothes and their fit, and to differences in body build, circulation, and metabolism. In this era of plunging thermostats, when down-filled clothing has graduated from the outdoorsman's realm to the indoor person's world, comfort dictates that the warm choice is the wise choice.

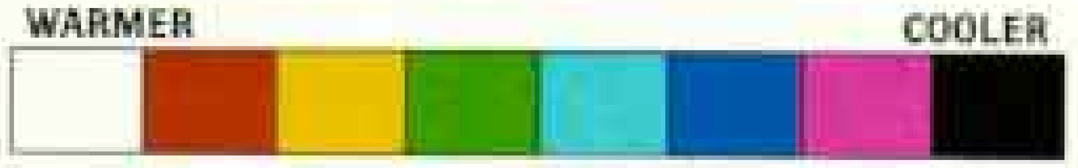
OUTDOOR CLOTHING COURTESY EDDIE BAUER, INC.

VANSCAN™ THERMOGRAM BY DAEDALUS ENTERPRISES, INC., ANN ARBOR, MICHIGAN (BELOW); JUNEBUG CLARK



HEAT LOSS: A THIEF IN THE NIGHT

WARMER — COOLER



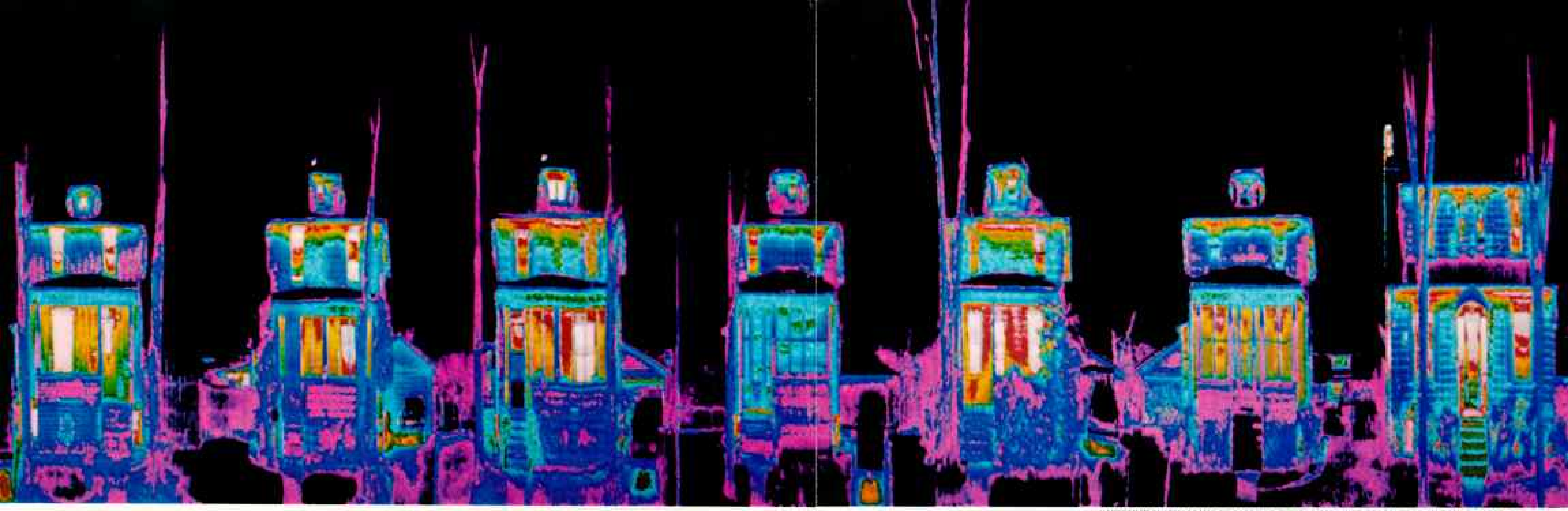
TO FOSTER a more energy-conscious community, the city of Plymouth, Michigan, launched a federally funded, innovative program using thermograms as a chief tool, both to heighten homeowners' awareness of conservation and to provide practical tips for insulating individual buildings.

In the small hours of two cold March nights, a van with an infrared scanner mounted in its side (**far right**) methodically patrolled the streets, recording the invisible temperature imprints of every building. Electronically transferred onto film, the data revealed houses like ghostly jack-o'-lanterns, lighted from within by escaping heat.

Plymouth mayor Mary Childs explains the program: "It points out things people can do themselves. And not only will they be more comfortable, they'll see the difference in their bills."

While absolute temperatures vary in different thermograms, temperature differences follow the same scale as on preceding pages (**color scale at left**). Windows and doors are the worst culprits, appearing white, red, and yellow as they radiate heat toward the cooler outdoors. Large display windows in an elderly commercial section (**bottom right**) show garish warmth. Cars on the street, themselves cool black and magenta, trap infrared heat beneath them in blue and yellow pools. A still-warm engine on the car farthest right glimmers red and white. Cooler tones in the store fourth from right reflect a lower thermostat setting. The three bright second-story windows of the building to its left show loss from an office with open shades, while the magenta window on their right opens onto an unheated closet. Most of the second-story windows farther to the right in the same group of buildings demonstrate the insulative benefits of drawn shades, appearing cooler even though they front apartments warmed by artificial means and by occupants' body heat.

Heat loss from an exposed foundation shows in the white strip at the base of the house next to the stores, leaking through the uninsulated stone from a basement warmed by a pottery kiln and uninsulated furnace and pipes. Similar foundation loss is seen in the house at far left (**above**) on a block of older two-story homes. To its right, past an unheated garage, a house built in 1923 shows severe heat loss through walls containing



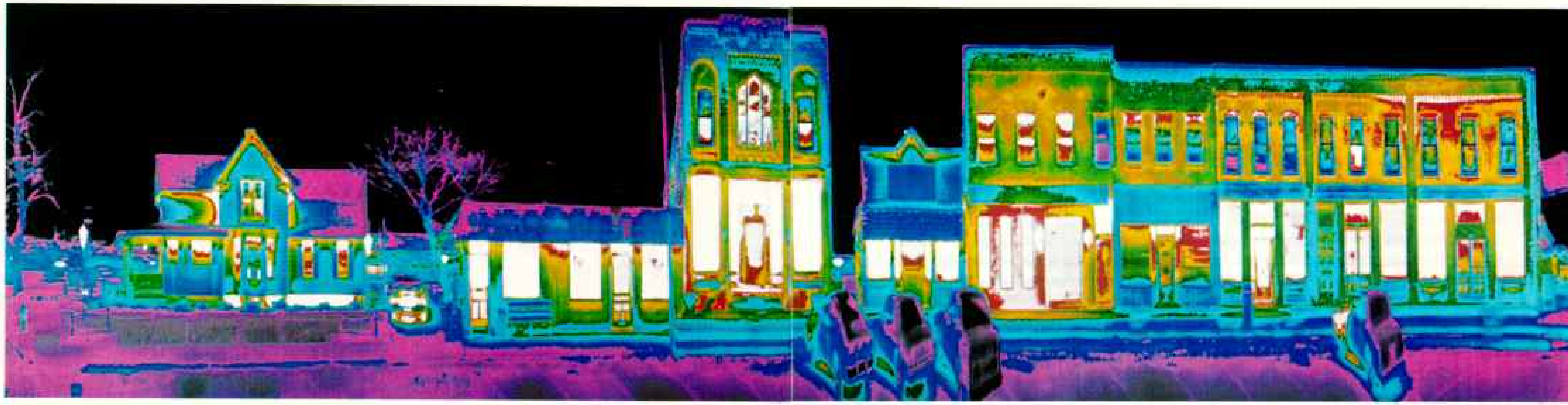
VANSCAN™ THERMOGRAMS BY DAEDALUS ENTERPRISES, INC.; HERBAL LONG (MIDDLE PHOTOGRAPH)

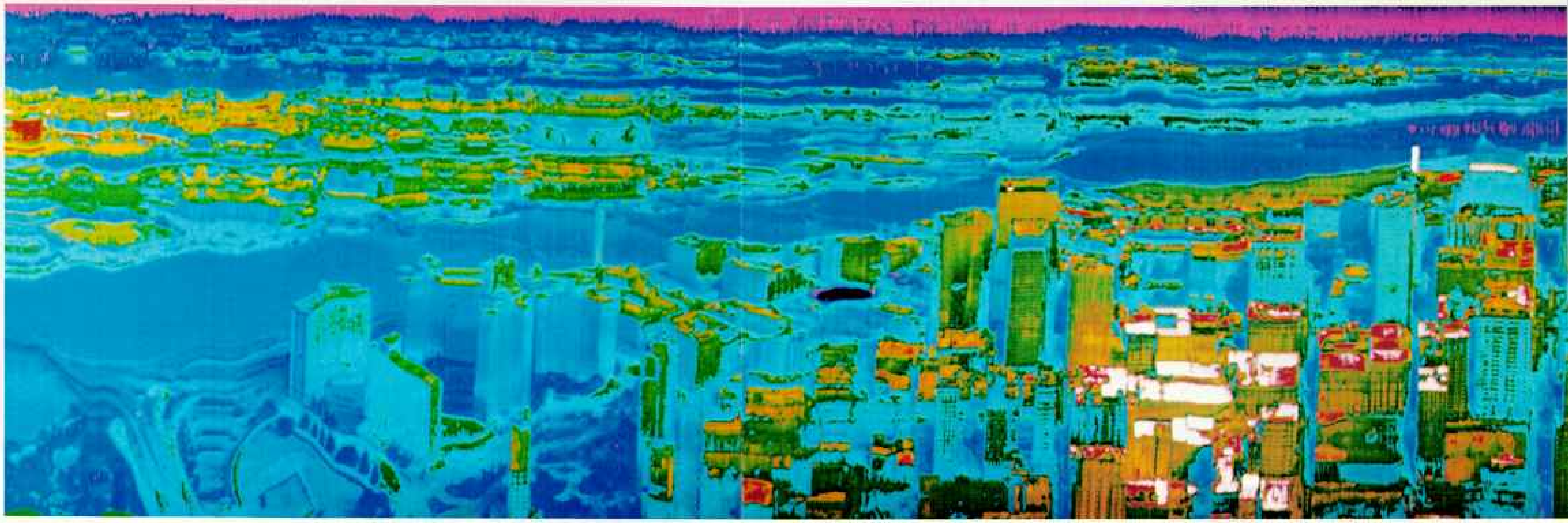
little or no insulation, woefully inadequate in today's battle against rising heating bills. When volunteers who interpret the thermograms to residents advised owner Michael Beauchamp to insulate his walls and attic, plug leaks in door and windows, and consider enclosing his porch, he summed up the reaction of many. "It's got to be done. When you're looking at $100 heating bills, it gets to be more than you can handle. It might be all right if we were paying for it and staying warm, but it's cold in here!"

The house fourth from right tells a happier story. "When I bought this house, it leaked like a sieve," Tom Richards recounts. Now with blown-in wall insulation, ten inches of attic insulation, a glass-enclosed porch acting as a heat lock, new storm windows and doors, caulking and weather stripping, and cardboard behind the attic dormer window (a hot spot in many of his neighbors' similar homes), his 1918 dwelling shows the least heat loss on the block.

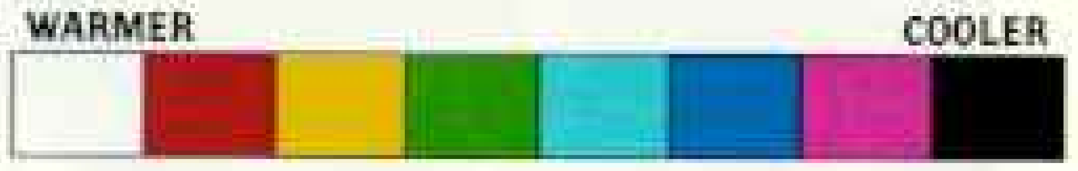
Ranch houses in a newer neighborhood (**below left**) also appear to show more efficient heat retention but have chinks in their armor.

Red and yellow windows blare radiation, while loose stripping tinges a front door yellow in the center house. On the roof of its neighbor to the right, above red and yellow windows, a chimney glows white, appearing even warmer than the red-and-white electrical transformer at its same height to the left. Poorly dampered chimneys suck warmth into the sky with a voracious appetite—just one of many thieves stealing heat in the night.





MAPPING URBAN HOT SPOTS



*WITHIN the massive heat machine of the city, distinct heat islands reveal themselves as clusters of white, red, and yellow roofs and walls in a thermogram of downtown Pittsburgh (**above**). Some warmth lingers from solar energy—the aerial scan was made under overcast skies on a day of intermittent sunshine. Additional heat escapes from cars and buildings. Warmth is trapped in narrow streets, and walls absorb infrared radiation from each other. Thus urban agglomerations modify their own environment.*

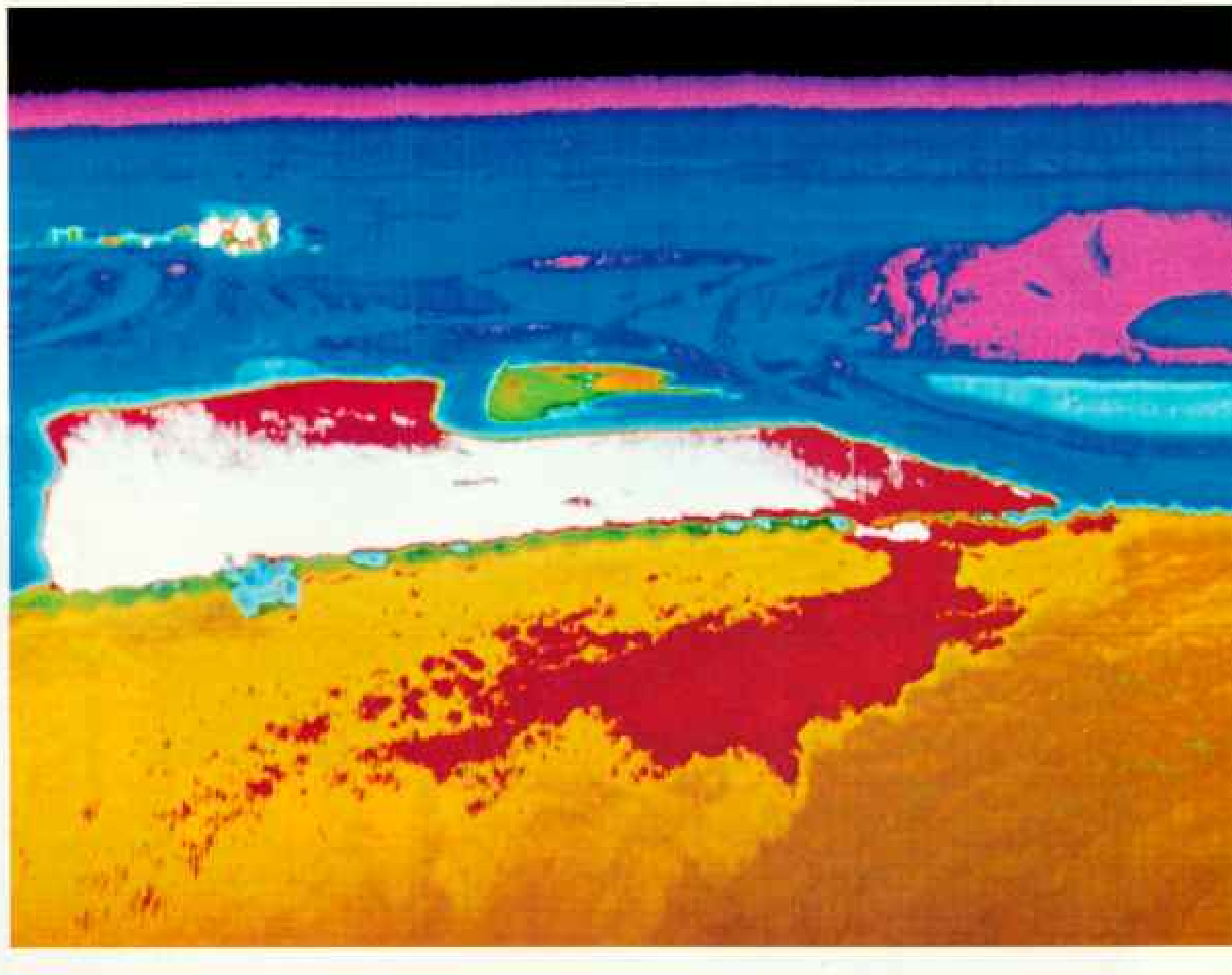
Low-storied masonry buildings from early in this century create the hot spot at center. Tar-and-asphalt roofs absorb and radiate solar heat; heat-stealing skylights and poor insulation from that era add to walls' and roofs' brightness.

Built in the 1950s, high rises near the bridge at far left appear much cooler, due in part to their steel walls; different materials, even at the same temperature, send varying signals to the scanner. Metal often appears deceptively cool. But the roofs, of similar materials to those in the hot spot, appear strikingly cooler due to more modern insulation.

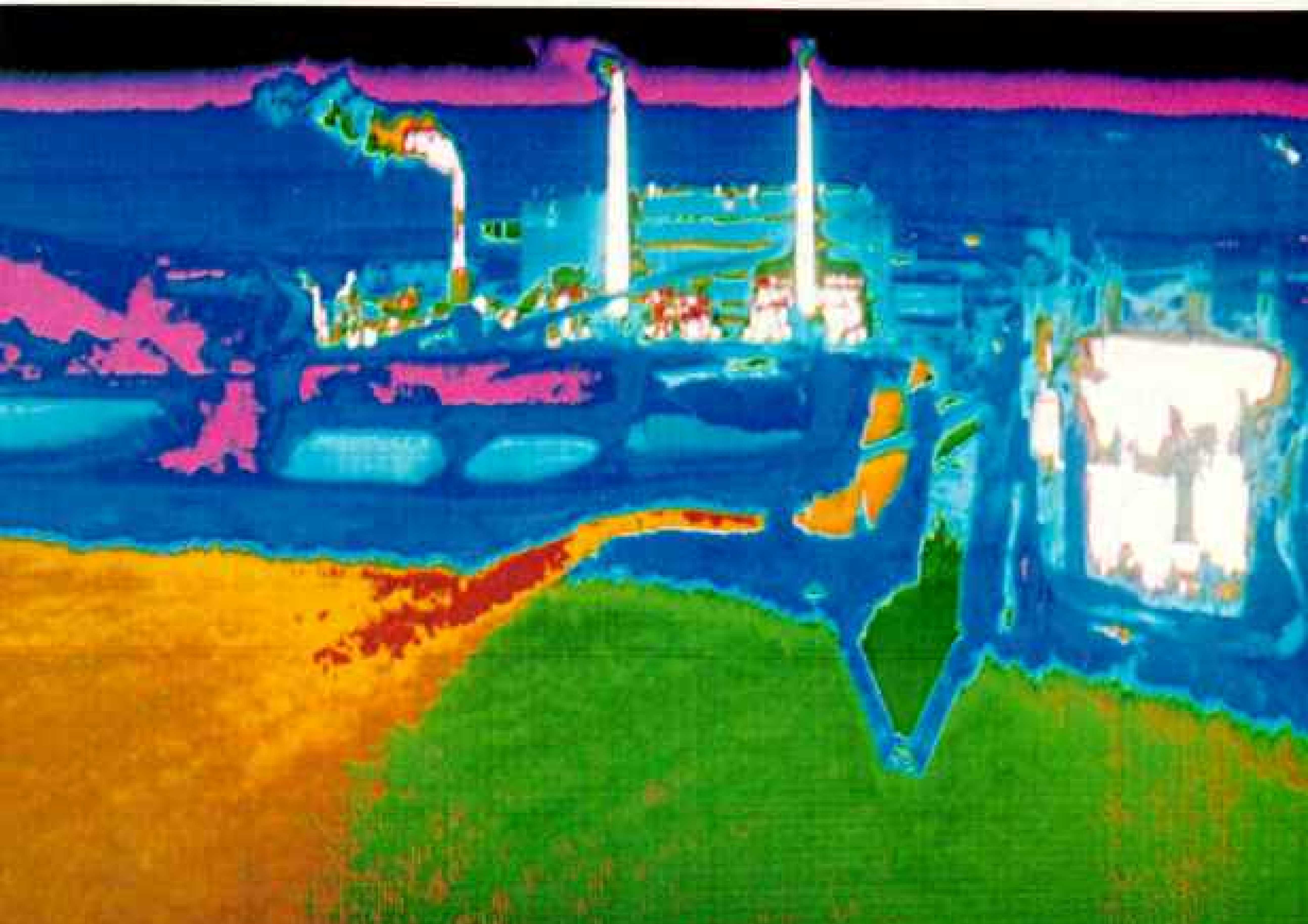
The monolith of the U. S. Steel building reveals vertical coolant-filled columns installed for fire safety, here distorted by the airplane's motion. Horizontal bands at middle and top are windowless machinery floors. Horizontal and vertical white strips to the left represent a warm copper roof and the stack of a steam-heating plant. Approach roads to the bridge at far left appear lighter blue than the bridge, illustrating the familiar warning, "Bridge freezes before road."

*Beside Lake Michigan, in Gary, Indiana, a coal-fired power plant's stacks glow white at midnight (**right**). Coal makes a magenta mound behind blue ash-settling ponds. Cool lake water flows toward the plant in the canal at right, returning in its crooked neighbor with heat (red and yellow) from the firing units. At far right, warmth radiates from a limekiln. At far left, a cooling pond for the factory behind it adds more warmth to the lake. The thermogram shows the waste of energy in the making of power. When we can see the waste, we can begin to reduce it.*

THERMOGRAM TEXT BY DOUGLAS LEE



AIRSCAN™ THERMOGRAMS BY DAEDALUS ENTERPRISES, INC.



(Continued from page 4) Domestic oil production peaked in 1970. In every year but one since 1967 we have used more oil from our proved reserves than has been found in new reservoirs.

When our own oil production became insufficient, it was all too easy to supplement it with cheap oil from abroad. A few voices reminded us that petroleum was a finite resource and that we should prepare for the day when it would be exhausted. But hardly anyone paid attention. Foreign purchases meant little until the Organization of Petroleum Exporting Countries (OPEC) quadrupled crude-oil prices during the 1973-74 embargo. Instead of $3 a barrel, the liquid black gold was suddenly priced near $12.

Shock surged throughout the non-OPEC world. Of the large industrial nations only the Soviet Union produced all the oil it needed. The less developed countries, with far less money to spend, were stunned.

Dismayed by the dwindling purchasing power of the dollar, OPEC continued to ratchet up its prices. By 1980 the benchmark, or base, price had been set at $32. Many oil countries charged substantial premiums, and traders on the spot market demanded even more.

In 1970 our national bill for imported oil was three billion dollars. In 1978 it was 42 billion. In 1979 it topped 60 billion. In 1980, even though conservation efforts and the recession significantly reduced the volume of oil imports, the price for those imports reached the staggering figure of 80 billion dollars. That was a quarter of a billion dollars every day for imported oil.

Such a drain has seriously skewed our balance of trade. Last year all our agricultural exports, on which we depend heavily to make up our trade deficit, amounted to only about 40 billion dollars.

This hemorrhage of money has played a significant part in the weakening of the American dollar in international exchange and in stimulating inflation at home. Recession and unemployment have been aggravated. And not the least of the repercussions is the haunting fear that action to protect our foreign supply of petroleum will lead to a major war.

In every way we are paying an extravagant price for our energy-rich way of life.

The problem has not been entirely oil, of course. The whole U. S. economy has been heavily dependent on cheap energy—cheap electricity, cheap natural gas, cheap coal, cheap hydropower, as well as cheap oil.

Except for hydropower, which requires no fuel, these energy sources are no longer cheap, and their escalating cost is itself a serious matter. But none poses the sobering threat of economic dislocation, social disruption, and national peril that accompanies every barrel of imported oil.

What's to be done about it? Can the American people find long-range solutions to this problem of voracious demand versus uncertain supply? Can we manage to get through the critical years until the big solutions may be ready? Understanding six basic truths about energy may help.

1. We are not running out of energy—yet.

It is an irony that we should be caught in an energy bind. The United States is one of the richest nations on earth in energy raw materials. We have the world's largest single share of coal reserves. Even though we import oil, we are the world's third largest producer of petroleum. We are at the moment virtually self-sufficient in natural gas. And we have by far the largest nuclear power output of any nation.

Further, as energy prices escalate, it becomes more and more profitable to search for ways to exploit marginal resources. For example, conventional oil pumping can get only about a third of the oil out of the ground. But so-called tertiary methods, using steam, carbon dioxide, or detergents, can eke out additional amounts. Similarly, high prices are leading to attempts to wrest oil from shale and other formations that do not give up their wealth easily.

Though our known gas reserves have been shrinking rapidly, optimists are excited about prospects of enormous unconventional deposits, especially in "tight sands" formations. If they can be exploited, our usable gas reserves would be expanded manyfold.

2. Fossil fuels are, however, finite.

The bounty of hydrocarbon fuels—coal, oil, and gas, which biology and geology conspired to trap underground millions of years ago—is limited, and it is not being replaced. Once a barrel of oil is burned, it is gone forever.

Over the long sweep of history, human beings will look back and note with awe (and chagrin) that their ancestors stripped the planet of most of this exhaustible endowment within the span of a few hundred years. Twentieth-century people alone will have used up the bulk of it.

Many analysts believe that, despite the current frenzied search for new deposits, the dwindling of our proved reserves of oil and gas can only be slowed, not halted.

If unconventional sources should not come through, gas reserves would be gone in another ten years at recent rates of use, without any further additions. And the new finds of the past decade have averaged only about half of what we consumed.

The oil situation seems no less gloomy to many experts. As Earl T. Hayes, former chief scientist at the U. S. Bureau of Mines, points out: "There is no longer much argument with the conclusion that U. S. resources of conventional oil will be seriously depleted by the year 2000."

Oil company officials concur that the prospects for finding much more U. S. oil are bleak. Gulf Oil executive Robert W. Baldwin says, "There's no way, over the long run, that you can reverse the decline curves on crude-oil reserves in the U. S."

Government energy officials say that Alaskan production may level off soon. Prudhoe Bay, largest find in U. S. history, could be exhausted in another ten years at the current rates of extraction.

Moreover, government reports indicate, the situation abroad is not much different. Oil production in the Soviet Union, largest producer in the world, is expected to peak in the early 1980s. And the rich North Sea fields will probably begin to decline by 1984.

Arabia's wealthy oil sheikhs recognize

FEWER IMPORTS, MORE CONSERVATION, INNOVATIVE NEW SOURCES

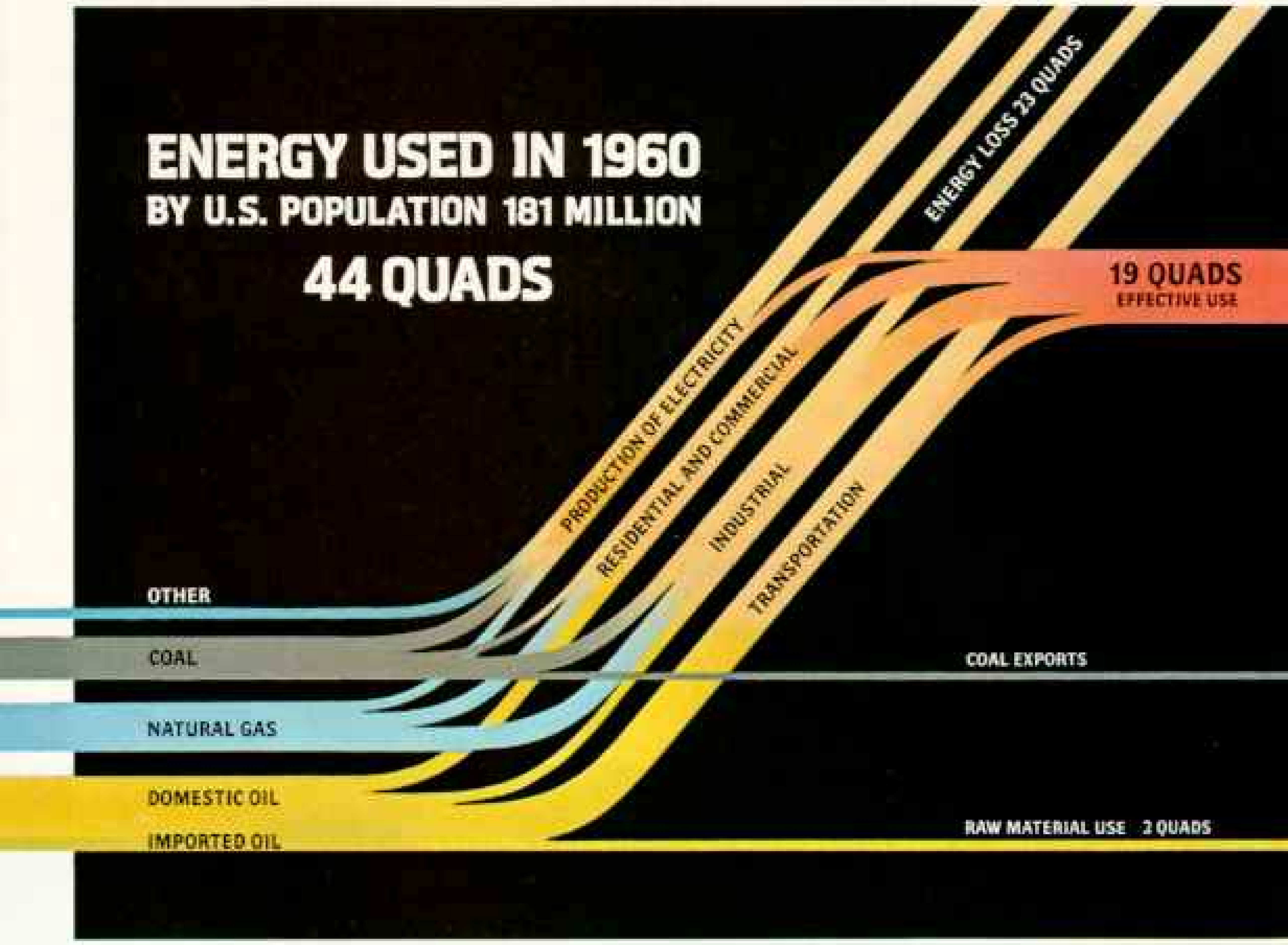
Oil in the United States was plentiful and cheap. In 1970 imports cost about 3 billion dollars. Despite the 1973 Arab oil embargo and subsequent soaring prices, the U. S. more than doubled oil imports in the '70s.

By 1979 the U. S. oil import bill had jumped to 60 billion dollars and energy use peaked at 79 quadrillion Btus. In 1980 consumption declined, reflecting conservation and recession.

In the '80s oil imports will be constrained, domestic production encouraged by price decontrol, and power plants will convert to coal. Prices and government actions will result in more fuel-efficient cars and homes.

The economy will likely shift from oil and natural gas to coal, nuclear, and synthetics. Coal will become the nation's primary energy source, though nuclear may become the major producer of electricity.

DATA AND INTERPRETATION BASED ON ENERGY INFORMATION ADMINISTRATION PROJECTIONS



Energy sacrificed *to convenience, 45 quads of power were "lost" in 1979—more than the total U. S. energy outlay in 1960. Heat lost in engine combustion*

that even their vast pools could be played out within a few decades.

Coal is the one fossil fuel whose reserves are so immense that they are not in danger of exhaustion within the near future. But rapid expansion of facilities for coal transport is difficult. Moreover, the burning of coal poses special problems of serious pollution that may sharply limit its usefulness within a few years.

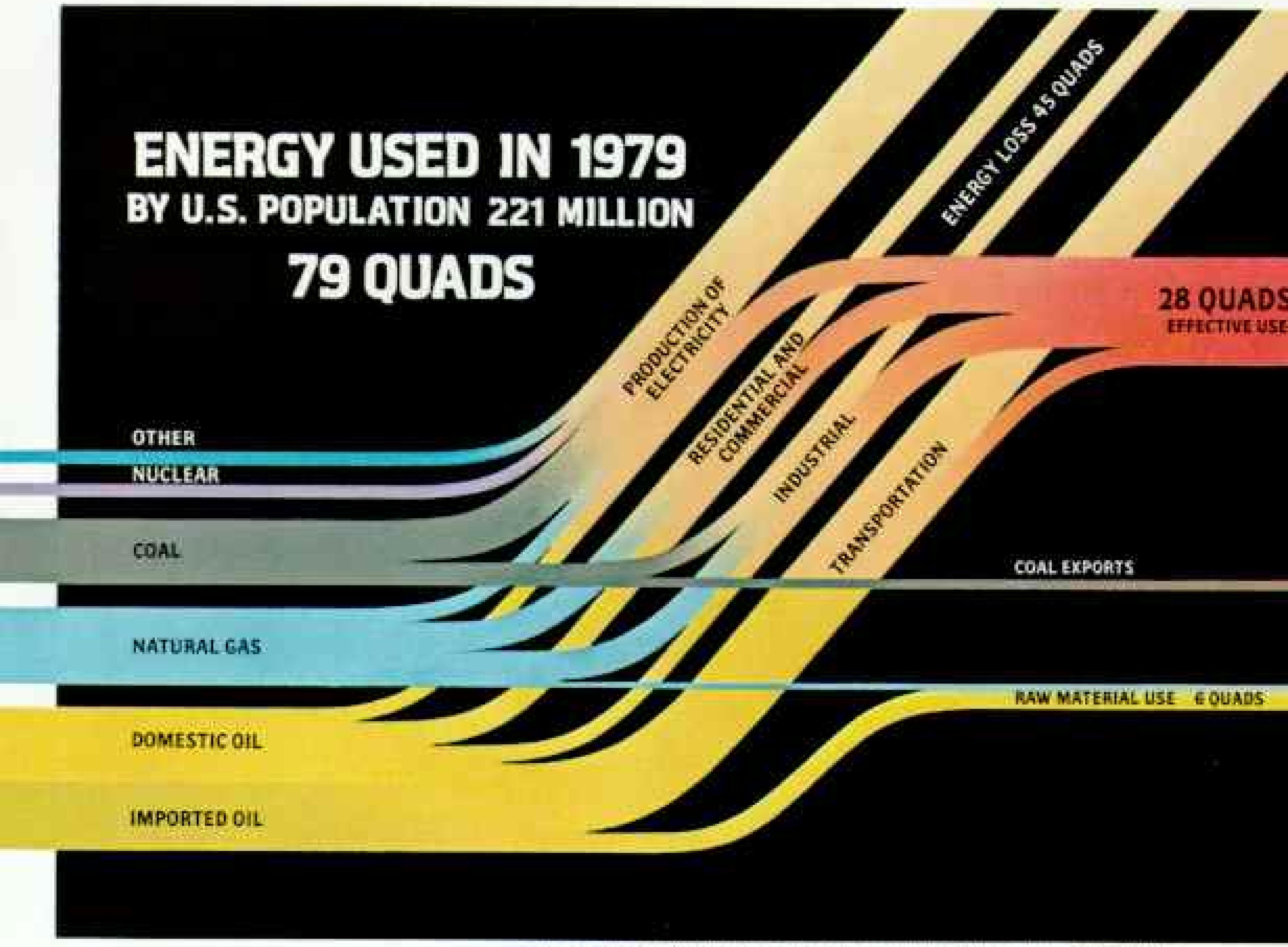
3. There is no quick fix.

Americans like to believe that technology will solve any problem quickly if we work at it hard enough and throw enough money at it. After all, we sent men to the moon, didn't we?

But in the case of energy such a belief is compounded of wishful thinking and a lack of understanding of the limits of technology when faced with complex and intractable problems. It also fails to appreciate that often the obstacles are not technological but institutional—for example, pressure from interests that feel they would be adversely affected by new developments, or inertia on the part of builders, unions, architects, local government officials, and the buying public.

One has to look back in history only a little way to see how the most ambitious plans can go awry. In 1973, at the time of the Arab oil embargo against the United States, the administration unveiled with much fanfare a Project Independence. Said the President, "By the end of the decade we will . . . meet our own energy needs without depending on any foreign energy sources."

Today, after more than seven years, we are frighteningly further away from energy independence than we were then. The much heralded plans for huge increases in nuclear



DATA FROM U.S. DEPARTMENT OF ENERGY; ART BY PAUL M. BREEDEN; COMPILED BY MARGUERITE B. HUNSIKER

and along transmission lines, and conversion losses in the production of steam to turn turbines, make transportation and electricity the big "losers."

energy, coal production, development of shale oil, and coal liquefaction, were all laid aside or delayed.

Unfortunately, all the major solutions that may have a *substantial* effect on our fuel supply are years away, usually much further than their sponsors care to admit. They require development and careful testing of new technologies, mobilization of many billions of dollars in new capital at high interest rates, and construction of gigantic facilities. They often involve such risks that private enterprise will tackle them only after extensive subsidies and guarantees by the federal government.

For these reasons, energy analysts do not expect any large contribution from such new sources as shale oil, oil from coal, or geothermal energy until the 1990s or later.

The renewables—biomass, electricity from the sun, ocean thermal energy, wind power, and so on—also will be slow in coming, although the Department of Energy has been working toward a goal of 20 percent from those sources by the year 2000.

And fusion—the great hope of abundant, renewable energy—is likely 40 years or more away, even though this $600,000,000-a-year federal program is expected to become the largest effort ever concentrated on a single technological advance anywhere.

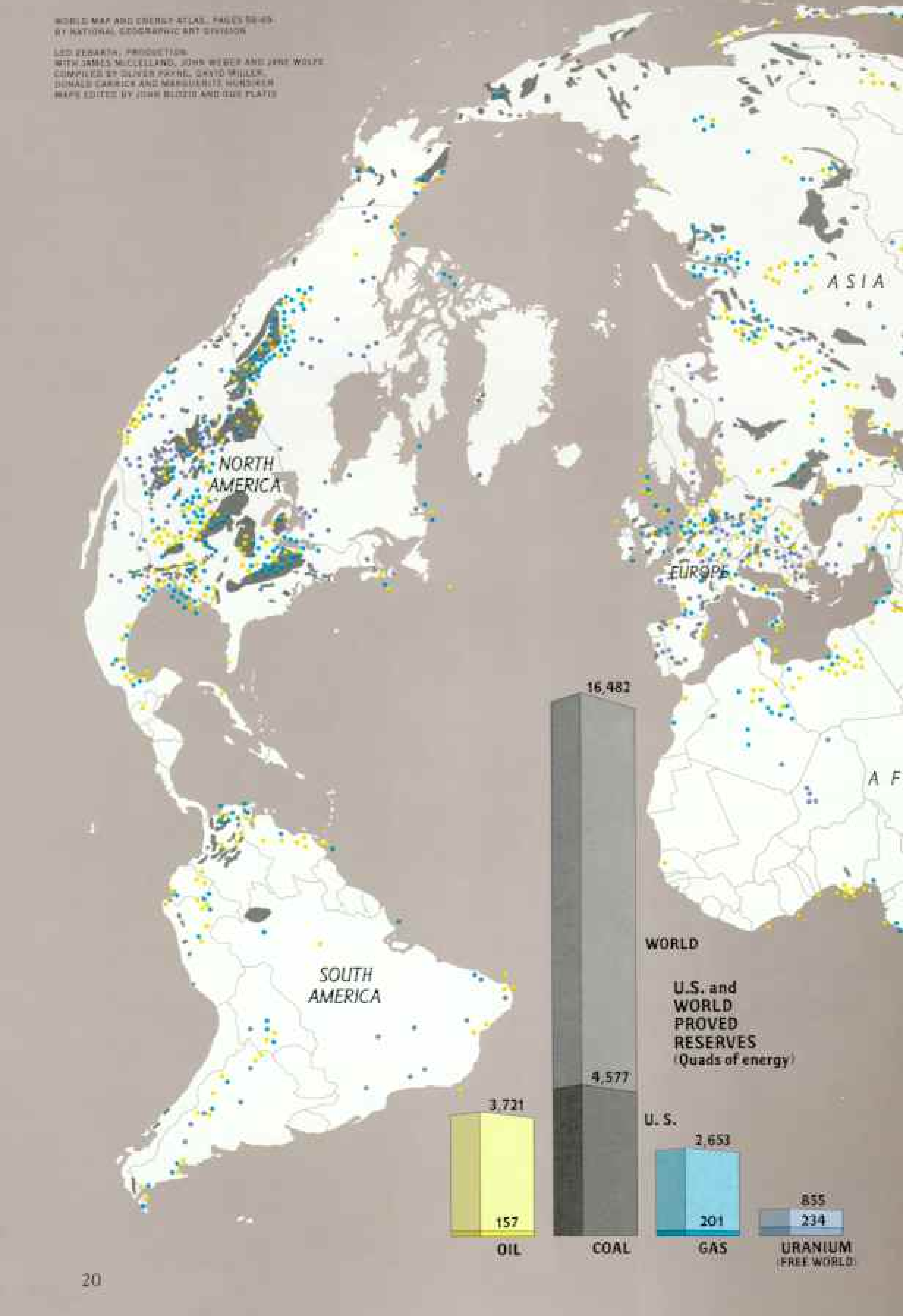
4. There is no free lunch.

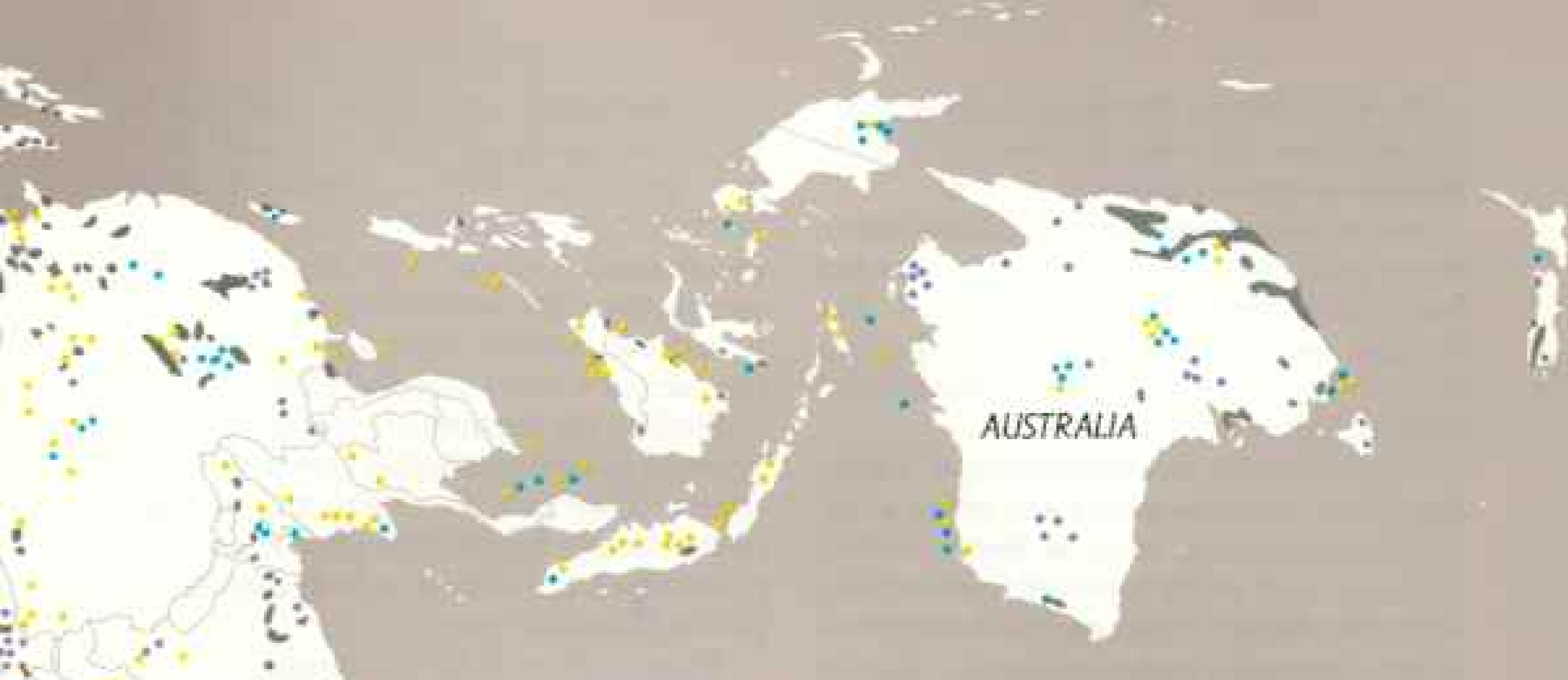
Virtually every proposal for adding to our energy supply involves hidden costs, unpleasant side effects, and uncertainties.

Nuclear energy, for example, already provides a tenth of the electricity in the United States, and would be capable of rapid expansion if licensing procedures were greatly speeded up. A dozen new plants could be licensed this *(Continued on page 22)*

WORLD MAP AND ENERGY ATLAS, PAGES
BY NATIONAL GEOGRAPHIC ART DIVISION

LEO ZEBARTH, PRODUCTION
WITH JAMES McCLELLAND, JOHN WEBER AND JANE WOLFE
COMPILED BY OLIVER PAYNE, DAVID MILLER,
DONALD CARRICK AND MARGUERITE
MAPS EDITED BY JOHN BLOZIS AND GUS PLATIS





WORLD ENERGY RESOURCES

Haves and have-nots

THE FUELS shown here account for about 94 percent of the world's energy production—297 quadrillion Btu's in 1979. Coal fills 27 percent of the global energy budget—a rate of use that would not deplete known reserves until the 22nd century. Oil supplies some 134 quads a year—a rate that would exhaust present reserves in about 30 years. But oil consumption continues to rise; many experts think it will peak around the year 2000 at about 165 quads—exhausting known resources much sooner.

Some geologists estimate that yet-to-be discovered deposits of oil and gas will equal present reserves. New coal resources may double those we now know of, while uranium may exist in quantities several times the proved reserves.

Nature was not democratic in dispersing its wealth. Many areas of south Asia, though teeming with people, are energy starved. The vast interiors of Africa and South America appear as fossil fuel deserts. These regions, however, have been little explored.

The industrialized regions to the north, rich in coal and uranium, are also comparatively well off in oil—the U.S.S.R. being the world's largest producer, and the United States number three, after Saudi Arabia. There are critical exceptions: Japan must import 90 percent of all its energy, while Western Europe—whose only significant oil lies in the North Sea—imports more than half.

As energy resources rise in value, they gravitate to the developed nations, mostly in the north, where only a quarter of the world's people enjoy some 80 percent of its wealth. The growing disparity between these nations and the poorer ones to the south has spawned a "north-south" dichotomy in world politics.

year, according to the Nuclear Regulatory Commission. All told they would increase nuclear megawattage by 25 percent.

But nuclear energy bears the handicap of worry over radioactivity—a worry that has been sharpened by Three Mile Island. The breeder reactor conjures up fear that the plutonium it produces might increase proliferation of the nuclear bomb.

Coal also poses serious handicaps. Unfortunately it contains sulfur and other undesirable substances, such as heavy metals, which are only partly removed from burning emissions despite costly and difficult procedures. The sulfur emissions damage human lungs; they combine with moisture in the atmosphere to form acid precipitation that defaces monuments and buildings and kills the life in countless lakes.

Of far greater portent is the accumulation in the atmosphere of carbon dioxide from burning coal and other fossil fuels. Carbon dioxide tends to trap heat on the earth's surface; in sufficient concentration it could create the dreaded greenhouse effect.

Studies in both the United States and the United Kingdom forecast that the concentration of carbon dioxide by the middle of the next century will be double what it was before the industrial revolution.

Such a concentration, say some scientists, could increase average global temperatures by two degrees Celsius, and polar temperatures by as much as seven degrees. That much warming, slight as it may seem, would seriously affect distribution of rainfall and could create deserts of much of the Northern Hemisphere breadbasket. It would be an irreversible catastrophe of unparalleled magnitude, affecting all mankind.

Other energy sources offer their own peculiar problems. Synfuels involve extensive strip mining, enormous cost, and demands for water that may be prohibitive. Solar electricity also will be costly. And it may run into interesting legal problems: New Mexico is the only state that protects a solar collector from being blocked by another structure.

Wind turbines will have to be given sites with great care to avoid aesthetic problems. The noise they produce has proved to be objectionable in some cases, and in large numbers they may create interference with communications.

Alcohol from agricultural products for use in cars raises the specter of food versus fuel. As Lester Brown, president of the Worldwatch Institute, warns, "The potential demand is virtually limitless: even converting the entire world grain crop to alcohol would not provide enough fuel to operate the current world automobile fleet."

Finally, the burning of biomass, favored by some environmentalists, greatly worries others. They fear that there will be rapid destruction of forest lands and serious deterioration of agricultural soils if they are deprived of organic matter.

There is, indeed, no free lunch.

5. The energy problem is global; what we do affects everybody else.

Americans, who spend more than a quarter of the world's energy output, have been called a consumption-drugged people. The average U. S. citizen uses the energy equivalent of a barrel of oil every six days.

"The rest of the world looks with virtual disbelief" at our energy failures, says a preliminary report to the National Academy of Sciences' Committee on Nuclear and Alternative Energy Systems, which led to the major study *Energy in Transition 1985-2010* (the CONAES Report). And even Saudi Arabia, our strongest OPEC ally, is said to be disappointed in our conservation efforts.

Heavy U. S. demands for oil are of immediate consequence to other nations: Western Europe must get 55 percent of its energy from oil; Japan gets 75 percent. And since most of these nations have little or no oil of their own, U. S. competition in the oil markets of the world is significant.

A new competitor may soon complicate the situation further. The Soviet Union now regularly exports part of its 12 million barrels a day to its satellite states in Eastern Europe as well as to the West. But according to estimates of the U. S. Central Intelligence Agency, Soviet oil production is about to peak and will soon drop; by the mid-1980s the Soviet Union will be an oil importer.

What covetous advances the Soviet Union might then make toward the rich oil sands of the Middle East can only be guessed, but it is a matter of grave concern to many nations already scrambling to keep their oil tanks filled.

Meanwhile, other nations are seeking to move away from oil as rapidly as possible. Just as in the United States, they are increasing their investment in solar, geothermal, and wind power. France, the Soviet Union, and Japan, for example, are expanding their nuclear facilities. France, especially, has committed itself to an aggressive nuclear development that is expected to produce 20 percent of the nation's energy by 1985 and a possible 50 percent by 2000.

These efforts are of extreme importance to us. The security and welfare of all countries of the West are completely intertwined, and we are vulnerable together to oil cutoffs.

6. Energy efficiency and conservation are all-important from now on.

As we have seen, major new energy technologies take too long to help much in the 1980s. Even if large new gas and oil fields are discovered, they, too, will require years of development.

How, then, do we become less vulnerable to disruption of our foreign oil supplies?

Study after study reaches the same conclusion: The cleanest, least expensive, and least vulnerable energy option today is to use less by being more efficient.

As Chauncey Starr of the Electric Power Research Institute says, "Only conservation can be implemented quickly enough to make a substantial difference."

It means cogeneration of electricity along with industrial heat, developing ever more efficient automobiles, car pooling, improving building designs, using more and better insulation, and so on.

Last year alone, conservation efforts combined with effects of the recession reduced our annual oil imports by nearly 20 percent, with daily shipments dropping from 7.9 million barrels in January to 6.5 in December.

The CONAES Report sums it up:

"The problem is in effecting a socially acceptable and smooth transition from gradually depleting resources of oil and natural gas to new technologies whose potentials are not now fully developed or assessed and whose costs are generally unpredictable. . . . The question is whether we are diligent, clever, and lucky enough to make this inevitable transition an orderly and smooth one." □

ENERGY TERMS

Barrel—*A liquid measure of oil, usually crude oil, equal to 42 gallons or about 306 pounds.*

Barrel of oil equivalent—*Energy equal to a barrel of crude oil—5.8 million Btu's.*

Biomass—*Living matter, plant and animal, in any form.*

Btu (British thermal unit)—*The amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. About a quarter of a Calorie.*

Carcinogen—*A substance or agent producing or inciting cancerous growth.*

Cogeneration—*The production of two useful forms of energy from the same process. In a factory, for instance, steam needed for industrial processes or space heating is first run through turbines to generate electricity.*

Efficiency—*The ratio of useful work or energy output to total work or energy input.*

Fossil fuels—*Fuels such as coal, crude oil, or natural gas, formed from remains of plants and animals.*

Gasohol—*In the U. S., a mix of 90 percent unleaded gasoline and 10 percent ethyl alcohol.*

Geopressured gas—*Natural gas that is dissolved in hot brine and trapped under great pressure deep within the earth.*

Greenhouse effect—*The warming effect of carbon dioxide and water vapor in the atmosphere. These molecules are transparent to incoming sunlight but block infrared (heat) radiation escaping from the earth.*

Megawatt—*A unit of power equal to 1,000 kilowatts, or one million watts. A gigawatt is a billion watts.*

OPEC—*The Organization of Petroleum Exporting Countries, 13 nations that aim at developing common oil-marketing policies.*

Photovoltaics—*The process by which radiant (solar) energy is converted directly into electrical energy using a solar cell.*

Quad—*A quadrillion Btu's. The energy contained in eight billion gallons of gasoline, a year's supply for ten million automobiles.*

Renewable energy source—*One that is constantly or cyclically replenished, including direct solar energy and indirect sources such as biomass and wind power.*

Reserve—*That portion of a resource that has been actually discovered but not yet exploited and which at present is technically and economically extractable.*

Synfuels—*Fuels synthesized from sources other than crude oil or natural gas and used in place of them or their derivatives, primarily for transportation and heating boilers.*

America's auto mania

By DAVID JEFFERY
Photographs by BRUCE DALE
BOTH NATIONAL GEOGRAPHIC STAFF

THE AUTOMOBILE carries us to our birth, conveys us to the grave, transports us on the errands of mortality, and stands parked at the center of our energy problem: The freedom of mobility it grants costs us about 30 percent of all the petroleum we burn. It has been, and still is, a costly status symbol, although taste born of necessity now savors the well-made, fuel-efficient car. The automobile also transcends the utilitarian to become art, at least in California.

To the layman a flamed '34 Ford coupe (***above***) cruising Van Nuys Boulevard in Los Angeles might be taken at face value as the California Kid. The connoisseur, however, knows it for a kind of starlet stand-in, one of ten or so copies from across the United

States and Europe mimicking the original that Pete Chapouris built—the hot-rod star of the movie *The California Kid*.

If the Kid has become, as Chapouris says, "a piece of folklore" in a nation dedicated to the four-wheel pursuit of happiness, Second Decorated Car with its San Francisco area creator, David Best (***right***), is avant-garde rococo. Best belongs not to a salon but to an "art gang," where he holds the title of chaplain. His car is encrusted with found objects and about 500 glass eyes. Its motifs are death and violence on the highway, as influenced by the pageantry of Spanish religious floats and by Victorian sewing boxes. More recently, the water buffalo hood ornament was stolen. "In a way it was an appropriate ending," says Best.

JAMES A. SUGAR

REINCARNATION. That is the fate, the karma, of most automobiles. But that destiny is being postponed as people abandon the idea of throwaway cars and drive them longer to save money and, eventually, energy. Obsolescence has become obsolete, and lowered speed limits have reduced both human and sheet-metal carnage on the highways.

Imported cars have become increasingly popular, partly because buyers believe them to be better built, longer lived, and less wasteful of fuel. Yet every car finally expires. Most end in junkyards, where they still have useful life; batteries are taken for their lead, and crankcase and lubricating oil may be salvaged as fuel to fire boilers.

Junked cars are also a source of parts for the artist, the customizer, the restorer, or anybody who needs, say, a grille for a 1956

Chevy. Beyond that, the car may be mashed flat and freighted to a shredding and reprocessing center such as Sidbec-Feruni Inc. (***above***), located at Contrecoeur, Quebec.

Large-scale reprocessing of junked cars for their steel goes back at least to the late 1930s, and scrap now makes up about a third of new steel produced. So a showroom beauty may have within it remains from Studebakers, Packards, Edsels, DeSotos, Nashes, Kaisers, Hudsons, Crosleys, and Willys Aeros. And, of course, washing machines and toasters have their odd molecules of Cadillacs, Lincolns, and Chryslers. Yet despite the recycling of steel, the manufacture of new cars still accounts for 10 percent of all industrial energy use.

About a fifth of junked cars are bulldozed into landfills or rust away in weedy obscurity, never to be reborn.

OUR DRIVE-IN SOCIETY extends to every phase of life, and even beyond, as Americans eat, bank, watch movies, and worship from their automobiles—modern centaurs with steel bodies and human heads and hands.

Rush hours and rainy weather are popular times for the motorized bereaved to view the deceased at the drive-through facility (***left***) of the James N. Davis Funeral Home in Jacksonville, Florida.

In Orange County, California, many parishioners worship, take Communion, and contribute from their cars (***below***) at the Reverend Robert H. Schuller's Garden Grove Community Church.

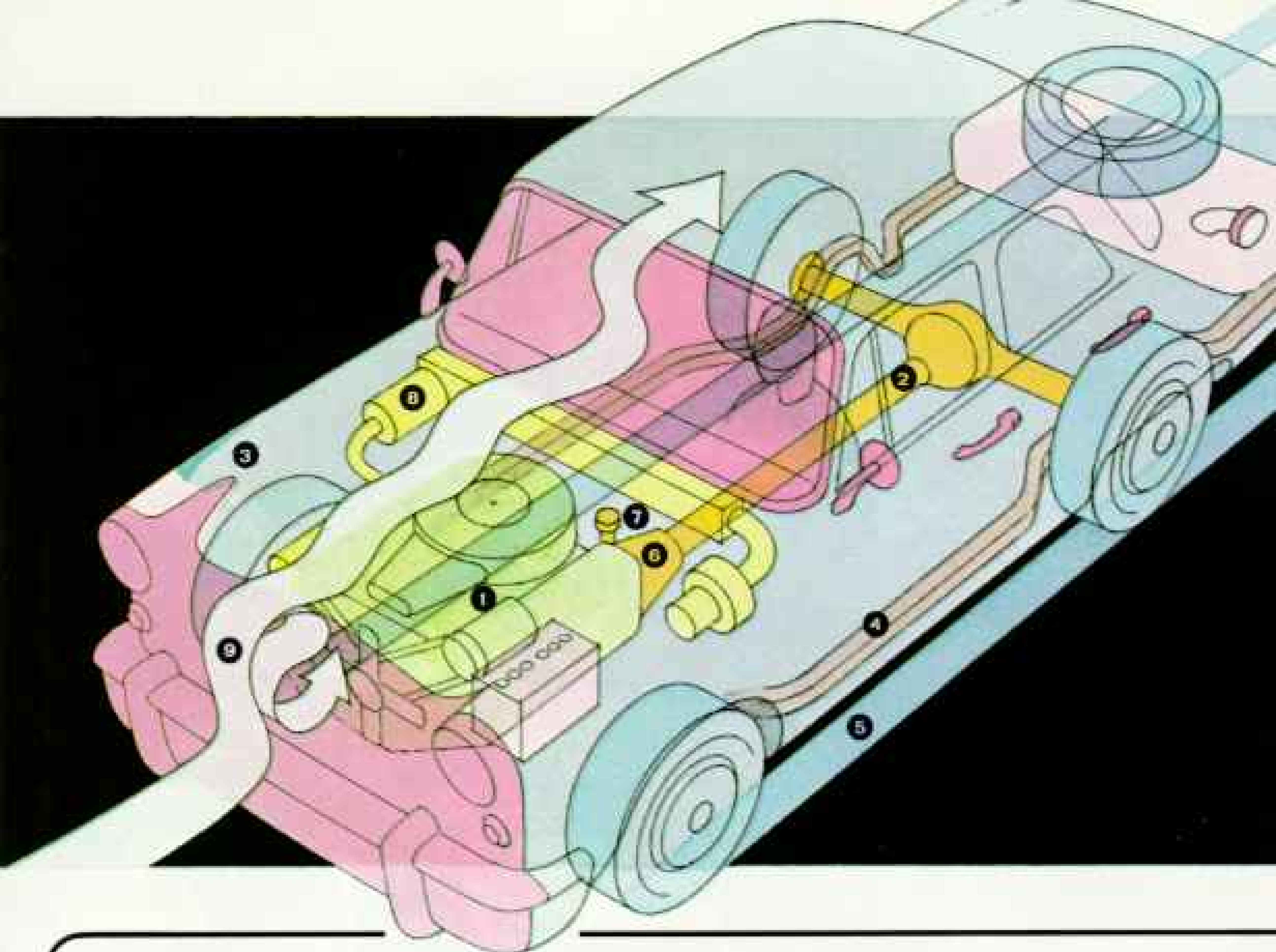
Vince Bruner owns and manages Robinson's Cruz Thru (***bottom***) in Fort Walton Beach, Florida; about half his business is draft beer to go, legal in Florida when the container is capped.

LIFE IN THE FAST LANES belongs to car and van pools, as well as commuter buses, for rush-hour sprints back and forth across the San Francisco-Oakland Bay Bridge (***above***). Pool vehicles with three riders aboard are exempt from tolls, and control lights for their exclusive lanes are always green.

Not far away, along the equally busy Golden Gate Bridge corridor, riders and drivers have joined in cooperative hitchhiking called the Commuter Connection. Instead of a thumb, each hiker displays a sign noting his destination. Drivers with similar signs on their sun visors make the pickup.

As ingenious as some energy- and money-saving uses of cars may be, a very large problem remains for American cars. The popularity of small, fuel-efficient imports, such as the ranks of mostly Japanese cars put ashore in Long Beach, California (***right***), has brought economic dislocation to domestic producers. Blame has been passed out in many directions, and while solutions may be in sight, they are not yet in hand. America's love affair with the car goes on, with the subcompact its new object. After all, is the California Kid much bigger? □


LANE
BUS



THE AUTO: problem child

MASTODONS of the interstates might have lived forever had it not been for petroleum prices. As recently as 1978, gasoline sold for less per gallon (in constant dollars) than it had in 1960. Now prices tick ever upward as reserves grow shorter and supplies less secure.

Shown above on the left is a car typical of those now on the American road (average age, 6.4 years; average miles per gallon when new, 13.1). On the right is a car with features designed to reduce, or even eliminate, petroleum use.

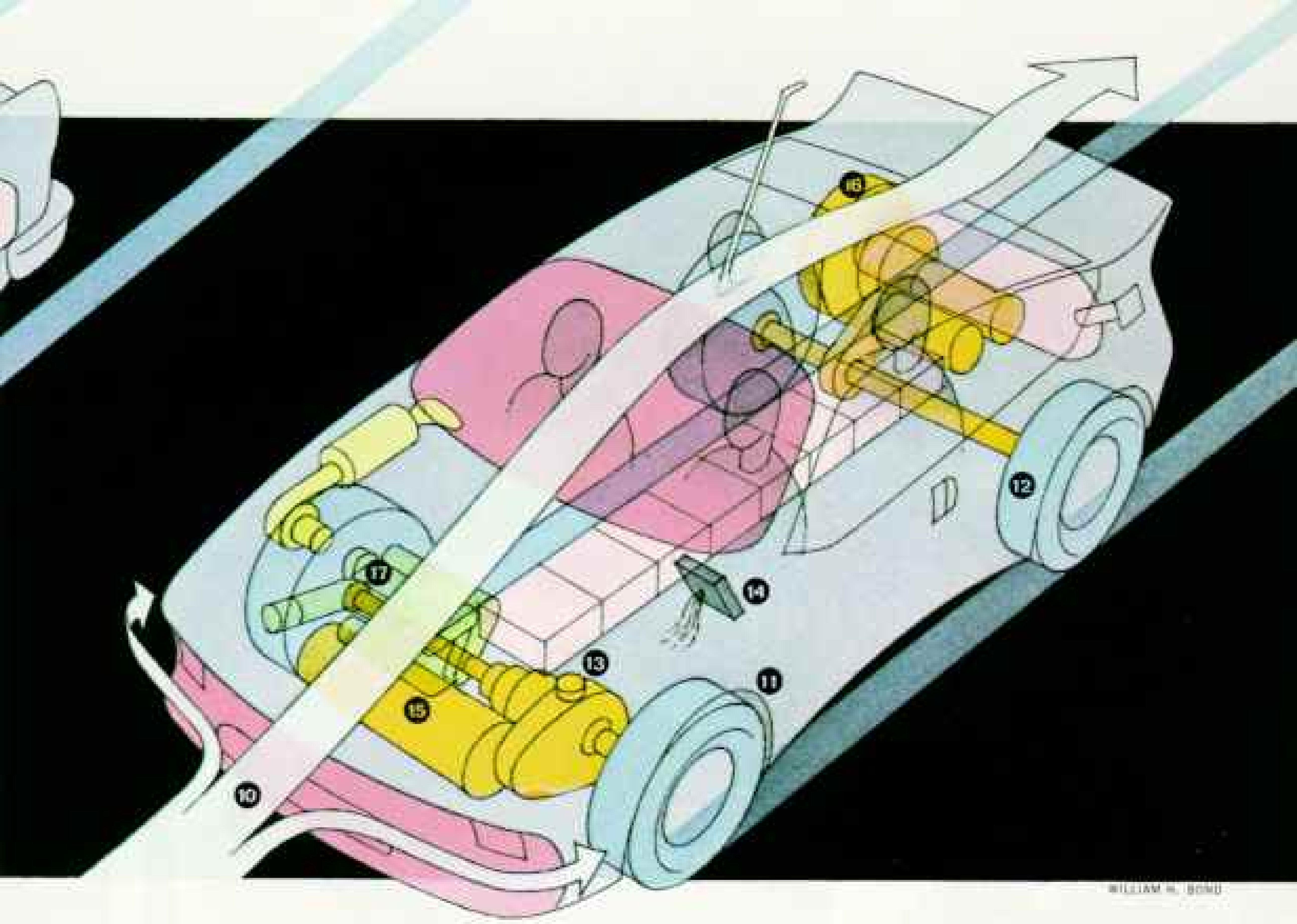
Yesterday's dreamboat, today's gas guzzler, is overweight (22 times heavier than a 150-pound driver), overpowered, oversize, and very, very thirsty.

In the late 1970s standard American cars were downsized by trimming weight and exterior dimensions. Redesigns produced smaller and lighter vehicles with only half the cylinders of the once dominant V-8 engine (**1**). Front-wheel drive eliminated the shaft (**2**) from transmission to rear differential and saved 300 pounds. More weight in such areas as bumpers, hood, and body panels (**3**) may be lifted by substituting plastics and aluminum for steel. Overdesigned chassis (**4**) may be safely pared or replaced by integrated frame-and-skin shells as used in aircraft fuselages.

Although smaller cars are stingier with petroleum, they are not necessarily more efficient. Of the energy released in combustion only 12 to 15 percent is finally applied to move the car. Most of the rest is lost due to the basic thermodynamic inefficiency of the engine and escapes as heat. The remainder is drained off by such factors as aerodynamic drag, rolling resistance of tires (**5**), transmission slippage (**6**), internal friction (**7**), idling, and air conditioning (**8**).

Just to push air out of its way, a car uses 50 percent of available energy at 55 mph but 70 percent at 70 mph. Large frontal areas create air turbulence and drag (**9**). Bodies derived from wind-tunnel testing promote smooth air flow around the vehicle (**10**). Such details as mirrors, rain gutters, trim, and wheel wells and covers (**11**) can be improved aerodynamically. Fuel savings can be as much as 10 percent.

At cruising speed, rolling resistance of tires on the road consumes half the available horsepower. Radial tires can reduce



with a promising future

fuel consumption as much as 3 percent. Puncture-proof tires of plastic (12) could save even more and eliminate the cost and weight of a spare tire and wheel.

Automatic transmissions inflict a mileage penalty of about 10 percent compared to manual gearboxes. Continuously variable transmissions promise even better mileage, as does a stop-start engine that shuts down if a car is idling or coasting, cutting gas consumption by about 15 percent. A touch on the accelerator restarts the engine.

Better lubricants (13) and bearings will reduce friction, and microprocessors (14) will monitor systems and command adjustments to keep them at peak efficiency without—even despite—actions by the driver.

As the price of petroleum for gasoline and diesel engines converges with that of alternate energy sources, new power systems should become widely available, probably beginning with battery-powered electric motors (15). Their advantages: quietness, low pollution, and simplicity. Their disadvantages: limited range between recharges (which are also limited), weight, and bulk. New battery systems now under testing and development should give better performance. Efficiency may also be increased by using flywheels (16) to equalize power demands on batteries during acceleration and hill climbing.

Electric motors may be paired with small combustion engines in hybrid systems (17)—electric power for low speeds, combustion for highway cruising.

Power systems that run on compressed gases such as propane, methane, or hydrogen are more problematical for the personal car. Range is limited, distribution systems are not in place, and each station pump could cost $30,000. It remains moot whether so-called synthetic fuels (pages 74-94) could best be used directly in engines or to generate electricity.

Other combustion engines such as the gas turbine or external combustion may become options in the 1990s.

Proper maintenance of roads can improve mileage 5 percent. And since combustion engines operate best at about 40 mph, traffic ideally should be speeded up in cities and slowed down in the country—the former difficult though possible, the latter unpopular and impractical.

CONSERVATION

Can we live better on less?

To keep the home fires burning in the face of a chilling energy crunch, many Americans are retooling their homes and businesses. Their goal: slash our energy use while maintaining our standard of living through greater efficiency, alternative energy sources, and inventive conservation.

By RICK GORE
NATIONAL GEOGRAPHIC SENIOR WRITER

MARTIN ROGERS

Setting by *for a rigorous winter, Vermont store owner Dan Fraser stockpiles more than a hundred cords of wood, a renewable and, in New England, plentiful heat source.*

IT WAS JANUARY, and in Norwich, Vermont, general-store owner Dan Fraser spent the morning behind his house tending one of the biggest personal woodpiles in New England. Fraser would need little of his 100 cords to heat his home and 92-year-old store that season. But to Fraser "too much wood is just enough." It was like money in the bank. "I figure I can either burn wood or send my money to some damn fellow in the Mideast."

It was 5:25 a.m. on Whidbey Island in Puget Sound, and Gerry Shea began picking up 11 other commuters for their long daily trip via ferry into Seattle. The Seattle/King County Commuter Pool, which serves five counties, had gotten them together and provided van, gas, insurance, and parking. As they moved along a congested freeway, Mary Crane figured that together they were saving 27,000 gallons of gas a year. Commuter Pool was saving her $260 a month.

Jon Mulford started the day with a Jacuzzi bath in his new passive solar, earth-sheltered home overlooking the Rocky Mountains near Aspen, Colorado. He could bask not only in the warm water, but also in the knowledge that with his solar greenhouse and heat-retaining Trombe wall, he would seldom have to turn on the backup heat this winter.

At Sam Snell's pig farm near Auburn,

JAMES P. BLAIR, ABOVE; OTIS IMBODEN, RIGHT

Reflections on design: *Although glass facades tend to waste energy, the mirrored surface of Los Angeles' Bonaventure Hotel reduces the need for cooling by deflecting sunlight. Reflected radiation, however, may increase cooling costs for adjacent structures. Buildings gobble more than a third of the energy used in the United States. Pending federal energy standards for new buildings aim at cutting waste.*

Architects took advantage of the sun in designing the Terraset Elementary School in Reston, Virginia (**facing page**)*. Built from the ground down and sheltered by three feet of earth, the school has a canopy of solar collectors that helped save $14,400 in fuel costs in just one year. If a goal set by President Carter is met, solar and other renewable sources would provide 20 percent of U. S. energy needs by the year 2000.*

Illinois, scores of piglets suckled snugly on a concrete floor warmed by solar-heated water instead of electricity.

In a New York City skyscraper, Union Carbide's Ron Wishart was preparing a talk on how his company cut its energy consumption 20 percent per unit of output, primarily by eliminating waste. Dozens of other major companies were finding similar savings. The Bell System had reduced energy use since 1973 by 10 percent while increasing business 70 percent. The 3M corporation said it regarded conservation expenses as investments because they pay back so fast.

In Harrisville, New Hampshire, Leandre and Gretchen Poisson harvested spinach and leeks in minus 10°F weather from solar-heated hotbeds. Discouraged by the high energy input of American agriculture, which requires 15 calories of fuel to produce a calorie of food, the Poissons have rediscovered and adapted French intensive gardening techniques, which enable home gardeners to be nearly self-sufficient in food with a very small plot of land.

These were just a few of thousands of energy pioneers, people who had decided that perhaps the simplest way out of our petroleum fix is to stop using so much of the stuff.

Light at the End of the Bridge?

That same January evening in San Francisco I stood at a hotel window looking out through the rain at car lights streaming over the San Francisco-Oakland Bay Bridge. Off and on for nearly two hours I watched those cars. Thousands upon thousands of pistons driven by a fuel that seemingly grows dearer with each ping. Thousands upon thousands of California commuters, perhaps the country's most conspicuous energy consumers, crossing a bridge.

It was a perfect image. I had come to California to explore a novel concept: Many experts now say that, using existing technology, we can cut energy use dramatically and live just as well, if not better. We've already begun to conserve, thanks largely to the rising price of fuels. Our gasoline use has dropped about 11 percent since 1978. Growth of electrical demand has slowed sharply. Industry has cut its use of all energy by 14 percent per unit of output since 1973.

Yet too few of us are pioneers. We are like

GREG DAVIS

HARNESSING THE WIND

IT LACKS *halyards, sheets, shrouds, and most of the rigging that ships used in the past age of commercial sail. Yet the Japanese "Shin Aitoku Maru"* **(above)** *is the prototype of what may be a new fleet of sail-aided cargo ships. The incentive: Japan's acute need to conserve imported oil, the same oil that ships carry as cargo.*

In a 30-knot wind abeam, the sails on the fully loaded ship can provide 53 percent of the power to travel at 12 knots. To get the most from other wind speeds and points of sail, a microcomputer system gives automatic commands to trim the steel-framed canvas sails by rotating the masts. In a fair and strong wind, the engine slows down automatically. Otherwise, the engine works no harder than necessary to maintain constant ship speed. With efficient equipment and design, fuel savings can be as high as 50 percent.

Wind is secondhand solar energy; its basic driving force is the unequal heating of the earth and atmosphere. It is given characteristic flow patterns by the earth's rotation.

As every sailor and kite flier knows, winds constantly shift in direction and vary in speed. Although utilities would have to learn to accommodate the variable outputs of wind machines, researchers believe wind power could become a continually useful source of energy.

Its availability depends on geography. Wind generators are most practical in the Great Plains, in mountains, and along certain coastal areas. One scheme uses 200-foot-high tetrahedral wings moving around a circular track on wheels coupled to generators.

The Wind Energy Systems Act of 1980 has initiated an eight-year, 900-million-dollar program to develop cost-effective wind-power systems in the United States, and a number of large wind turbines are already in the experimental testing or development stages. But it would take 30,000 large turbines and thousands of smaller ones to supply 10 percent of the nation's electrical power needs by the year 2000.

Small windmills can be used by individuals; in 1920 perhaps a million were in use in the U. S., mainly on farms. Denmark alone had about 25,000 in the 1890s. After the horse, ox, and himself, man's primary mechanical energy source before the industrial revolution was wind. It has a role to play again.

those California commuters crossing the bridge—except we don't know how to reach the other side. Burdened by our overcomplicated lives, we sit and wait for a simple fix.

When I began this assignment, conservation meant insulation and heat pumps to me. It meant a President telling us to endure cold homes and curtail. Conservation seemed resoundingly dull. I was wrong.

As I focused my sights on pioneers in energy, I found a spirit of self-reliance and an exuberance, a belief afoot that the 1980s will be a turning point for America.

In Bernardston, Massachusetts, I sat in a town meeting as New Englanders, appalled at the soaring cost of imported oil, came up with ways they could become more self-reliant: Burn more waste wood from their forests. Make their own methane from dairy-cow manure. Grow sugar beets and turn them into alcohol to fuel cars.

Yankee Ingenuity Tested

The people in the nearby village of Heath had already learned they could generate most of their power with ten wind machines.

The neighboring Berkshire hill town of Chesterfield had found that two solar panels and two large wood stoves could heat the building that houses their snowplows—a $5,000 savings in heating oil.

This spirit is being stimulated by activists who hope to make their drive for renewable energy and efficiency as strong as the environmental movement was in the 1970s.

"We believe in living off our income—the sun and the wind—and not off our principal—our deposits of fossil fuels," one of these activists, Jim Benson, told me.

Benson, founder of the Institute for Ecological Policies in Fairfax, Virginia, crisscrosses the country talking to community groups and trying to build the large constituency that conservation lacks and badly needs. He throws out provocative figures.

In Butte, Montana, for instance, he tells the people that the average family there now shoulders $4,000 a year in energy costs, $1,000 of that hidden in the costs of goods and services they buy. By 1989, he says, those costs will be $16,000 per family.

On Long Island, Benson points out that a typical homeowner who invests $2,500 in cost-effective conservation and solar-energy measures could save enough fuel to pay for the work in seven years or less and help the local economy as well. Over the next four decades at least 16 billion dollars from saved energy could stay in Long Island consumers' hands rather than go into overseas and out-of-state bank accounts.

"This country can spend 30 billion dollars in three ways," Benson likes to say. "One, we can buy 2.7 million barrels of oil every day for a year. That's 30 billion dollars gone.

"Or we can build ten synthetic-fuel plants. In ten or fifteen years those plants *may* supply half a million barrels a day. Consumers will spend at least 18 billion dollars a year to buy and burn that new fuel.

"Or we can put that 30 billion dollars into residential conservation over the next three years. We would then be saving half a million barrels a day in fuel oil alone. Each year we'd also save 230 billion cubic feet of natural gas and 46 billion kilowatt-hours of electricity. That's 9 billion dollars a year we wouldn't spend on energy!"

Some cities—notably Portland, Oregon, and Seattle, Washington—have already seen the connection between conservation and their economies. Citizens in Portland spent thousands of hours working out plans to reduce energy use in the city 34 percent by 1995 and thereby keep a billion dollars a year from leaving town. Among the city's many new actions is a rule that by 1984 no house—new or old—can be sold unless it is certified to be weatherized. Seattle is hoping to convert some city buses to run on ethanol, which can be produced from local wood wastes.

Fitchburg Shows the Way

At first glance, one would say the pioneering spirit must have fled Fitchburg, Massachusetts, around fifty years ago. The former mill town of 38,000 people looks like so many stagnant, industrial towns in New England—depressed. But then there's that billboard on the edge of town: "Welcome to Fitchburg, the first city in America to FACE the energy crisis."

FACE? Anyone in town will tell you that means Fundamental Action to Conserve Energy. Last winter it seemed everyone in Fitchburg was armed with a caulk gun. A poster in the local weatherization office told the story: "Send the Ayatollah a message—Fitchburg doesn't need his oil."

Like most New England cities, Fitchburg has relied heavily on foreign oil. FACE began as a local task force in late 1979, when heating oil prices were doubling and there was widespread fear of the elderly poor freezing to death if the winter were severe. It snowballed into ten neighborhood training centers and scores of volunteers, working with federal ACTION personnel. They spent 16-hour days showing Fitchburgers how to seal up the leaky old homes that are prevalent there—and that help make New England a major drain on the nation's economy. The basic message hammered home was that almost anyone can cut his household energy bills by at least 20 percent with simple, low-cost steps such as caulking and weatherstripping.

Sixty percent of Fitchburg's households took some action, enough to make "Follow Fitchburg" a rallying cry for numerous cities that are adopting its plan. Still most participants in Fitchburg took only the cheaper, easier steps. A follow-up study revealed that many Fitchburg residents either did not know what further, major steps to take or could not afford the work.

Starting this year the federal government will address both problems. It now requires all large utilities to offer free or cheap energy

ELECTRICITY FROM THE SUN

ONE SENSES THAT maybe, just maybe, a solar revolution is brewing. The photovoltaic, or solar electric, cell could turn out to be the joker in the global energy deck, the breakthrough that could help disperse the gloom from our energy horizon. One must be cautious. It is easy to be overenthusiastic about these safe, nonpolluting energy producers. But in solar circles optimism runs high that we will be creating electricity from the sun sooner rather than later.

Solar cells work. They were developed to help power the United States' space program and have performed impressively. Last year in California they powered the maiden flight of the "Gossamer Penguin" **(facing page)***, the world's first piloted solar airplane. But they have been exorbitantly expensive, and while costs have dropped sharply, the price of producing electricity with photovoltaics is still more than ten times as high as average utility rates. Many industrial and utility officials doubt it can be made cheaply enough to have much impact in this decade.*

On the other hand, high-priced oil is changing the economics of energy production dramatically. In the United States, Europe, and Japan solar firms are pressing hard on photovoltaics, using technology similar to the kind that made the mini-computer available to everyman. The Department of Energy's photovoltaic program director, Paul D. Maycock, believes the cost of photovoltaic electricity could drop enough to make solar cells competitive with conventional sources of electrical power by the mid-1980s.

Federal regulations require public utilities to buy electricity from qualified independent producers at a price roughly equal to the cost the utilities would have incurred in producing it.

By 1985, predicts Solar Lobby chairman Bruce Anderson, homeowners will begin putting panels of solar cells on south-facing roofs and walls. "The solar energy striking a home," says Anderson, "can generate more electricity than the owners need, even for charging an electric car. The rest can be sold for a profit to the utility."

Phoenix builder John F. Long has produced such a house. A major Japanese electric firm has built three model solar homes. The company says the homes are far more efficient than conventional houses and use less than a third as much power. More testing is needed, but such homes may be available in Japan within a decade.

Major American photovoltaic firms have been bought by oil companies, a further indication that photovoltaics could indeed become an important energy source.

Affordable photovoltaics could significantly alter the current energy distribution network, particularly as cheaper batteries become available that can store the excess electricity generated on sunny days. These batteries, charged by solar cells or by wind, could make each home its own electrical generator and filling station.

How does a solar cell work? When photons, which are energized particles of light, strike certain specially prepared layers of semiconductor materials, their energy knocks electrons loose. The electrons then begin to flow into connecting wires, becoming a current of electricity.

Today's thin, brittle photovoltaic cells are made from silicon, the second most abundant audits. The utilities must also help arrange financing and installation of energy-saving improvements. The Tennessee Valley Authority, however, already has developed an audit-conservation program that practically has had customers beating on its doors.

I doubt that anyone has ever called TVA Chairman David Freeman easygoing. "Don't tell me your problems. Get it done," he snapped to a secretary before motioning me into his suite overlooking Knoxville.

Freeman, well known as an abrasive workaholic, has jarred a lot of people over the past three years at TVA, the country's largest electricity producer and long a citadel of nuclear power, all-electric homes, and bureaucracy. With 14 reactors being built, TVA suspended construction on four, and embraced conservation and solar energy. Freeman urges rural customers to burn wood. He promotes making alcohol fuel from the South's forests.

"TVA began life in the Depression as a noble experiment. Its purpose was to put a green cover back on the land and raise the standard of living of the people here," he said. "It lost its spirit of adventure and experimentation after the war. Now we are going back to our roots. We want to be a model, to demonstrate what can be done."

Freeman initiated a revolutionary conservation approach similar to one developed

element on earth after oxygen. Individual cells are mounted on a panel, wired together and covered with a protective layer, usually glass. Since a typical three-inch cell yields at most about half a watt, it would take at least 6,000 cells to supply the average American home with electrical needs exclusive of heating and cooling.

Currently most solar cells are made from crystals of high-purity silicon, grown through a time-consuming process. Diamond-edged saws then slice the crystals into wafers, wasting at least half the material. The expected price breakthrough will come when the crystals no longer have to be grown and cut so laboriously. Techniques are already being perfected that cast polycrystalline silicon from molds, draw silicon into thin ribbons, and grow thin films from a variety of materials. These ribbons, films, and cast materials require less time and promise to be more economical.

JAMES A. SUGAR

MODERN HOUSE, ANCIENT ARCHITECTURE

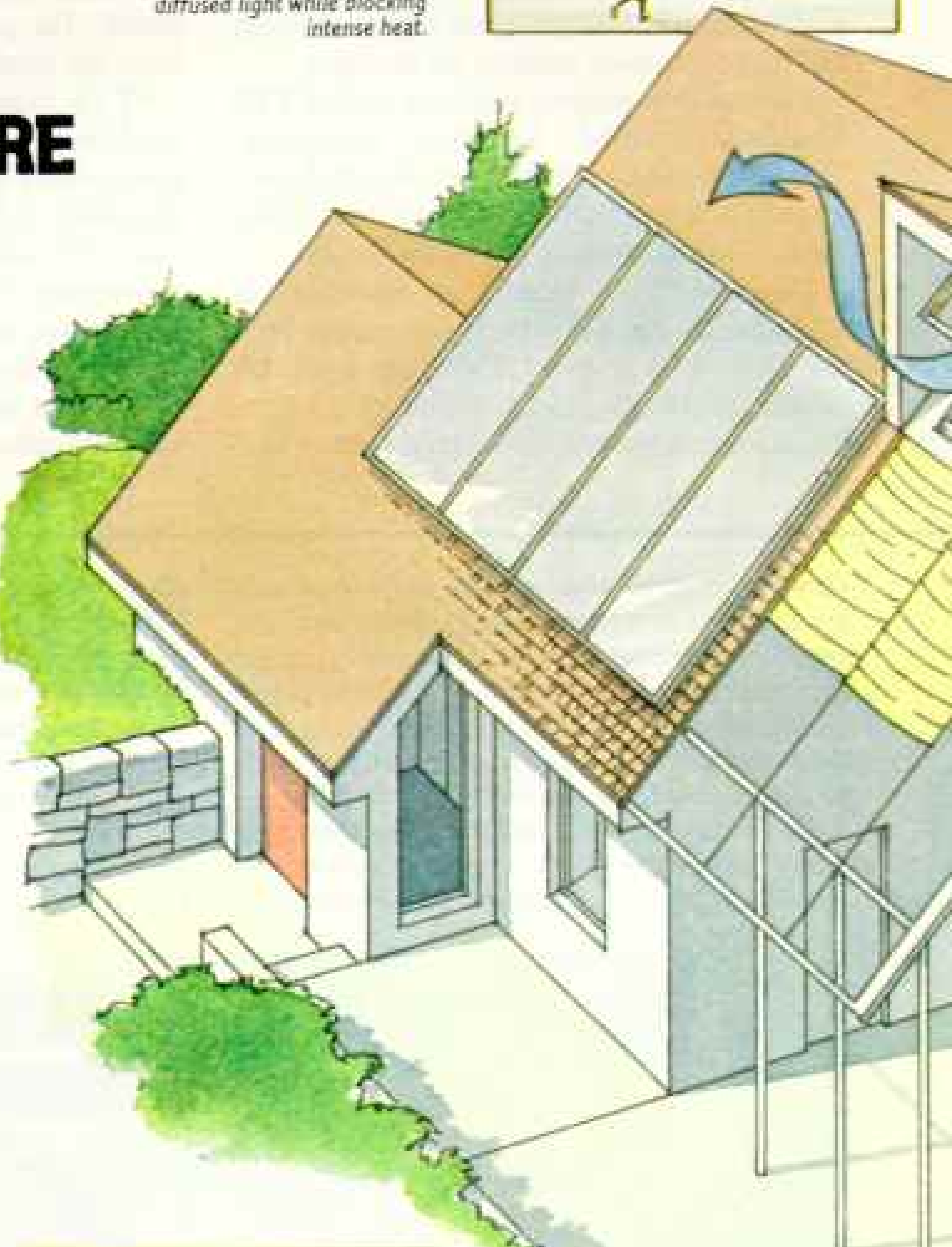
SHADE
The awning, simplest way to reduce solar radiation, is easily adjustable. Those of pale fabric or translucent plastics also admit soft, diffused light while blocking intense heat.

WHEN DRAGONS are fuel bills, the best castle is a home nearly self-sufficient in energy. The house shown here, "Geohouse," has no floor plan. It is a set of principles, most put to use centuries before the thermostat made constant temperatures possible. The principles follow from logical use of the elements: heat from the sun, insulation of earth, cooling of breezes and shade.

The insets around Geohouse illustrate how self-taught architects solved the problems of making human habitation comfortable with materials at hand. Geohouse applies these ancient solutions to the Northern Hemisphere's temperate zone and adds modern solar hot-water heating in roof panels.

The house is oriented south, so windows admit radiation from the low winter sun, while roof overhangs and awnings exclude the high summer sun. This passive solar heating is augmented by a greenhouse, a massive masonry wall and floor, and the rock bed beneath. The rocks and masonry absorb heat during the day and radiate it at night. The greenhouse glass admits shorter wave solar radiation but traps the heat of longer wave infrared radiation. Vents in the wall and operable windows encourage convective air flows that help heat in winter and cool in summer.

The north side of Geohouse is banked with earth, whose temperature changes little, helping keep the interior cool in summer and moderate in winter, while blocking the north wind's blast.

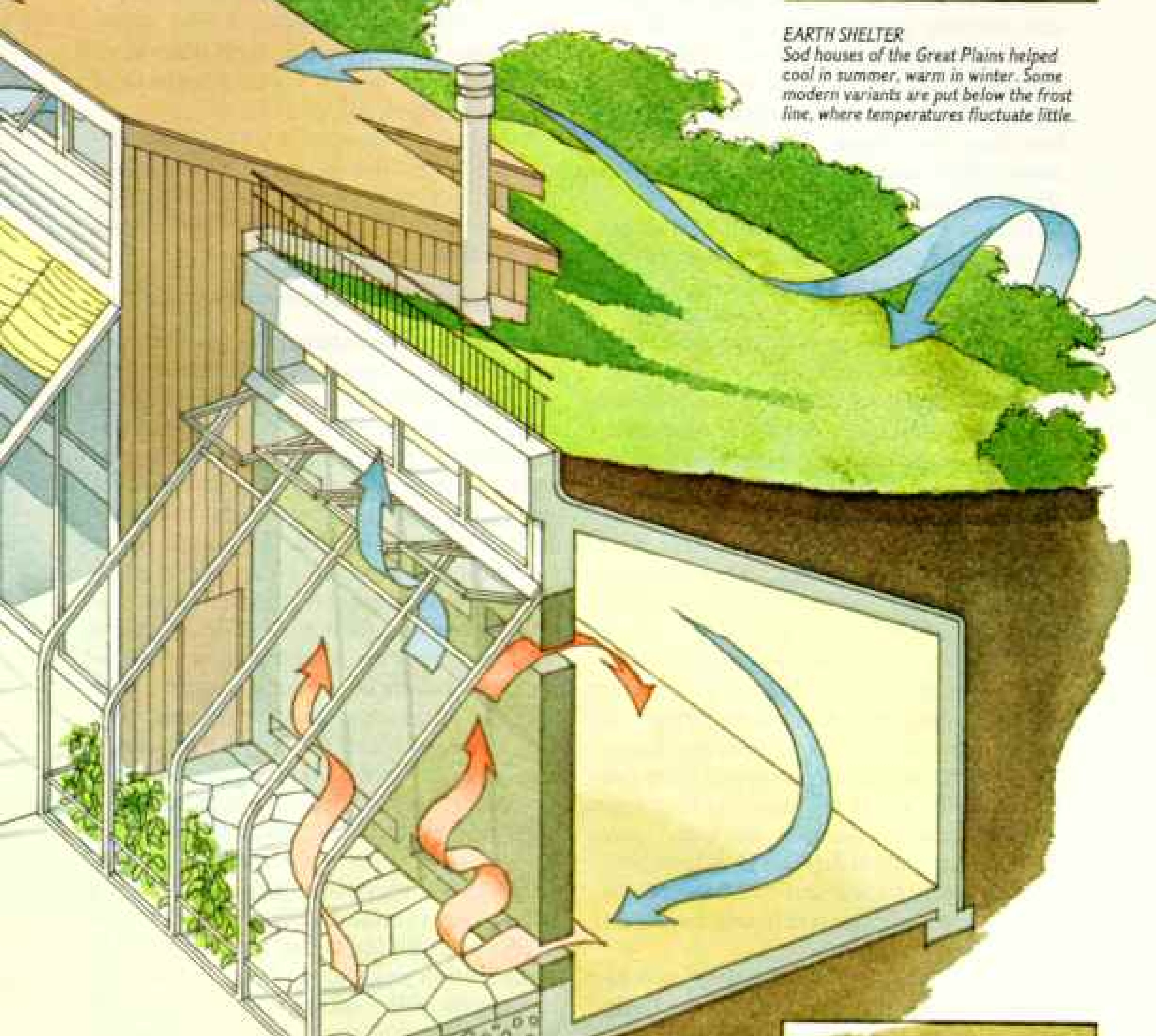


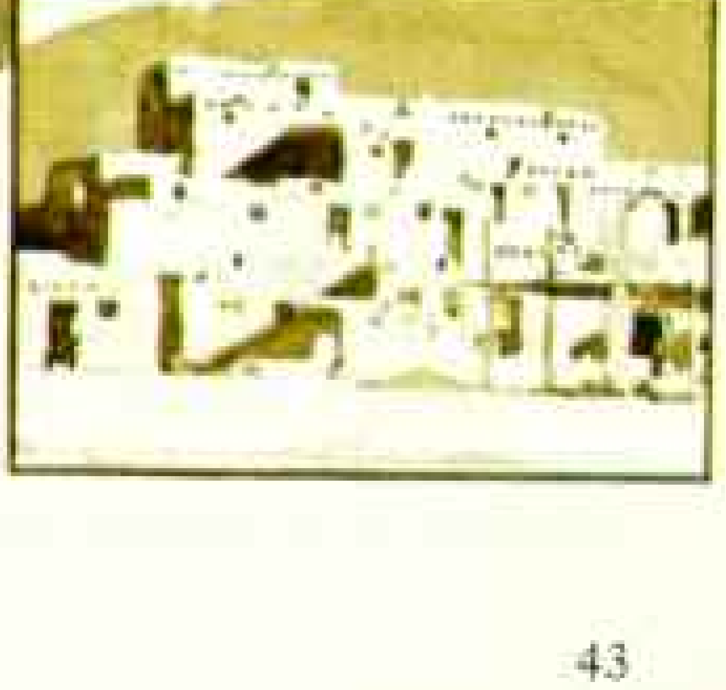
AIR LOCK
Though simpler in concept than the multipurpose tunnel into an igloo, a vestibule serves one of the same ends — protecting the interior from an inrush of cold air and outrush of warm.

SITE
Protected from the north by a cliff, a Pueblo village faces the winter sun. For effective passive solar heating, a house should face within 25° of south.

VENTILATION
In the tropics, houses are raised and open toward prevailing breezes. In Geohouse, windows, ventilators, and vents in the greenhouse wall ensure adequate air exchange and mixing.

EARTH SHELTER
Sod houses of the Great Plains helped cool in summer, warm in winter. Some modern variants are put below the frost line, where temperatures fluctuate little.





THERMAL INERTIA
Slow to heat and cool, desert adobe houses, like the thick wall, floor, and rock bed, absorb day's warmth to radiate it at night.

PAINTING BY WILLIAM H. BOND
NATIONAL GEOGRAPHIC ART DIVISION
WITH THE COOPERATION OF DAVID C. BULLEN, AIA

by utilities in Oregon, which is running out of new sources of the hydroelectric power that has given the Northwest cheap, abundant energy for decades. There, utilities audit and insulate all-electric homes. The customer qualifies for a zero-interest loan, payable when he sells the house.

As Ted Davenport of Portland's Pacific Power and Light explained it: "What's the difference between hanging storm windows and building a new power plant? We get more kilowatt-hours either way. Conservation's a lot quicker. And the kilowatt-hours we develop through conservation cost us less than two cents. Those from a new power plant run more than six cents and are climbing fast."

To that Freeman would add, "There are more uncertainties in the performance of a new power plant than in insulation."

TVA's conservation program had a 30,000-audit backlog last year with only word-of-mouth advertising.

A TVA auditor tells the customer which conservation measures would be financially worthwhile, estimates the cost and savings of each measure, and supplies a list of approved contractors. TVA pays the contractor selected, but only if the completed work satisfies TVA's inspector. The customer then pays for the work, interest free, on his monthly bill. A typical $1,500 job would cost $17.85 a month over seven years. At today's rates, the typical all-electric customer will save about that much in electricity. So the savings cancel out the monthly charge.

"By 1990 our conservation and solar programs will be worth the output of four to six 1,000-megawatt nuclear reactors," says TVA's conservation director Bob Hemphill. "Those programs will cost us at most 1.3 billion dollars. Four nuclear plants would cost us at least six billion."

For most utilities the energy crunch has brought an identity crisis. Some are beginning to view themselves more as energy-service specialists rather than simply power providers. The Pacific Gas and Electric Company, California's biggest utility, has transformed itself, with prodding from the Environmental Defense Fund and the state's Public Utilities Commission, into a proponent of conservation. At the PUC's command, it is offering tens of thousands of its customers incentives to install solar water heaters. It offers money to builders of energy-efficient houses and grants to cities that cut energy use. Vice President John Cooper told me the utility might some day actually give away efficient air conditioners or refrigerators just to get the energy guzzlers off their lines.

Southern California Edison, moreover, has announced that renewable energy is now a "preferred technology." The utility now believes conservation and alternative energy sources can provide for 30 percent of new electricity needs in the 1980s.

As valuable to our country and our economy as conservation is, it often costs more money than most people, companies, and utilities—many of which face serious financial problems—can muster.

Conservation Becomes Capital

How do we raise the capital we need? Innovative rate schemes or bond issues could help funnel conservation money through the utilities. Another idea is to treat conservation investors the same way we treat the people who put up the money to explore for new energy supplies. In other words, we might make it lucrative to "drill" for oil and gas in our buildings. How so? Well, it costs much less to save a barrel of oil through conservation—often less than $15—than to find a new one through exploration. Congress encourages private investors to underwrite oil and gas exploration by giving them very generous tax breaks. So, why not give similar shelter to those willing to put up capital for conservation? The Alliance to Save Energy, a nonprofit coalition of business, labor, consumer, and environmental groups, envisions a group of investors approaching homeowners through energy services companies and offering to pay for all justifiable conservation measures—in exchange for two-thirds of the energy cost savings realized by the homeowners. Like oil and gas investors, the conservation investors would be able to write 50 percent of their investment off their taxes right away.

In a leaky New England home with an old oil furnace, for instance, $1,000 invested in furnace improvements, insulation, and weatherproofing could save 40 percent of the homeowner's heating bill—or about

$480 a year. The investors would make their money back on this house in less than four years. After the investment group had made a reasonable profit, the homeowner could buy the investors out and keep all the savings.

House Detectives for Heat Losses

"Most of the houses we audit are considered well insulated," Gautam Dutt said en route to New York's Westchester County with several other Princeton University "house doctors" (page 48). "Most utility audits would say don't do anything. But we can often save an extra 20 percent."

We stopped at a house in New Rochelle. A crew from Consolidated Edison, which was working with the Princeton team on a pilot project, had set up a large fan in the doorway. The fan was turned on, pushing warm air out any available crack.

Dutt began inspecting the house with a heat detecting device called an infrared scanner. Through this scanner, about the size of a TV minicamera, hot spots appeared red and cold areas black. We crawled into the attic. Cherry red regions glowed where missing insulation or air gaps around vents had created invisible breezeways for the warm air being forced out of the house below.

While Dutt was in the attic, a colleague paced the family room with a pencil-like stick that puffs smoke. The smoke streamed into numerous invisible air leaks along the floors and ceiling moldings. Once located, these leaks were easy to patch.

"Most people are astonished at the leaks we find," said Austin Randolph, the Con Ed crew chief. "One woman drove around looking for our truck to thank us. She had turned her thermostat down six degrees and still felt more comfortable than before."

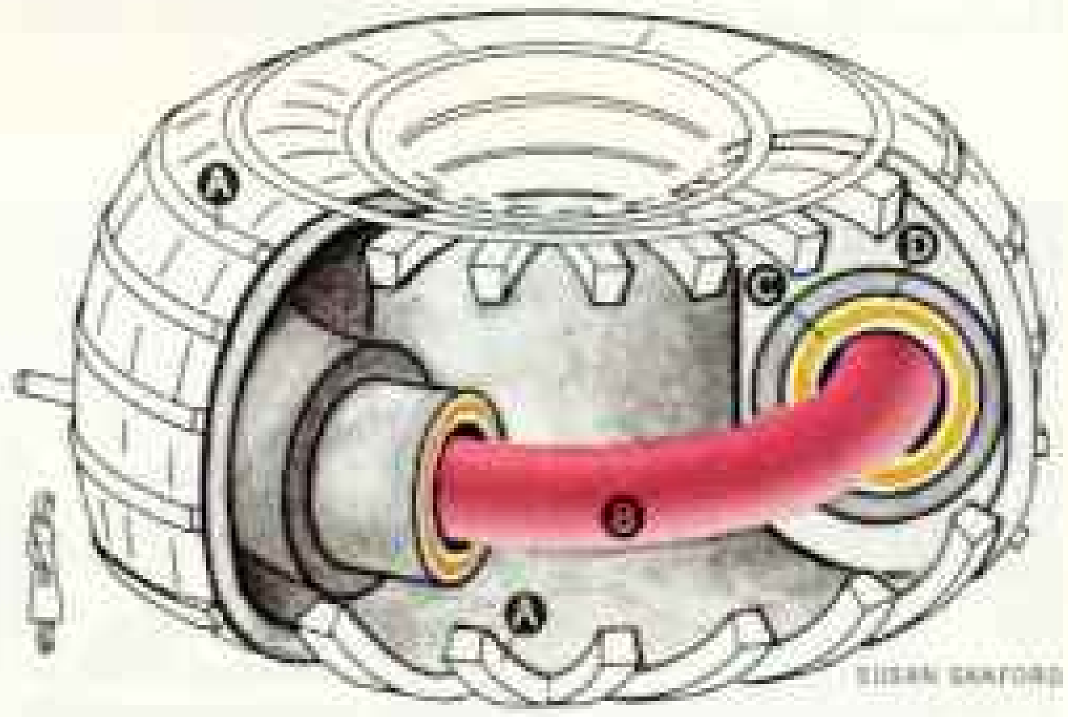
Dutt and his colleagues want 40,000 house doctors to be trained over the next few years. They say a vigorous house-doctor program for the country's 70 million homes would cut home-heating demand in half and save the equivalent of two-thirds of our Arab oil imports.

Dramatic savings are also possible with new houses. "We can take the average new home built near Chicago down from needing about 800 therms of natural gas a winter for

THE FUSION SOLUTION

"THE ULTIMATE ANSWER to the energy problem"—thus many scientists envision nuclear fusion. It promises virtually limitless energy, but poses perhaps the greatest technological challenge ever faced by mankind.

Fusion is the process that makes the sun and stars burn and powers the hydrogen bomb. Unlike the familiar fission reaction, which splits the heavy atom, a fusion reaction joins the nuclei of



two light atoms, in this case deuterium and tritium, forms of hydrogen. In both cases there is a loss of mass and a release of tremendous energy.

To achieve fusion, scientists must re-create the extreme conditions that exist inside the sun, where heat reduces matter to an ionized gas called plasma. In this plasma, atomic particles become so energized that they overcome their electrical repulsion, collide, and fuse, releasing energy and making the process self-sustaining.

Researchers know how to create and heat a plasma. But how do you confine a plasma and keep it hot enough for fusion? The most advanced device is the Tokamak, using electromagnetic coils (A) formed in the shape of a doughnut, for creating a magnetic field to squeeze and contain the plasma (B).

In a fusion-powered electrical generating plant, helium (C) could be used to carry heat from a lithium blanket (D) surrounding the plasma to a heat exchanger, where steam would be created to run turbines.

The U. S.'s largest experimental Tokamak, at Princeton University, begins operating this year.

Fusion offers immense advantages over today's fission reactors: only a fraction of the radioactivity, no threat of meltdown, and a plentiful source of deuterium from water. But fusion technology is so complex that some feel it will never be inexpensive enough to use. In any case, commercial fusion will not come before the year 2000.

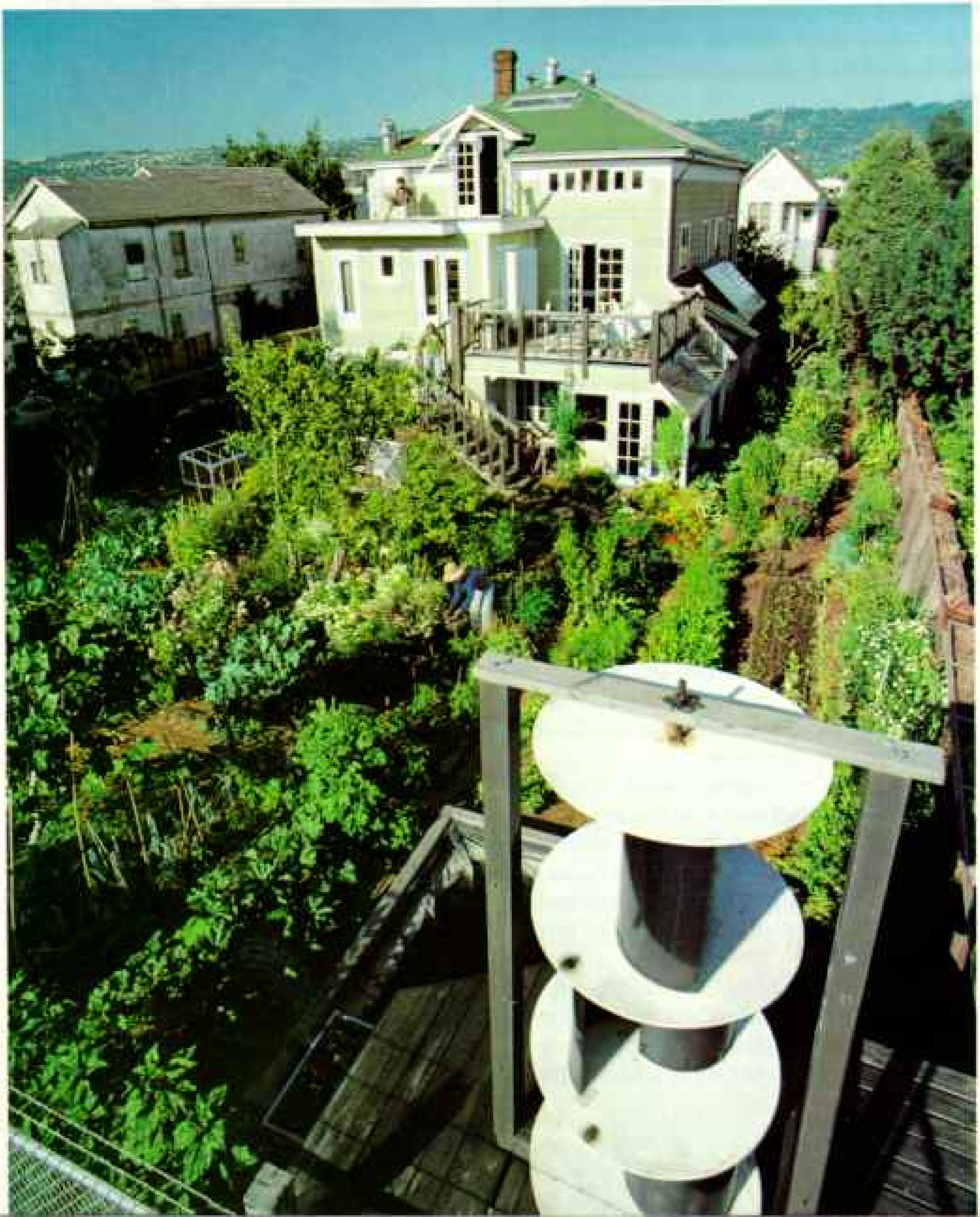
space heat to between 300 and 400 therms," said Dr. Arthur Rosenfeld, a buildings specialist at the Lawrence Berkeley Laboratory in California. "You add about $1,000 to the price, but so does 10 percent inflation in two months. We simply put in more insulation, plug the bypasses, and use good windows. We can build houses so tight we'll need mechanical ventilators."

These new "air-to-air heat exchangers" can eliminate the recently publicized problem of toxic substances building up in the air in weather-tight houses. Smaller and cheaper than window air conditioners, they use very little energy. They provide fresh air, just as an open window does, while retaining 75 percent of the heat from the stale air.

Rosenfeld predicts that by 1990 we may have windows as thermally efficient as today's walls, furnaces that are 90 percent efficient, and widespread use of solar hot water and passive features.

Many homeowners have already built houses that use very little energy. In Davis, California, I drove down Anderson Road with Mayor Sandy Motley. Similar subdivisions lay on either side of us.

"They look identical, don't they?" said



Motley. "But the houses on the left use only half the energy of those on the right."

Davis has pioneered building codes and regulations that, among other measures, require that new houses be oriented south. That way most windows can take full advantage of the sun's heat in winter. Trees, vines, overhangs, or awnings must shade windows during Davis's hot summers. Shading alone can cut air-conditioning demand in most Davis homes in half. At least two builders have found Davis's energy awareness a boon.

"People began asking us for solar houses," said builder John Whitcombe. "We didn't know how to build them but we sensed a good business opportunity."

So Whitcombe devised an active solar system that heats a house by running water warmed in rooftop collectors through the floor slab. He had just finished a 95-unit solar apartment complex and was working on a 120-house solar subdivision.

"This solar house will cost $750 more than a conventional house," he said as we toured a home he built and lives in. "In this climate it will save at least $500 each year in energy costs. On the apartment complex,

***Energy bills are minimal** at the Integral Urban House (**left**), a project of the Farallones Institute in Berkeley, California. A group of biologists, engineers, and architects bought the house in 1974 and outfitted it as a model of self-reliant city living.*

*Solar panels on the roof heat water. A wind machine, foreground, aerates an aquaculture pond. The lawn area produces crops pollinated by honey-making bees (**right**).*

*A composting toilet (**above**) conserves water and, with the addition of grass and leaves, breaks human waste into an odorless, rich compost that after $2^1/_2$ years is removed (**above right**) and used to condition soil around flowers and trees.*

ALL BY CHRISTOPHER SPRINGMANN

MICHAEL S. YAMASHITA, ABOVE AND BELOW

A VISIT FROM HOUSE DOCTORS

IF SOME ENERGY RESEARCHERS from Princeton University have their way, an army of tens of thousands of "house doctors" will be calling on millions of American homes a year. This army would visit every household by the mid-1990s.

They would prescribe the standard cures for leaky homes—caulking, weather stripping, more insulation, and storm windows. They would tune up furnaces or prescribe new ones. More important, they would use special instruments to locate a whole category of air leaks no one knew about until recently and seal them on the spot.

In the mid-1970s a Princeton team realized that no one really understood how a house performs thermally. With federal funding, the team began putting instruments in well-insulated New Jersey homes and found that, despite insulation, the houses were losing three to five times more heat through the roof than expected.

Demonstrating their techniques (**above**), *the team sets up a large fan, called a blower door, to create a 20-mile-an-hour draft in this home. While Gautam Dutt monitors instruments to calculate the overall leakage of air from the house, his associate Kenneth Gadsby, at right, scans ceilings and walls with an infrared heat detector.*

Cold spots appear dark in the scanner, indicating that heat is being lost through some invisible bypass.

The house doctors locate other leaks with a "smoke pencil" (**below**). *A smoky tracer streams into an electrical socket, another source of unexpected heat leaks in most homes. Inexpensive foam gaskets can be used to seal these outlets.*

Nearly every house, the team discovered, had many paths through which surprising amounts of heat bypass the attic insulation. These might be as obvious as a hole in the attic floor or a missing insulation batt. Many bypasses, however, are obscure. Hollow interior walls or openings where the plumbing vents and electrical wires pass the attic floor can be breezeways for heat to the outside.

A one-square-foot opening around a

furnace flue, the team found, loses hundreds of times more heat than it would if stuffed with three and a half inches of insulation.

They estimate that, overall, 2 percent of the energy used in America is simply wasted by escaping through these attic bypasses.

Although such leaks can be plugged cheaply and easily with fiberglass insulation, finding the bypasses usually requires house doctors' training and equipment.

From an energy standpoint America's housing stock is in bad shape. Ninety percent of our houses were built with less than six inches of attic insulation, and a fair amount of that was put in carelessly.

Experts differ on what it would cost to tighten up an "average" house, as well as how much such measures would save. This is because houses, like climates and labor costs, vary so much.

The Princeton group estimates that a commercial house-doctor visit and quick fix would cost from $200 to $400. Even such a summary treatment should lower heating bills by 15 to 20 percent, Dutt estimates.

A full-fledged retrofit by a contractor would run from $1,500 to $3,000, but could save half a home's yearly heating costs. This investment, they say, would give a much better return than the interest paid on savings accounts. If all the country's 70 million residences had house calls, and their owners followed the doctors' advice, we would save the equivalent of two-thirds of our Arab oil imports.

*Significant savings could be achieved, Dutt emphasizes, by remedying conductive heat losses through windows, which can be major energy drains. Triple-glazed windows, insulated shutters, or coverings such as the Window Quilt being put in place (**below**) can cut window losses dramatically.*

DICK DURRANCE II

moreover, we received $312,000 in solar tax credits. That's more money than we'd normally make as profit on the whole project."

Builder Michael Corbett, on the other hand, stresses passive solar techniques, which are fast becoming the approach of choice among solar architects. These techniques rely not on solar collectors or elaborate plumbing, but on the architecture of the building to trap and store the sun's heat in winter and reject it in the summer. The solar orientation and south-facing windows that Davis requires are of passive design.

So are Trombe walls. These are simply masonry outer walls with vents at top and bottom. A glass plate on the outside of this wall creates a pocket of air that heats up when the sun strikes it. The warmed air rises and flows out of the upper vent into the house. Cool room air is pulled in through the lower vent to be solar heated. The masonry wall heats up too, but it takes about six hours for the heat to work its way through the brick. This time lag lets the sun warm the house well after dark.

New Life for an Old Idea

Corbett's 217-house subdivision, Village Homes, is a collage of solar ideas. His favorite technique is the sun-room—or greenhouse if you grow plants in it.

The greenhouse, an old idea, is becoming one of the most popular and effective ways of heating houses with the sun. In New Mexico and Colorado, inexpensive greenhouses warm the farm homes of low-income Chicano families and permit the growing of food all year. In Agawam, Massachusetts, Mary and Ernie Bleeck said their new greenhouse off the kitchen serves as a toasty, cheerful living room on sunny winter days, letting them turn off their furnace. When they open their kitchen door and windows, the greenhouse heats that room too.

In Michael Corbett's scheme a bed of rocks sits under the slab floor. In winter, the warm air from the sun-room is pumped through pipes embedded in the rocks. As the rocks are warmed, they warm the slab, which in turn heats the house. In summer, the vent from the sun-room is closed and another outside air vent is opened for a few nighttime hours. Cool night air is pumped through the rocks, chilling the slab and helping air condition the inside. Deciduous trees shade the sun-room during the summer as well, reducing heat buildup.

Midway across the country the people of Soldiers Grove, Wisconsin, are building a new solar-heated downtown. The old downtown had been repeatedly flooded, and the villagers decided they would rather construct a new waterproof village center off the floodplain than new levees.

The townspeople had not seriously thought of going solar, however, until they met architect Rodney Wright and his wife, Sydney, a city planner.

"We simply told them that we could design their downtown so that 75 to 90 percent of their heating could be provided by the sun and it wouldn't cost them a penny more," said Rodney Wright.

"You may call people out here hicks, but we know what makes sense," said Ron Swiggum, former village president. "Having this energy-efficient downtown is going to give our businessmen more opportunity to compete with those in bigger cities. Especially as transportation costs go up."

I climbed into the sweltering glazed-roof "solar attic" at Cecil Turk's new grocery store. The attic collects heat and fans blow it downstairs as needed. "The other day, with the wind-chill factor, it was zero outside and 152 degrees up here," said the foreman. "My men are almost down to their shorts in the dead of winter building this place."

The upper Midwest is excellent country for solar energy, insists Sydney Wright, not because the region has that much sunlight, but because it needs the heat so badly.

Putting the Wind to Work

Solar energy also drives the winds, and this year several utilities will begin buying wind power. In Honolulu, Hawaiian Electric spokesman Dick Bell told me a private firm, Windfarms, Ltd., is about to build 20 four-megawatt wind machines on Oahu for his utility. When the wind blows, said Bell, "we won't have to burn as much oil."

Oil is clearly Hawaii's energy problem. The island state imports all it consumes. This vulnerability, however, has sparked an aggressive energy program.

"All those things Hawaii makes you think of—the sun, the ocean, the trade winds, volcanoes, even our sugar—these are wonderful resources," Governor George R. Ariyoshi told me. "I truly believe that, using these, Hawaii can in the not too distant future become self-sufficient, at least in electricity."

As he spoke, Hawaii's sugar industry was burning its cane waste to produce nearly all the electricity it needs, plus up to 40 percent of the electricity the public consumes on two of the less populated islands.

More solar water heaters per capita were glittering on Hawaiian roofs than in any other state. A test project to create electricity by using the temperature difference between warm surface water and the deep cold water right offshore had just succeeded (see box, following page). Hawaiian Electric hopes to be buying 50 megawatts of this ocean power, known as OTEC (ocean thermal-energy conversion), by the late 1980s.

Learning to Harness Volcanic Heat

This year steam from hot volcanic rocks on the Big Island will begin driving turbines to feed electricity into that island's power grid. These geothermal sites can eventually provide much, much more power than the Big Island can use. If economical undersea cable can be developed, the Big Island could export energy.

A few years ago most people thought that in order for geothermal energy to be useful it had to be geyser hot. No longer. Plain hot water—often less than boiling—can be used in numerous industrial processes ranging from dehydrating potatoes to pasteurizing milk to washing beer bottles. Perhaps most important, it can heat buildings.

The West has tremendous geothermal potential. In Boise, Idaho, I drove with geothermal expert Dave McClain past dozens of turn-of-the-century mansions along Warm Springs Avenue. "Some of these old homes have 24 rooms and no insulation, but they have geothermal heat," said McClain. "That means it's been costing only $200 or so a year to heat them."

As Canadian natural-gas prices soar, Boise is expanding its hot-water system. "At least a third of the buildings in the city could be heated geothermally," said Phil Hanson, director of the Boise Geothermal Project, which wants to hook downtown office buildings up to hot-springs water. "The owners of 82 buildings want to be connected. More than 300 residences are waiting to get hooked in. One developer wants to build a 4,000-home geothermal community."

Few cities have good geothermal resources as close as Boise's. A major geothermal drawback, in fact, is that it is often not where it is most needed. But as many as 300 cities, mostly small, could go geothermal. Reno is one. And the Northwest Natural Gas Company is exploring the idea of bringing hot water 40 miles from volcanic Mount Hood for use by Portland industries.

The earth itself can help conserve because just below ground the temperatures are moderate all year. Increasingly, people are building houses at least partly underground. "A well-designed earth-sheltered house can save between 50 and 90 percent of the energy that standard houses use," said Charles Lane of the Underground Space Center in Minneapolis. In 1978 the country had 30 such houses. Now, he estimates, there may be as many as 3,000 under construction.

Chuck Lippi built one of those first earth-sheltered homes in 1974 outside Luverne, Minnesota, near the blizzard-blown South Dakota border. He covered his roof with sod, as did many earlier pioneers, and planted prairie grass on the hill that protects three sides of his home.

"When we built it, people kept asking us about dirt walls," said Lippi. "They thought we lived in a dark and dingy cave."

Lippi's house is far from dingy. A south-facing greenhouse throws light throughout the main living areas. "On sunny days, even when it's minus 20° with a bitter wind blowing, the greenhouse heats the house to 75°," said his wife, Consuelo. A wood stove, with backup electrical heat, warms the house at night and on snowy days.

Power Springs From the City Dump

Today we actually have too much of one renewable resource—garbage. We could save considerable energy by recycling more refuse. Alternatively, some communities may soon be turning it into electricity. Dade County, Florida, plans to burn three-fifths of its daily collection to generate enough power to electrify 40,000 homes. Los Angeles' garbage could displace 13 percent of

DAVID DOUBILET

THE PROMISE OF OCEAN ENERGY

LIKE A VAST STORAGE TANK, the oceans absorb nearly 75 percent of the solar energy that strikes the earth. OTEC, which stands for Ocean Thermal Energy Conversion, is a way to tap this energy by making use of the temperature difference between sun-warmed surface waters and the cold ocean depths.

The OTEC idea works best in the tropics, where the surface is warmest. Inside one OTEC system, warm water vaporizes a low-boiling-point fluid such as ammonia. The vapor drives a turbine to generate electricity. Cold water pumped from 3,000 feet down condenses the vapor back to a liquid. A cable might carry the electrical output to shore, or the plant could serve as a floating factory, making hydrogen for fuel or extracting minerals and chemicals from the sea.

OTEC needs no land, causes no pollution, consumes no fossil fuel. While OTEC energy today would cost more than conventional electricity, this gap could close in the 1990s.

A mini-OTEC project off Hawaii (**above**) *has worked on a small scale. The Department of Energy estimates that by the year 2000, OTEC could replace 400,000 barrels of oil a day.*

the oil its city-owned utility now consumes.

On a hot day on Staten Island, New York, I hiked—as fast as possible—to the top of a 50-foot-high garbage mound at Fresh Kills, the world's largest garbage dump. Well below my feet, bacteria were turning old buried garbage into methane.

"We drill down and draw the gas out," said Gene Luntey, president of Brooklyn Union Gas Company. "We will clean it and end up with a product just as good as what comes out of the well in west Texas."

Fresh Kills could one day provide enough gas to fuel 16,000 homes on Staten Island. As I hurried off the hill, I realized that leftovers from a Chinese dinner I ate ten years ago when I lived in Manhattan might warm a New York family next winter.

Just as intriguing is a technique called Anflow, which uses specialized bacteria to clean municipal sewage and industrial waste water. Such treatment today requires considerable energy. The bacteria do it with half the energy and can generate methane in the process.

New Use for Walnut Shells

Agricultural wastes also offer significant potential. At the Diamond Walnut Growers' cavernous plant in Stockton, California, research engineer Ted Garbeff handed me a bag filled with a coarse brown powder.

"Crushed walnut shells," said Garbeff. "We produce up to 35,000 tons of the stuff a year. We've always sold it as poultry bedding, toy fillings, and for making glue."

Walnut shells also make good fuel. Diamond has begun to burn them in a boiler to "cogenerate," a term that means making both electricity and heat together.

Many plants that make steam for heating and industrial processes can cogenerate electricity by first running the steam through turbines. This can save 30 percent of the energy required to do both separately.

Industry uses more than a third of our nation's energy. Cogeneration could cut that amount by 15 percent. In theory, Texas's refineries and petrochemical plants could cogenerate 123 percent of the electricity the state uses.

A city can cogenerate, too. St. Paul, for instance, plans to heat its entire downtown with waste heat from a utility power plant.

Diamond Walnut Growers' shell-power cogeneration is especially beautiful. First, the fuel itself is renewable. Also, waste heat from the walnut burner warms the plant, eliminating a big gas-fired boiler. And the walnut burner generates three times as much electricity as the plant needs. Diamond sells the excess power to Pacific Gas and Electric.

In the past, utilities have resisted the idea of buying electricity from such independent suppliers. Now they will have no choice. New

WHERE DO SOCIETY MEMBERS STAND?

AS THE RETURNS from a recent survey of National Geographic Society members' attitudes on energy began coming in, it quickly became clear that members are indeed grappling with this complex subject. A surprising 56 percent of those polled returned their surveys. They did it, moreover, with impressive speed.

Almost all respondents volunteered specific comments, which is again unusual for such opinion polls. Many members called for a crash program like the Apollo project that sent men to the moon. Others bluntly demanded that the government keep its hands off the energy business. "Leave the energy problem to free enterprise," wrote one Westerner. A midwestern member sarcastically agreed: "As soon as big business figures out a way to put a meter between the sun and the consumer, we will probably solve the energy problem!"

Solar and wind power, a hydrogen economy, a fully nuclear future, a recycling society—almost every idea had its advocate. The diversity of members' viewpoints on this volatile subject was not surprising. However, the depth of their concern was.

Seventy percent of our members believe the energy situation to be "serious." Sixteen percent consider it a "crisis."

What are they doing about it? Ninety-one percent of the members said they turn off more lights. Eighty-one percent use less energy to heat their homes. Fifty-nine percent have also reduced their water-heating loads.

Eighty-five percent use less energy for their federal regulations require utilities to purchase electricity from anyone who wants to produce it. Moreover, the utilities must pay a price roughly equal to the costs they avoid by not having to generate that same electricity themselves.

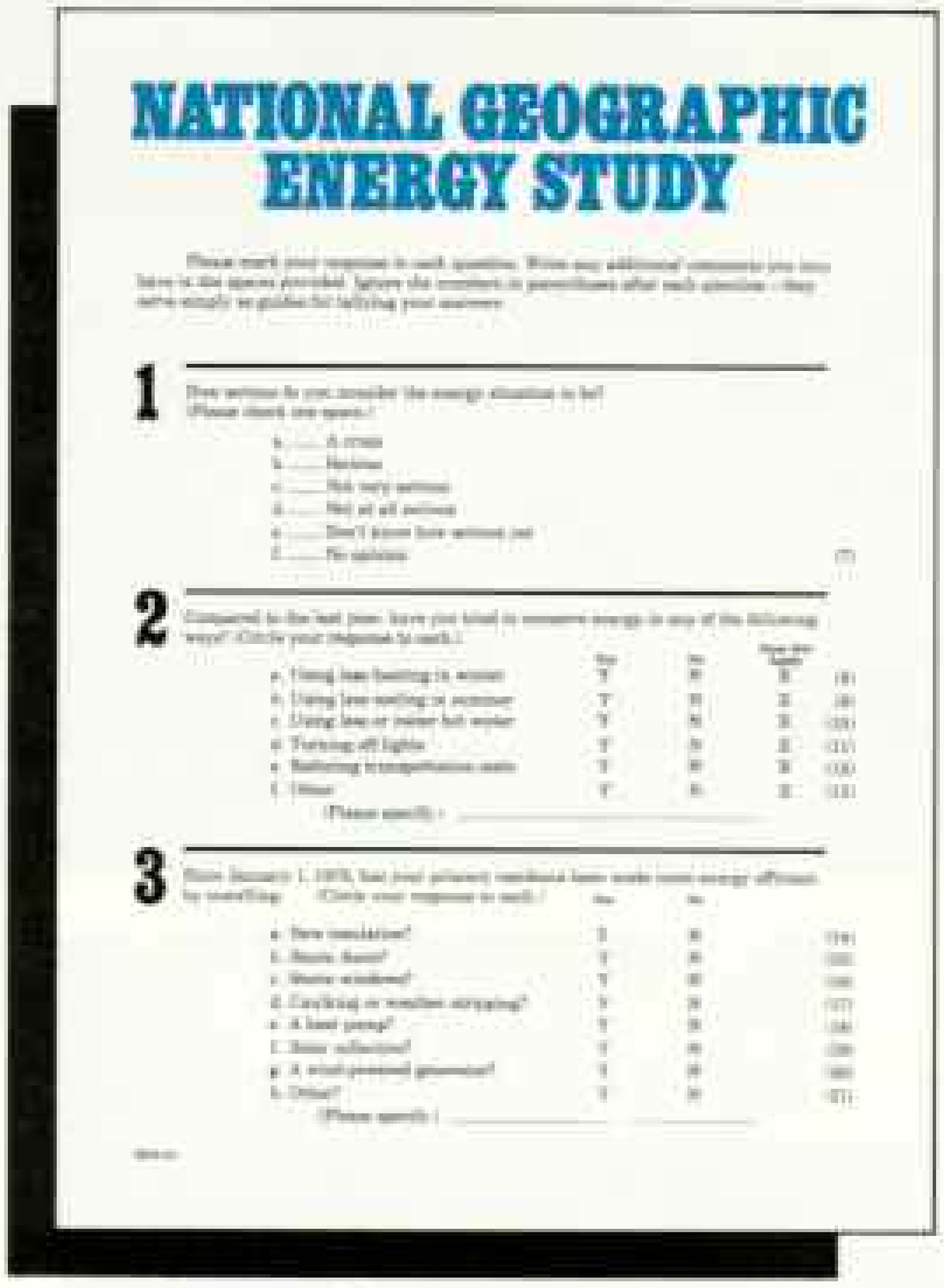
Cogeneration produces vigorous pioneers, especially in New York City with its extremely high electricity rates.

On the day that the 1,000 families who live in the Big Six Towers in Queens declared their energy independence from Con Ed, workers dug up the utility's electric cables and severed them. Later the first of the five cogeneration machines that Big Six had installed started up. The lights went back on and cheers echoed between the towers.

Cogeneration will save the cooperative apartment complex $300,000 a year, said Big Six manager Richard Stone. Big Six could also generate an extra 22 million kilowatt-hours it wants to sell to Con Ed.

transportation, mainly by taking vacations closer to home and organizing their driving to make fewer trips. Forty-one percent walk more, 20 percent bike more, and 16 percent have recently joined car pools. Eleven percent use public transportation more frequently.

How do higher prices affect their gasoline consumption? While 42 percent say that dollar-and-a-quarter-a-gallon gas has severely curtailed their driving, 29 percent say they will not make a major cutback until a gallon costs two dollars. Sixteen percent said it has to reach four dollars and two percent said five. More than half would rather wait in line for gasoline than pay higher prices, with retired persons indicating the greatest willingness to wait.


NATIONAL GEOGRAPHIC ENERGY STUDY

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More than two-thirds of our members have made their homes more energy efficient. Half have caulked or weather-stripped. Thirty-five percent have added insulation; 25 percent have put on storm windows. One percent now boast solar collectors.

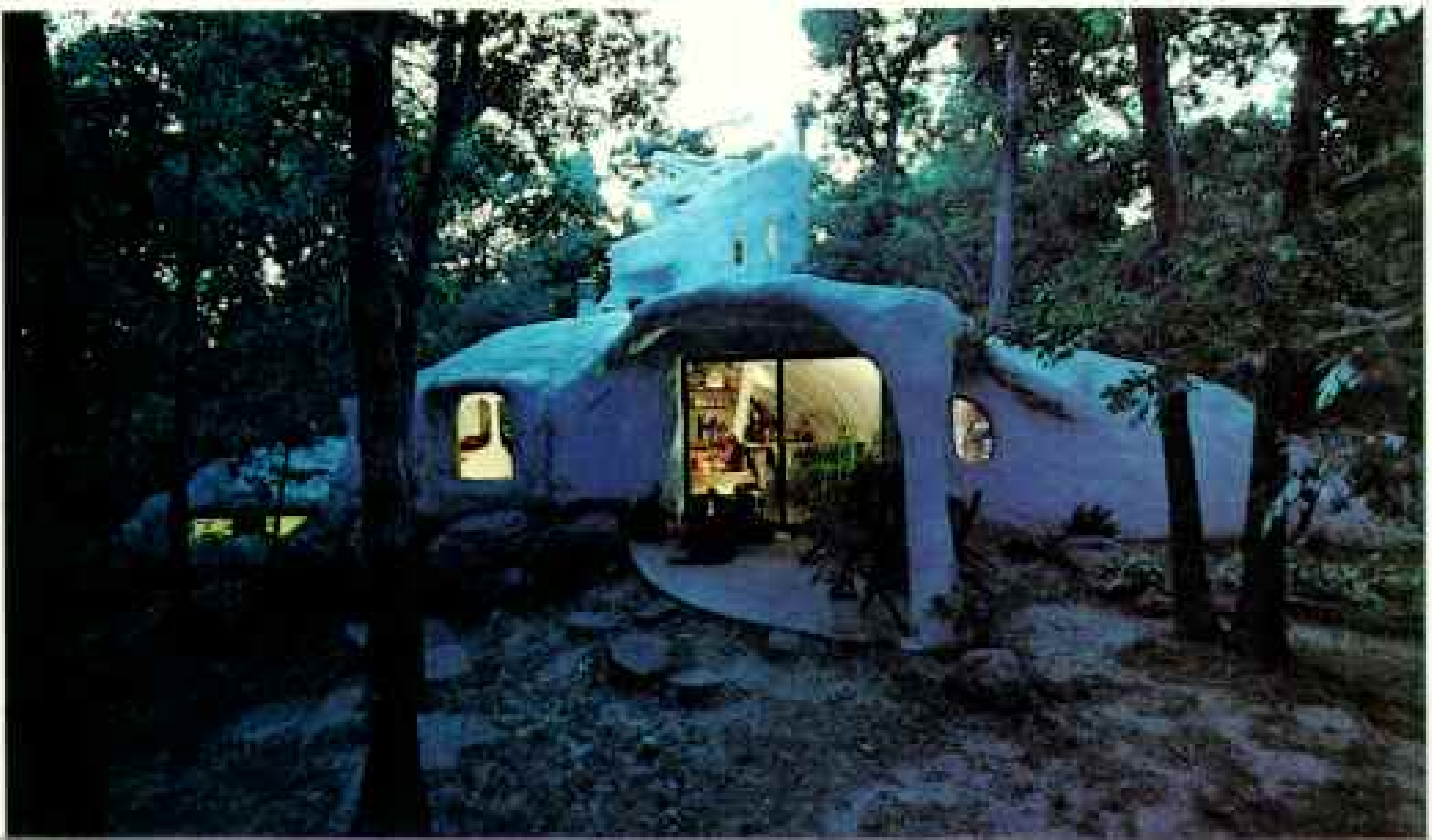
So much for what they have done already. Geographic members have some strong opinions about what they or the government should be doing in the future.

Ninety-one percent feel the United States should be *independent of foreign oil and gas by the year 2000, but only 77 percent believe we actually* can be *energy self-sufficient.*

A startling 92 percent believe the government is handling the energy crunch poorly. Nearly three-quarters, nevertheless, want the government more involved in energy. Ninety percent think our habits of consumption have contributed to the problem. Nearly as many believe the auto and oil industries share the blame.

A slim majority of members wants to limit the number of cars imported. A more substantial majority opposes military action to secure foreign oil if our supplies are cut off. In that event 62 percent of the members favor gas rationing.

Members were given several energy alternatives and asked which they thought were practical, and then which ones were desirable. Conservation was everyone's favorite alternative. Eighty-eight percent think it is practical; 84 percent said it is desirable. By contrast, 86 percent feel that using more coal is practical, but only 64 percent think it is desirable. Nuclear power likewise gets a 72 percent practical rating versus a 53 percent desirability vote. On the other hand, solar energy ranks with conservation in desirability at 85 percent; 76 percent think it is practical. Fewer members think wind is practical—66 percent, even though 77 percent would like to have wind generating our future power. National Geographic members clearly vote for "renewable energy sources." Nearly 80 percent of the members feel renewables are a workable solution to our energy needs.

BOTH BY BRUCE FRITZ

*"**A warm cave** with all the comforts," say Fritz and Dona Frusher of their foam home (**above**). The couple fashioned the structure by inflating plastic sheets and spraying them, 6 to 8 inches thick, with polyurethane, a material used as insulation. A small forced-air furnace heats the house at a fraction of the cost for a conventional dwelling. The free-form structure seems to melt into its environment, a rocky bluff (**left**) near Barneveld, Wisconsin.*

"There are hundreds of entities like us in New York that can cogenerate," said Stone. "We can make our electricity and steam much more efficiently, using much less fuel, than Con Ed. We want to form a cooperative and integrate into their network so they can retire their old inefficient plants."

Con Ed is fighting the cogenerators fiercely. The utility can already provide more power than it can sell. It has no interest in buying electricity from scores, perhaps hundreds, of independent producers, and, despite the federal regulations, it intends to resist paying an encouraging price.

The cogenerators are being encouraged, however, by Con Ed's smaller rival, Brooklyn Union Gas, which foresees an abundance of the natural gas many cogenerators would use.

Grow Power in Your Own Home

Brooklyn Union is testing small, nonpolluting, efficient Fiat engines called Totems. They cogenerate electricity and heat in a 15-kilowatt size—perfect for small businesses and apartment houses. Totems can extract 90 percent of the energy in natural gas. Oil-burning utilities are lucky to capture 30 percent of the energy in their fuel.

Moreover, Sunpower, Inc., a small Stirling engine company in Athens, Ohio, has developed a "total home energy system" that could turn private homeowners into cogenerators. These quiet, file-cabinet-size systems, which could run on any fuel from gas to wood chips to rice husks, use two small, quiet Stirling engines of the free-piston variety. One drives a heat pump to air-condition and heat a home. A second engine produces electricity. The waste heat from both would heat water.

Cogeneration enthusiasts are not the only energy advocates emerging in New York City. With members of the Energy Task Force, a local activist group, I visited a half-demolished neighborhood nicknamed Banana Kelly because it is a curved stretch of Kelly Street in the South Bronx.

Nowhere had the energy crisis struck earlier or harder. For years, while residents of Manhattan's overheated high-rise apartments opened their windows in winter for fresh air, children shivered and pipes froze in the South Bronx. Landlords, sometimes

well-meaning, could not heat buildings at rents the tenants could afford. All too often the buildings were simply abandoned.

Throughout my travels, I had seen that the poor suffer most from the rising cost of energy. They drive the second-hand gas guzzlers. They live in houses without doors.

But something was happening here in the South Bronx, the national capital of despair. The residents of Banana Kelly had formed a neighborhood association, obtained loans, and were donating time and sweat to take title to the landlord-abandoned buildings they inhabited. The street was alive with people hammering and sawing. They were gutting tenement houses and rehabilitating them with insulation and thermal windows.

"We started out just wanting to save our own buildings," said resident Leon Potts. "We quickly realized that if we wanted decent lives we had to save the whole block."

So group members began winter-proofing nearby buildings that were ripe for abandonment. By replacing windows they kept energy costs—and rents—manageable.

"People were telling me last winter they were waking up warm for the first time," said Potts, "and superintendents were saying, 'Leon, you're right. I *am* using less oil.'"

Energy-guzzling Skyscrapers Obsolete

At the other end of the city rises the World Trade Center, the twin-towered, 110-storied monument to a generation of office buildings whose like we shall not see again. As designed, the World Trade Center used as much energy as the city of Syracuse.

Like most postwar skyscrapers, the center's windows do not open. As in most office buildings, lighting and the occupants' body heat throw off so much warmth that air conditioning is needed even in winter.

In the World Trade Center seven giant chillers previously cooled ten million cubic feet of air per minute down to 50°. That allowed building managers to keep temperatures comfortable in the warmest spots on any of the 194 one-acre floors. But the chilled air had to be reheated everywhere else. Just four switches control most of the lighting on each of the center's mammoth floors. That means if one person works late, he must light a quarter of the floor.

"Office buildings in New York City use 103 trillion Btu's of energy in a year," said architect Richard Stein. "Thirty percent of that—equal to five million barrels of oil—could be eliminated with simple fixes."

Changes are coming in office building design: Natural lighting, desk lamps, operable windows, smaller mechanical systems, and computer-controlled environments. Future buildings may use two-thirds less energy.

The World Trade Center staff, meanwhile, is trying to eliminate what waste it can. A host of technical changes have dropped the towers' total Btu use by 15 percent.

NEXT 12 PAGES

An atlas of America's energy resources

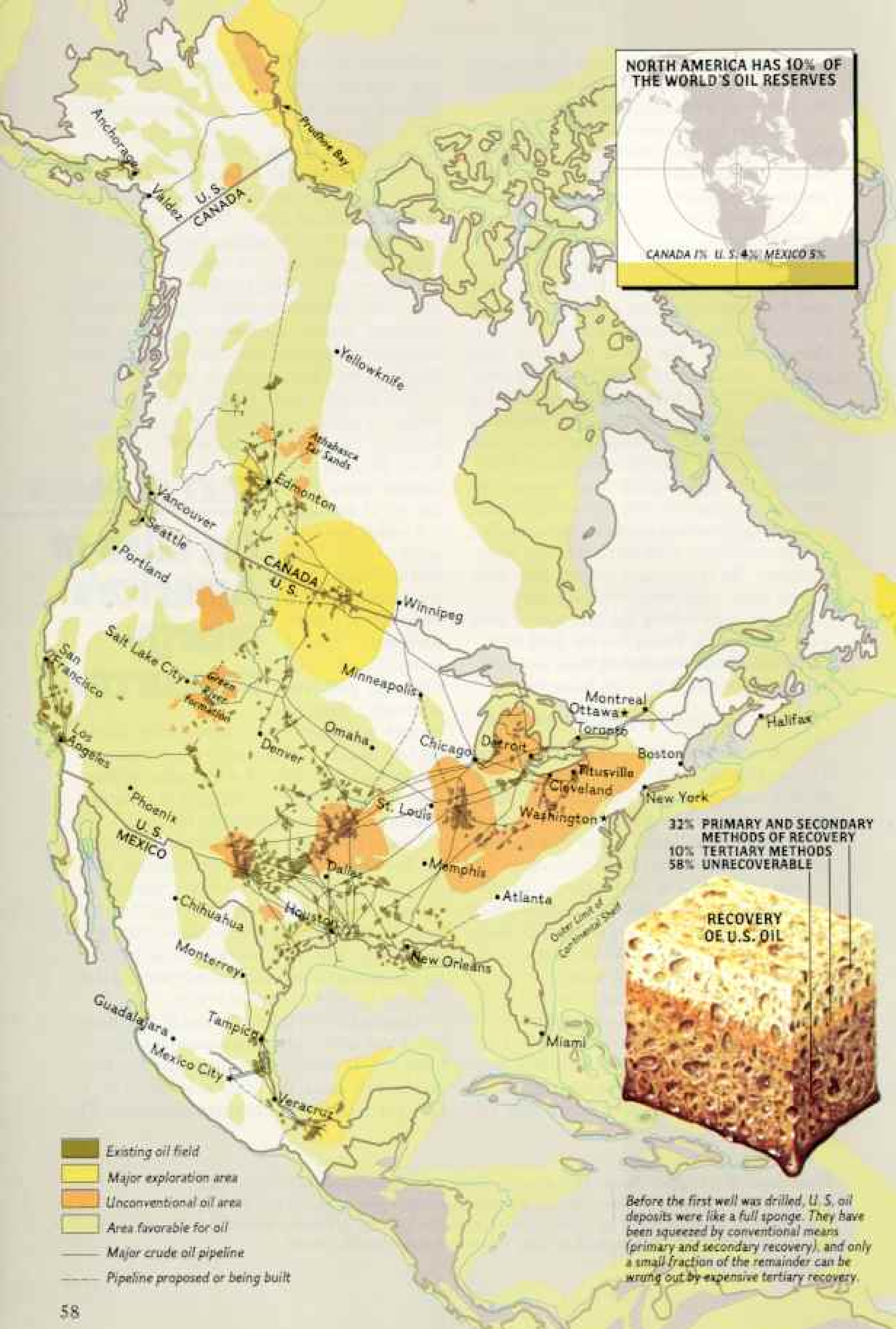
I ended my coverage atop the World Trade Center, talking with New York transportation official David Gurin. The city had just announced a plan to restrict rush-hour traffic across East River bridges to cars with at least two occupants. Gurin said it is part of a changing philosophy: to give priority on clogged Manhattan streets to car pools and public transit.

I was a continent away from San Francisco. Far below I could see cars inching, this time across the Brooklyn Bridge. Soon those commuters might be crossing at least two by two. Unwilling pioneers, perhaps, taking a small step. But then, working together car by car, house by house is the only way for the country to cross its energy bridge.

That lady with the torch was down there too. I had seen a lot of innovation and enterprise as I traveled her country. Too much to doubt we'll reach the other side. No way, I thought, is the lady's light going to go out. □

Meet Sam, the Copper Man: *He's strong, silent, and informative to scientists at Kansas State University. They use the instrumented manikin to gauge the insulation value of various types of clothing. Conservation can be a simple, skin-deep matter of dressing warmly enough to keep thermostats set low in winter.*

OTIS IMBODEN



Before the first well was drilled, U. S. oil deposits were like a full sponge. They have been squeezed by conventional means (primary and secondary recovery), and only a small fraction of the remainder can be wrung out by expensive tertiary recovery.

OIL
Lifeblood and liability

IN 1859, outside Titusville, Pennsylvania, "Colonel" Edwin Drake punched a hole some 70 feet deep, struck oil, and gave birth to America's oil binge. Petroleum quickly became the foremost fuel for lighting and lubrication, the earliest uses for this black milk of the earth that would ultimately nourish the world's largest industry. When the huge Standard Oil Trust monopoly was broken into 34 separate companies in 1911, several of its fragments remained among the world's largest firms.

Oil famines frequently threatened the U. S., but always drillers made new strikes, most notably the great fields of east and west Texas. Within a century after the Pennsylvania discovery, oil shouldered aside coal as the leading source of energy. By 1948, almost unnoticed, the United States already had become a net importer of petroleum.

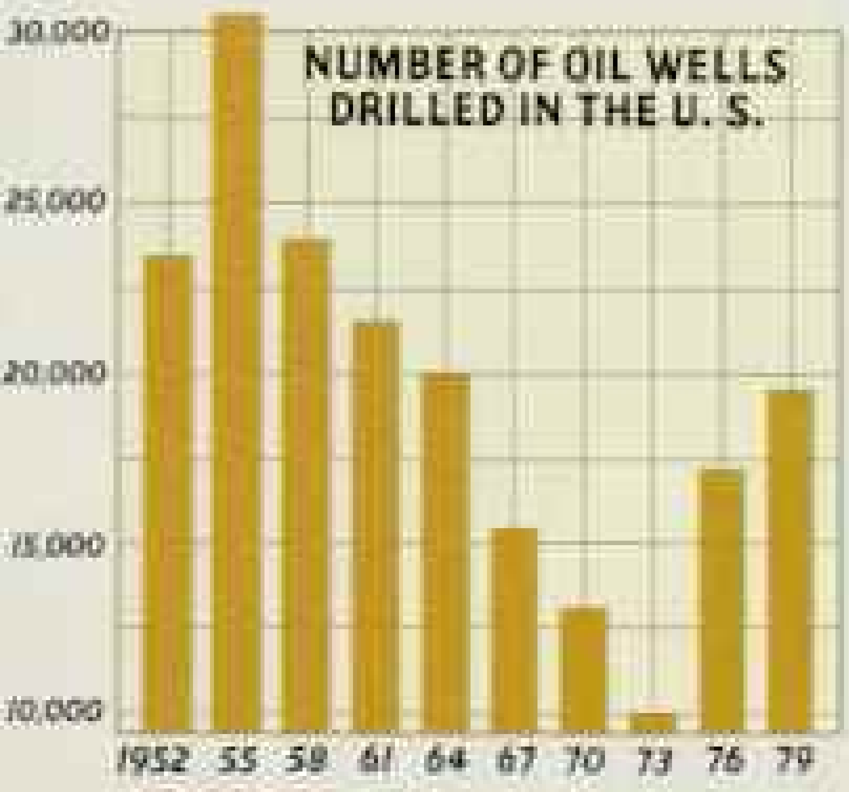
Oil's convenience particularly suited it for use in motor vehicles—a 42-gallon barrel of crude oil packs the same wallop as 5,700 cubic feet of natural gas or about a quarter ton of coal. During the past three decades we tripled our appetite for oil. Its extreme cheapness encouraged wasteful use.

In 1980 Americans consumed more than a fourth of the worldwide production of 60 million barrels a day—to propel our cars, trucks, and boats, to heat homes and drive industry, and to provide raw material for petrochemicals.

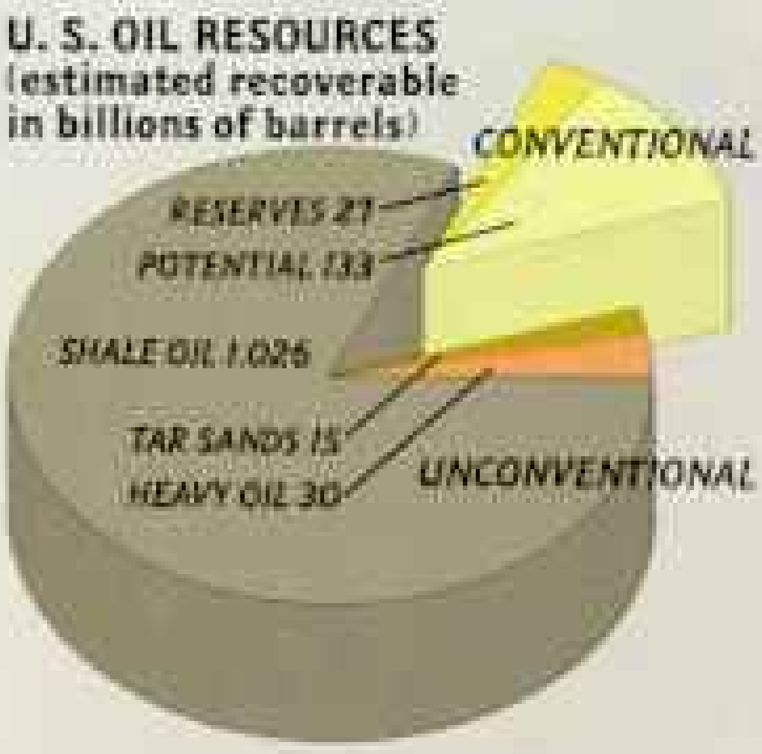
Of this immense flow of oil, nearly nine million barrels a day comes from domestic wells, ranking the U. S. third, after the Soviet Union and Saudi Arabia, among world producers. The remainder must be imported, and the bulk of these imports are controlled by the 13 member nations of the Organization of Petroleum Exporting Countries, who themselves produce half of the world's oil. But our dependence on imports is much less than that of Europe, and it pales beside that of oil-poor Japan, whose industrial economy must be fed by a mobile pipeline of tankers streaming in at a rate of four a day from foreign sources, located largely in the Persian Gulf.

At current production, the U. S. has the equivalent of nine years of oil reserves left. To counter this rate of depletion, we must discover the equivalent of three Prudhoe Bays in this decade alone. Yet most experts fear that few large fields remain to be found. More than 2.5 million wells have been drilled in the U. S.—four times as many as in the rest of the world combined. In 1980 drillers sank a record 60,000 domestic oil and gas wells, a fifth more than in the previous year and most of them deeper and far more costly than ever before. The investment in this urgent search reached 20 billion dollars that year alone. Yet new finds still fall short of the depletion rate.

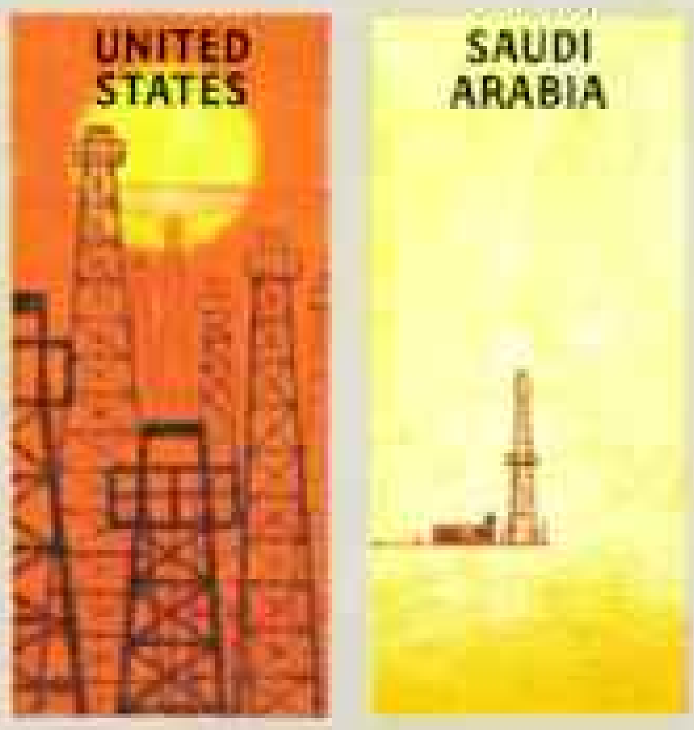
Discoveries of significant offshore fields, dramatic improvements in recovering oil from currently producing wells, rapid development of oil shales and tar sands, and the liquefaction of coal will be needed to halt this ominous decline—unless America learns to live on less.



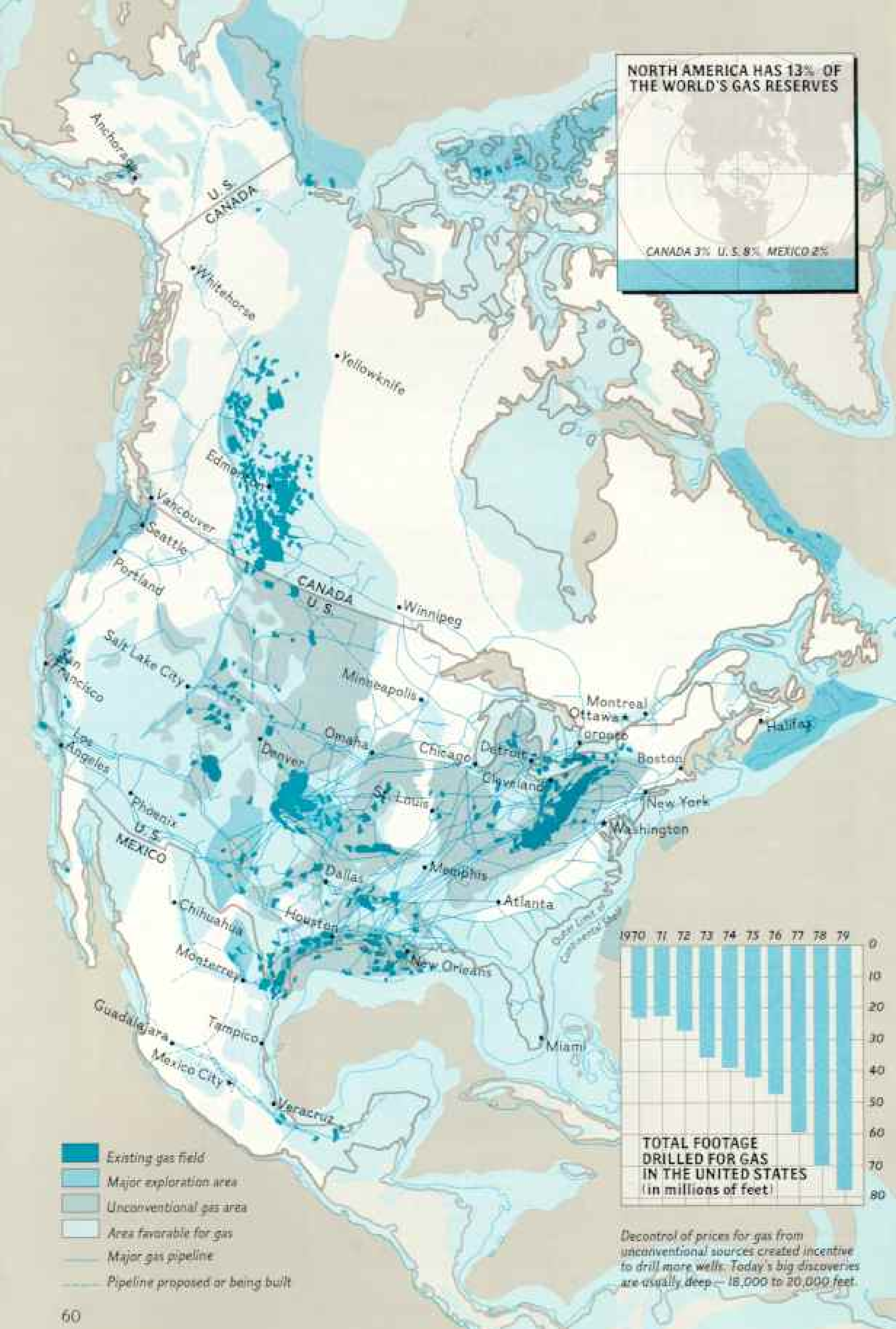
From a 1955 peak fewer and fewer wells were drilled in the U. S. as cheaper foreign oil became increasingly available. The Arab oil embargo of 1973, followed by escalating OPEC prices, helped reverse the trend and gave impetus to a surge in domestic drilling last year.



Our waning supply of conventional petroleum constitutes only a small fraction of the nation's natural resources containing oil. Other, unconventional sources will provide some of the raw materials for making synthetic fuels for transportation.



After a century of exploration, the U. S. has more than half a million producing oil wells. Saudi Arabia has only about 725. Yet on the average, each Saudi well pumps 800 times as much oil as its American counterpart. Altogether, Saudi wells can outproduce U. S. wells by more than a million barrels a day.



Decontrol of prices for gas from unconventional sources created incentive to drill more wells. Today's big discoveries are usually deep — 18,000 to 20,000 feet.

NATURAL GAS

Clean, convenient, and cheap

NATURAL GAS, flowing from an estimated 165,000 wells across the country, today supplies 26 percent of the nation's energy needs. Each year we consume 20 trillion cubic feet (TCF)—and for years production has outstripped discoveries of new reserves, leading many experts to consider gas a slowly dwindling resource.

Since 1978, when gradual decontrol of prices began, a surge in oil and gas exploration has revealed vast new gas fields in the Rocky Mountain region and the Gulf coast of Louisiana, though their potential is still undetermined. Estimates of proved reserves show that production in 1979 exceeded discoveries by 39 percent. By these measurements, U. S. reserves declined to 195 TCF in 1979. But the Department of Energy says discoveries in 1980 may have reversed this trend.

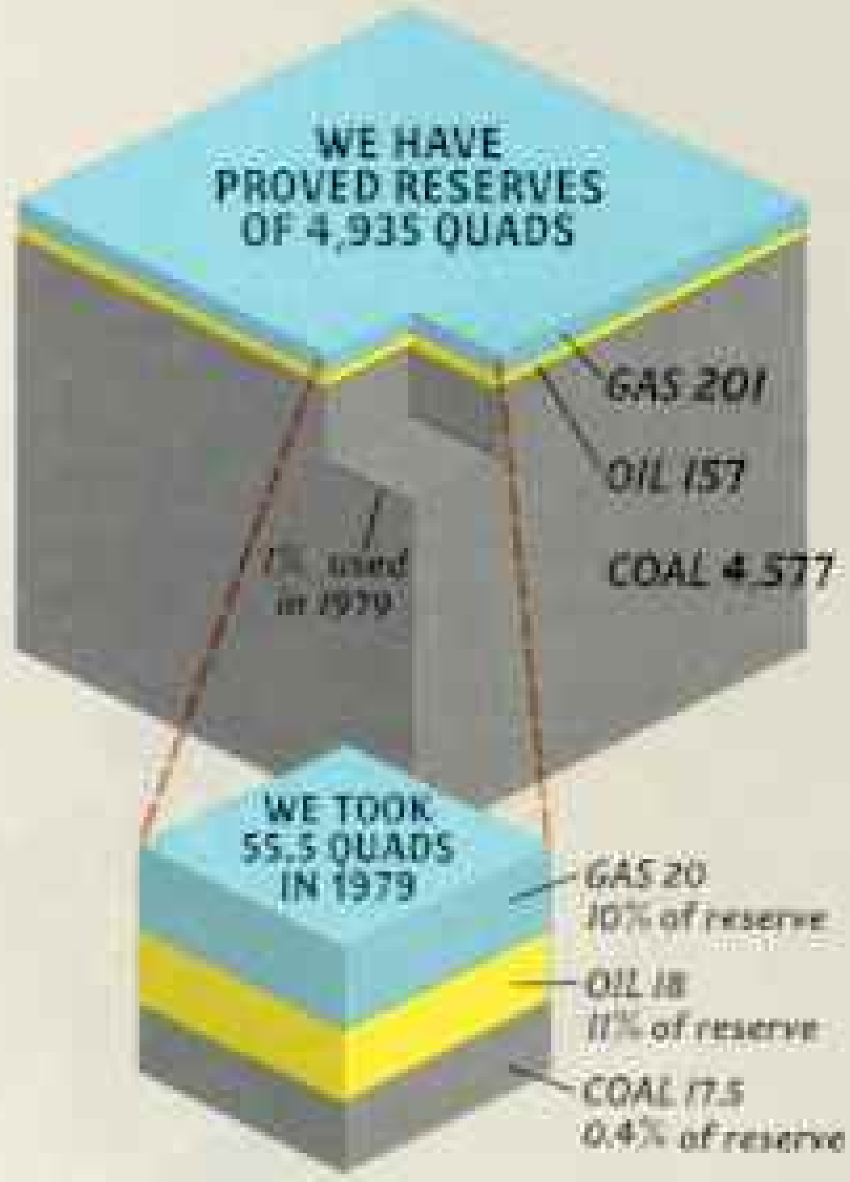
Meanwhile, policymakers advocate turning to new gas sources, including imports from Canada and Mexico, shipments of liquefied natural gas (LNG) from Arab states and Indonesia, the construction of a gas pipeline from Alaska, and the costly process of coal gasification.

Researchers are also looking more seriously at unconventional gas resources, long considered uneconomic to develop. Huge volumes lie locked in the Devonian shales of Appalachia, in the nation's enormous coal beds, and in the deep, brine-filled aquifers of the Texas-Louisiana Gulf coast region. According to the National Petroleum Council, the most promising unconventional resource may be found in concrete-hard geologic formations called tight sands, which underlie many regions of the country. Today the industry produces almost one TCF annually from such sands, which must be fractured underground by injection of high-pressure fluids to allow larger quantities of gas to reach the well bore. Tight sands in the contiguous United States may yield between 192 and 574 TCF, the council says, although other estimates place total deposits, including Alaska, as high as 800 TCF.

Behind the pronouncements of the policymakers lie enormous uncertainties. Vast areas of the nation's prospective oil and gas sediments remain to be explored, despite the drilling of 2,600,000 wells since 1859. Although drilling reached an all-time high in 1980, only 25 percent of the effort was devoted to gas. And the petroleum industry complains that leasing and environmental restrictions on federal lands have prevented or slowed exploration in some of the nation's most promising regions.

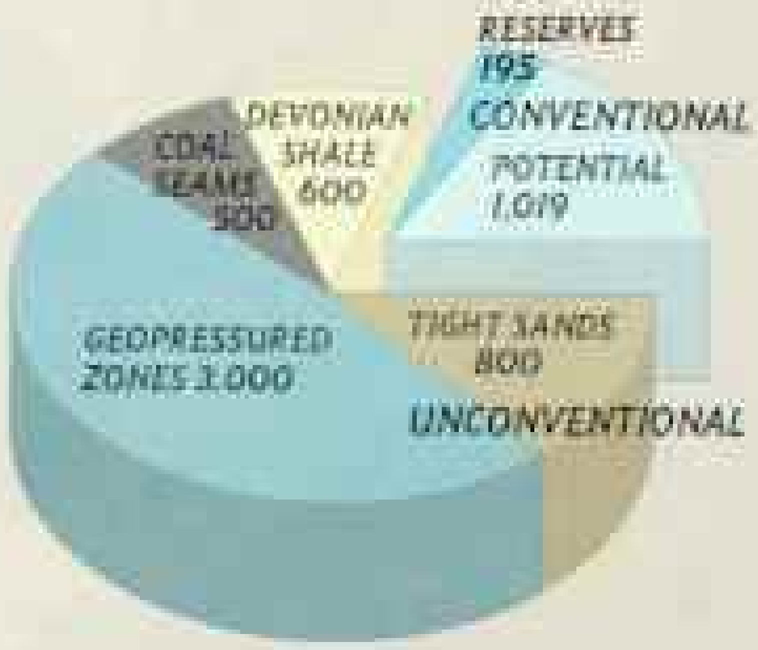
The result has been a fierce debate. Optimists, represented by the American Gas Association, claim that natural gas supplies could be increased to between 23 and 33 TCF a year through massive investments in alternate sources. But most analysts predict little change in U. S. gas supplies during the next decade.

"We can't base our hopes on unconventional gas until we've invested the money to find out what can be produced," says Hans H. Landsberg, senior fellow at Resources for the Future (pages 70-71). "It could be a huge resource—but we must plan conservatively."



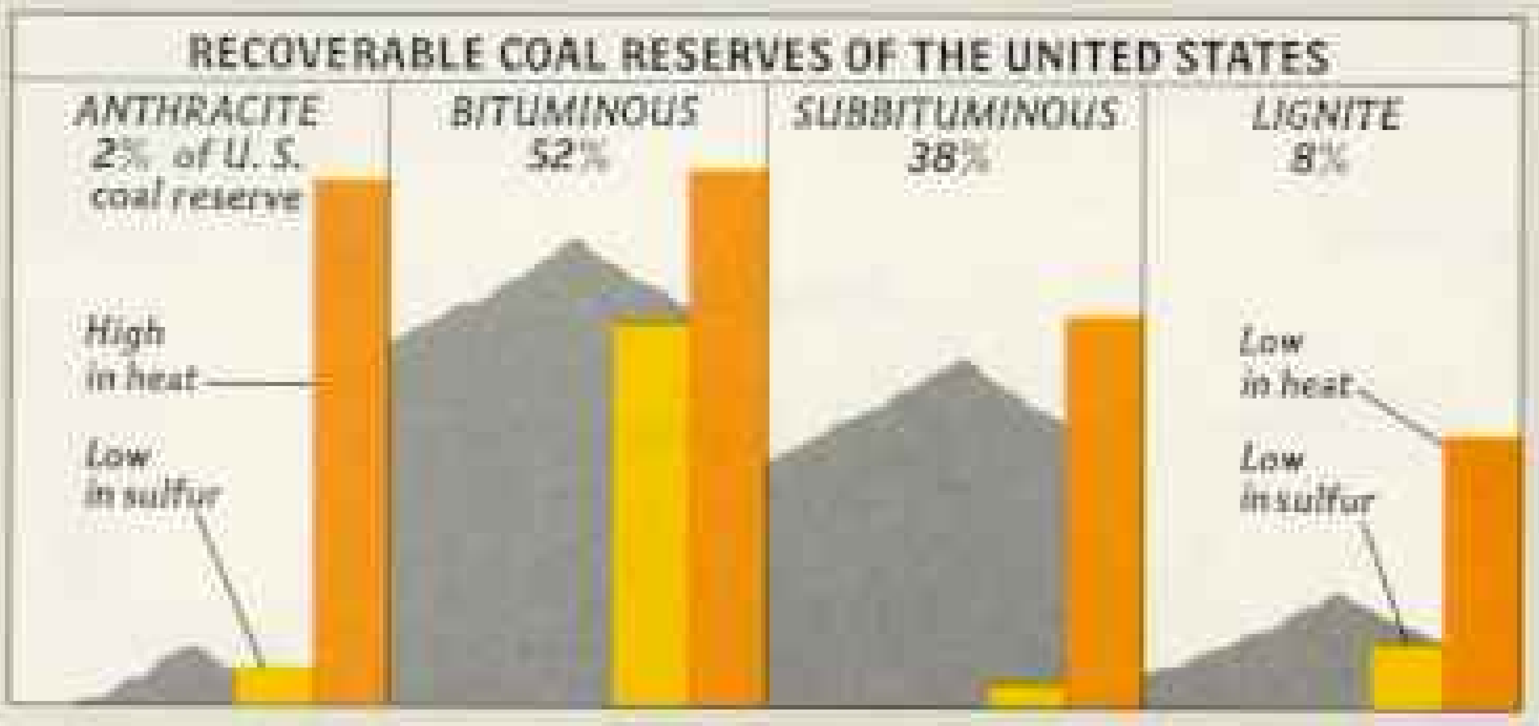
When U. S. fossil-fuel reserves are compared in energy potential as expressed in quads (a quadrillion British thermal units), coal is by far the largest. But when annual production is compared, natural gas goes to the top of the list, coal to the bottom. The use of oil is greater than either, but only about three-fifths is produced domestically; the rest is imported.

U. S. NATURAL GAS RESOURCES
(in trillion cubic feet)



The potential for unconventional sources of natural gas may be enormous, as will the costs of finding and drilling for them. Geopressured zones — brine-filled formations permeated with gas — represent a huge potential resource.

Mining methods changed as health and safety laws raised costs of underground mining and giant excavators were developed to remove surface deposits.



Variable in its composition, coal comes in four main ranks. Ideally, coal should be high in heat content but low in impurities. Sulfur is of particular concern since it is corrosive, degrades the quality of steel products, and contributes to water and air pollution. Most western subbituminous coal now being intensively exploited is, while intermediate in heat content, fortunately low in sulfur.

COAL

Abundant resource, abundant problems

A RECENT STUDY described coal as a "bridge to the future." As the most plentiful fossil fuel in the world, coal has the potential for filling a growing proportion of the demand for energy. But problems plague this promising old fuel.

Coal is found around the globe, but three countries (the United States, the Soviet Union, and China) own nearly two-thirds of all known coal reserves. At present rates of consumption, these reserves would last the world more than 200 years, according to conservative estimates. Furthermore, geologists think the world probably has 15 times this much coal.

While the United States has the largest share—more than a quarter—of the 786 billion tons of known world coal reserves, both the Soviet Union and China produce almost as much coal as we do.

In addition to the category of known reserves, the U. S. Geological Survey has calculated that the United States has an estimated 1.7 trillion tons of deposits at depths of less than 3,000 feet. Unfortunately, much of this coal is not accessible with present technology or at present prices.

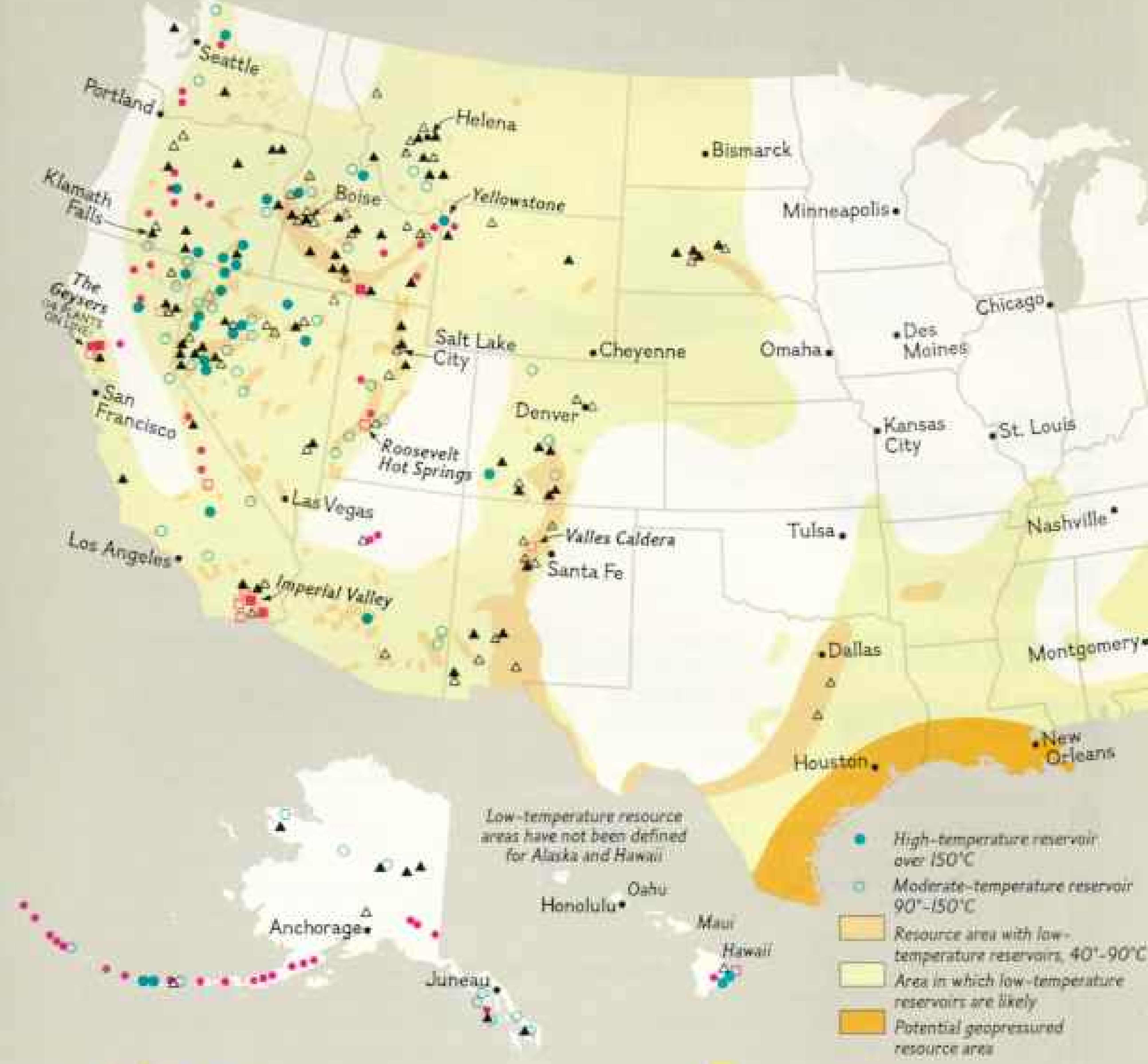
United States coal mining began in the mid 1700s, but coal did not overtake wood as the major source of fuel until the 1880s. As recently as 1925 this country relied on coal for 70 percent of its energy. Coal was itself overtaken by both oil and gas in the late 1940s because they were cheaper and easier to transport.

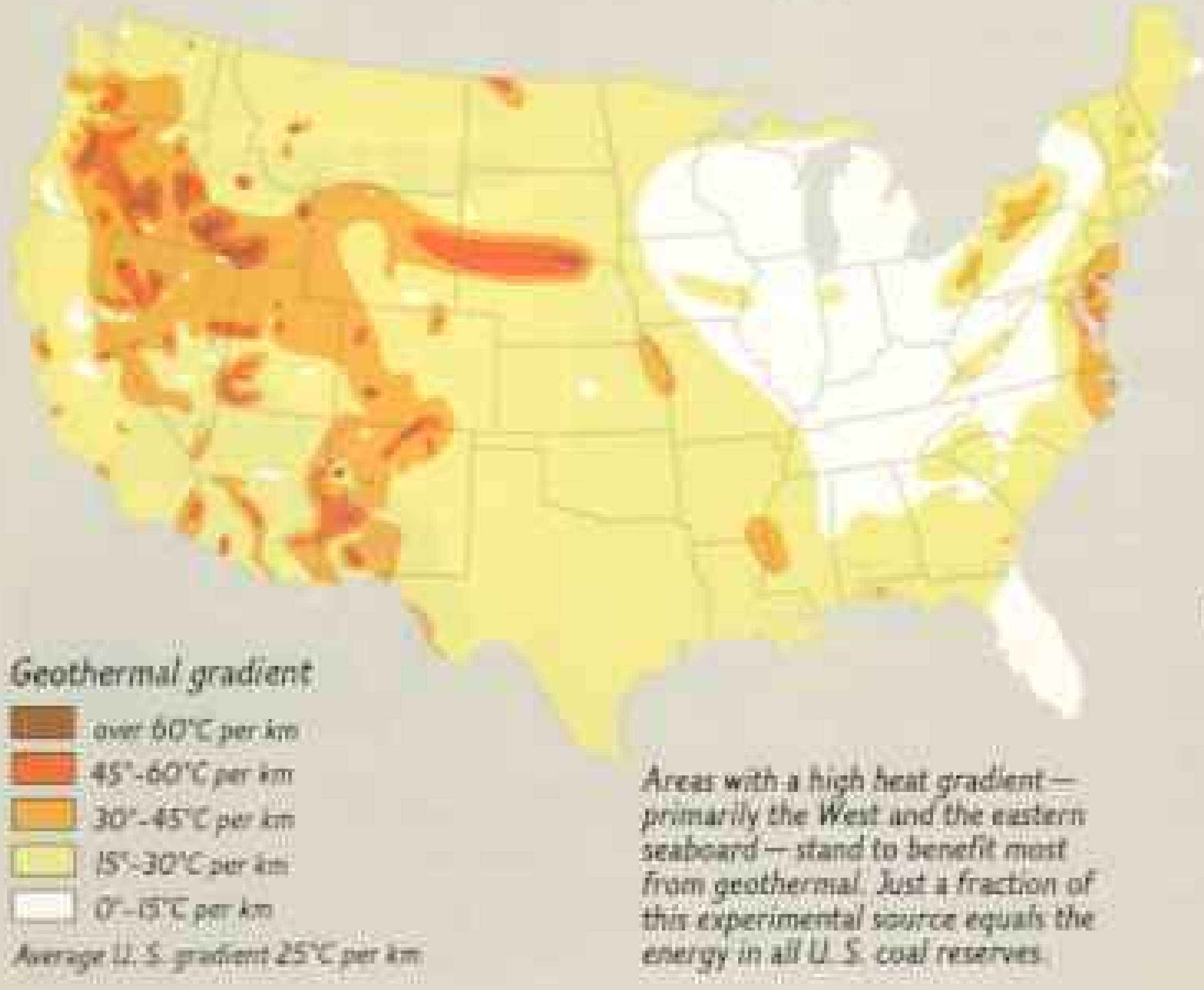
In 1979 a quarter of a million miners labored in some 6,000 American mines scattered over 26 states. They produced 780 million tons of coal, two-fifths from underground mines found mostly east of the Mississippi and three-fifths from surface or strip mines in both the east and west. The cost: more than a hundred lives and thousands of injuries that year alone.

Old King Coal has been deposed by cleaner, more manageable fuels, and calling the United States the "Saudi Arabia of Coal" will not put the former monarch back on his throne. Our gritty black coal provides only a fifth of the energy we use each year. Of the 680 million tons of coal consumed in 1979, 77 percent was burned by electric utilities.

To produce and use substantially more coal than we do today, a number of problems will have to be tackled: capital shortages at high interest rates, manpower (potential strikes and declining productivity), and transportation, including inadequate rail facilities. Environmental concerns include the proper reclamation of mine sites, potential changes in global climate caused by increased carbon dioxide from burning coal, and the emissions from coal stacks that erode buildings, poison lakes, and damage human lungs.

There is enough potential heat in a typical pound of coal to brew more than 100 cups of coffee. And there may be upwards of two trillion tons of deposits in the U. S., ten times as much as all the presently known coal reserves.





Areas with a high heat gradient — primarily the West and the eastern seaboard — stand to benefit most from geothermal. Just a fraction of this experimental source equals the energy in all U. S. coal reserves.

Usable steam can be generated when magma, or molten rock, heats groundwater. The magma itself cannot yet be directly tapped.

- ■ *Geothermal electric plant on line*
- □ *Geothermal electric plant planned or under construction*
- ▲ *Major direct-use facility*
- △ *Major direct-use facility planned or under construction*
- • *Magma near the surface*

GEO-THERMAL

Tapping the earth's furnace

GEOTHERMAL—earth heat—energy is one of our most plentiful resources. It results from the radioactive decay of rocks, which raises the earth's temperature an average of 25 degrees Celsius with each kilometer of depth.

Experts estimate that 32 million quads of energy are simmering within ten kilometers of the surface of the United States. Most can never be utilized, but interest in exploitable areas is quickening. Some 2,300,000 acres of federal land have been leased for exploration and development, and in 1979 drilling increased 25 percent over 1978.

The most common surface manifestation of geothermal energy is simply hot water. In Boise, Idaho, hot springs have heated homes since the 1890s. The earth's hot water is also used for industrial processing.

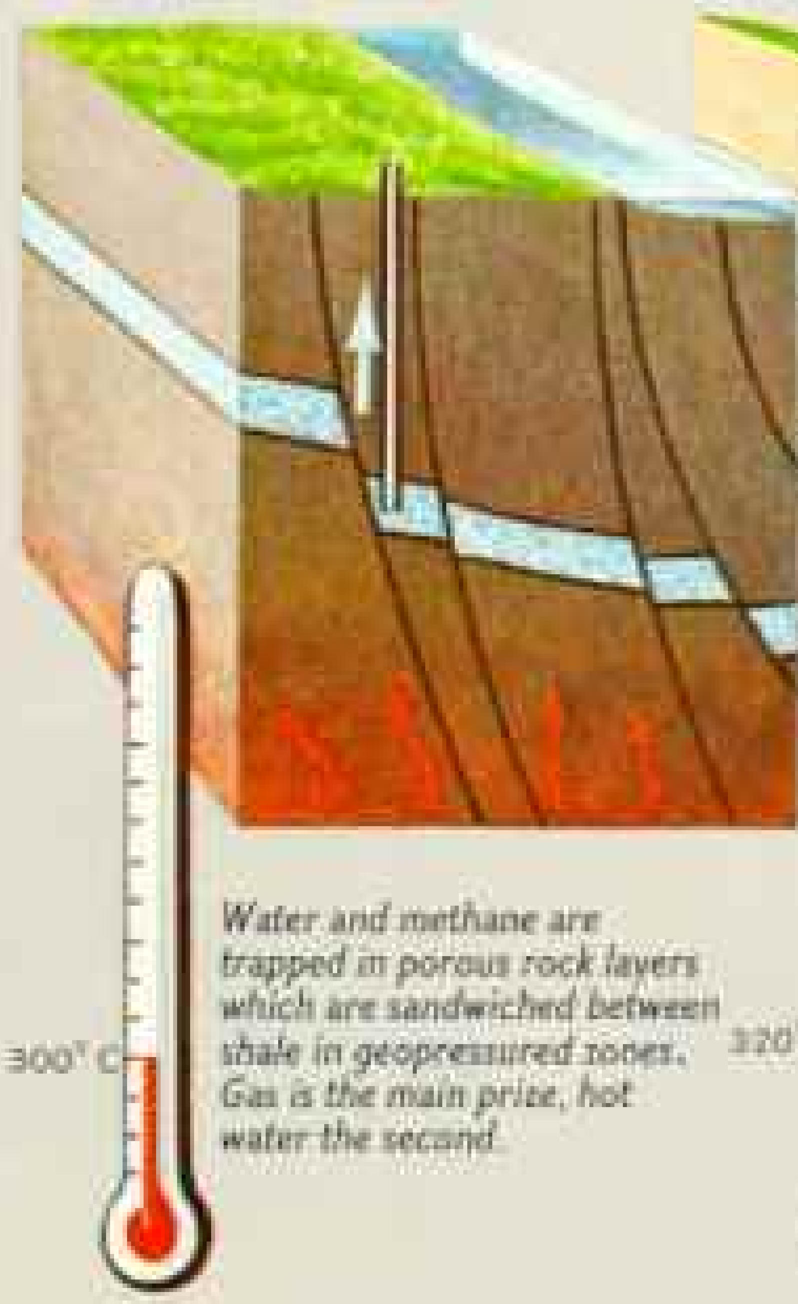
Steps to produce electrical power with hot water are being taken in California's Imperial Valley, where 200 megawatts are expected to go on line in 1983.

Earth heat sometimes exhibits itself as dry steam with high pressure and low water content. Such steam, driving turbines at The Geysers in California, produces electricity equal to half of San Francisco's consumption.

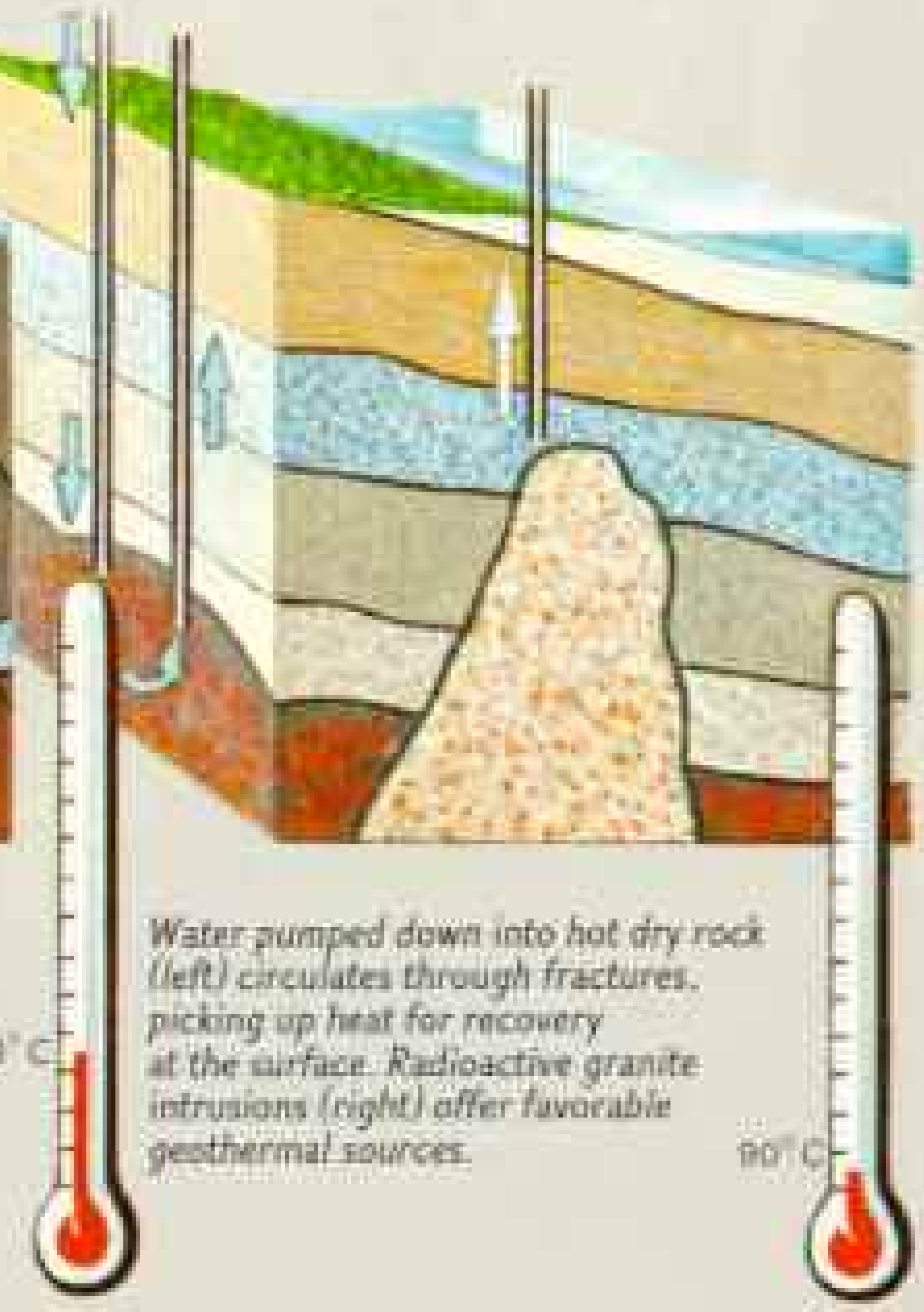
The Department of Energy is seeking to extract heat from a third type of reservoir, hot dry rock. Such formations contain heat, but no water to bring it to the surface. Plans are to circulate water through drill holes connected by man-made fractures in the hot rock.

Development and refinement of technology are necessary to make geothermal energy economically competitive with conventional sources of energy. However, experts estimate that by the year 2020 geothermal could be adding 18.5 quads annually to the national energy pool.

Cool water seeps toward the earth's warm interior. Heated, it returns along fractures to vent or become trapped under impermeable layers where wells can recover it.



Water and methane are trapped in porous rock layers which are sandwiched between shale in geopressured zones. Gas is the main prize, hot water the second.



Water pumped down into hot dry rock (left) circulates through fractures, picking up heat for recovery at the surface. Radioactive granite intrusions (right) offer favorable geothermal sources.

Mostly clustered in the Northeast and Midwest. 72 nuclear power plants are now on line, generating about 10 percent of the commercial electricity used in the U. S. Another 85 are under construction; 19 are on order.

URANIUM

Too hot to handle?

PENNSYLVANIA, which saw the birth of the oil industry, has also witnessed milestones in U. S. nuclear development—from the first commercial reactor at Shippingport in 1957 to the highly publicized nuclear accident at Three Mile Island in 1979. In the wake of the accident, public attention has become sharply focused on this energy source and its radioactive fuel that generates a tenth of our electricity. Doubts intensified by this incident make the future of nuclear power unclear.

The energy uranium holds is awesome. A pound of enriched fuel contains nearly three *million* times the energy in a pound of coal. Its radioactive power demands elaborate precautions during plant construction and operation and in the safe disposal of waste—still an unsolved problem and a subject of anxious study both here and abroad.

More than a quarter of the world's uranium underlies the western United States, primarily in New Mexico and Wyoming. Estimates suggest that these reserves could power all domestic reactors now operating, plus those under construction and in the planning stage, for their 30-year lifespans.

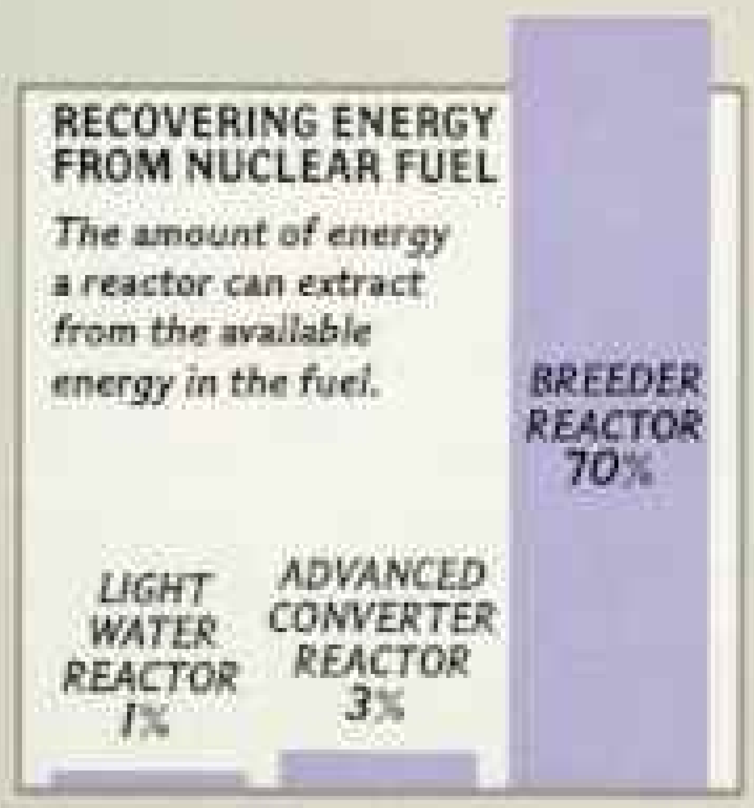
Last year the nation's 300 uranium mines gouged out some 20 million tons of ore. From each ton, mills and enrichment plants concentrate a few ounces of radioactive uranium 235, the isotope that the reactor splits to release the atom's enormous energy.

When the reactor boom blossomed in the early 1970s, utilities ordered a hundred plants in three years, and optimists envisioned 1,500 reactors generating thousands of megawatts by the year 2000. Then escalating electricity costs and the Arab oil embargo—coupled with quickening conservation efforts, rising inflation, and plant costs—slaked energy demand. Reactor orders dropped. Increasing health and environmental worries forced further plant delays. As a result, the American uranium industry has fallen upon hard times, and miners have been laid off.

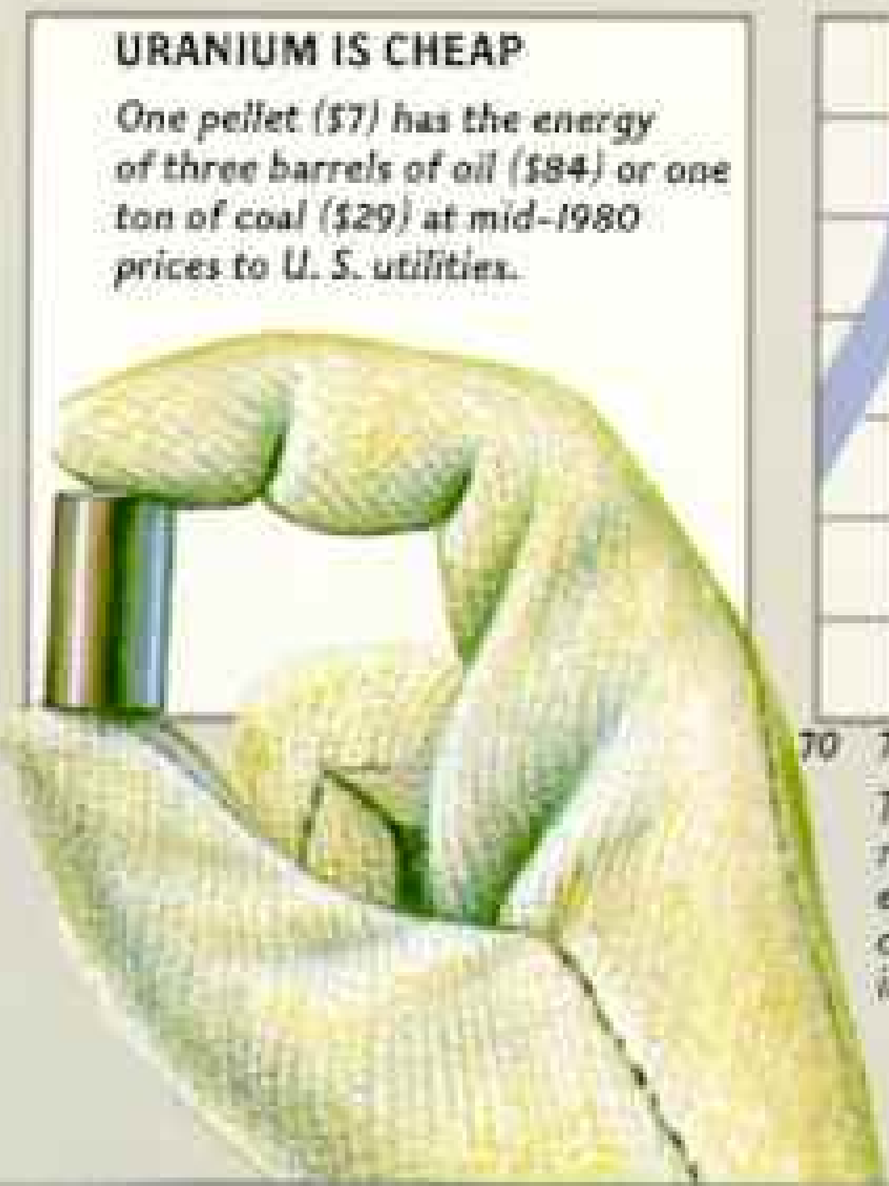
Yet nuclear energy has carved a vital niche, especially in New England and the Midwest. Reactors produce 80 percent of the electricity in Vermont, 60 percent of Maine's electric power, half of that in Connecticut and Nebraska. Outside the U. S., 21 nations operate 166 reactors, with the densest concentration in Europe.

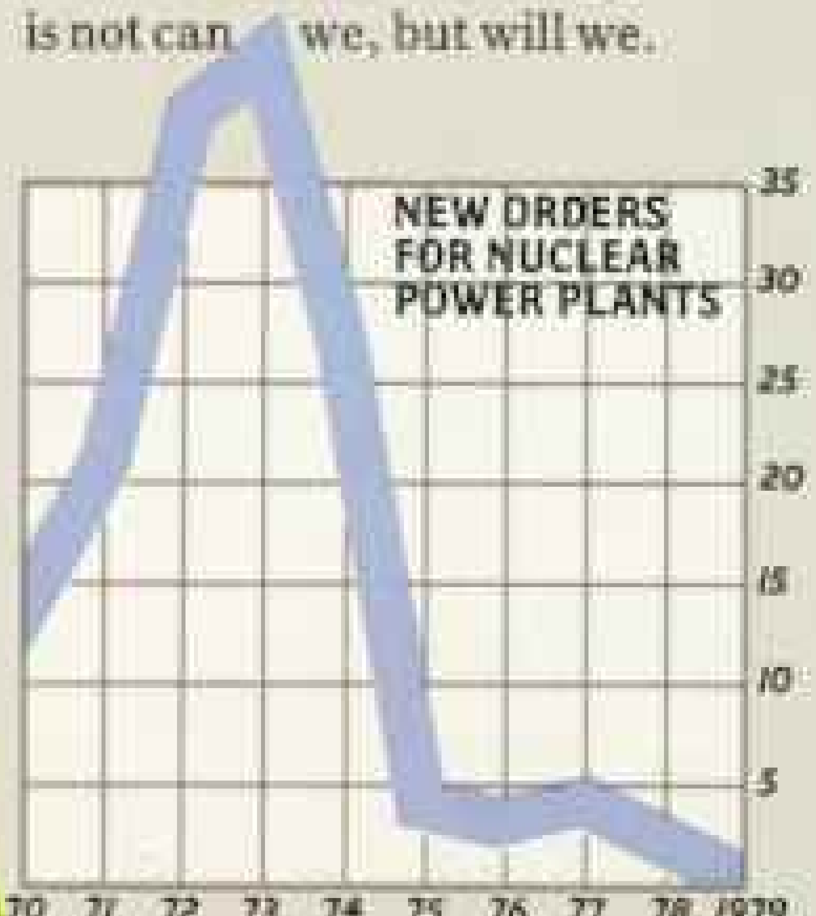
Research abroad and at home promises substantial improvements in reactor efficiency. In addition, recycling of spent uranium can recover much of the nearly one-third of the uranium 235 that is not consumed during a conventional operation. The breeder reactor, which produces more fuel than it uses, is already operating in four foreign countries. Breeders could multiply the reactor fuel supply 70-fold. But breeders convert uranium to plutonium reactor fuel, only a few pounds of which are needed to make a powerful bomb. Many fear nuclear weapons proliferation, and breeder development is stalled in the U. S.

With uranium, as with so many other fuel alternatives, the raw material and technology are already at hand. The question is not can we, but will we.



Most U. S. reactors are of the light water type, while Canada has developed a more efficient advanced converter. The U. S. is still debating the future of its breeder program.





The sharp decline in plant orders reflects higher plant costs, reduced electrical demand through conservation, tighter regulations, and increasing public opposition.

SOLAR ENERGY

Ours for the taking

THE SUN LAVISHES energy on the earth. Without its warmth our planet's temperature would never rise much above –450°F. Every year through photosynthesis, the solar energy embodied in the food and fiber grown in the United States exceeds the energy in all the oil we burn during the same period. Every year the sun drenches the U. S. with 500 times more energy than we consume. If we could tap only a tenth of that, the entire U. S. energy demand could be met with the rays striking just 2 percent of the nation's surface.

Although we usually think of solar energy simply as sunlight, the term includes many other resources. By heating the earth and its atmosphere, the sun generates wind, waves, rainfall for rivers, and ocean-temperature differences. The sun helps grow trees for firewood and plants that can be converted to alcohol.

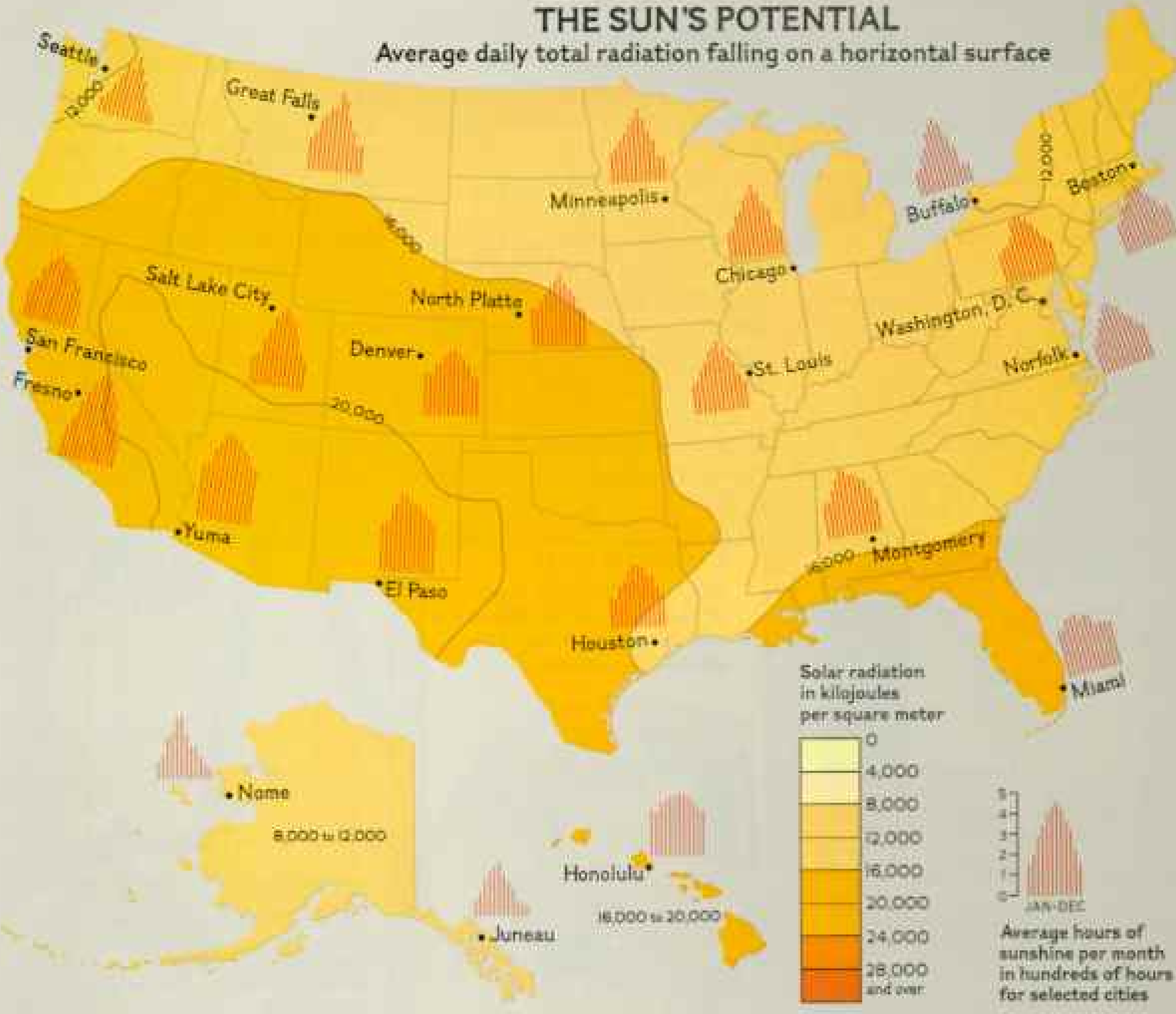
Solar resources already supply 6 percent of our energy, but mostly in the form of hydroelectric power and wood. Today we are learning new ways to harness the sun's powers.

The map below shows how the solar energy potential in kilojoules (roughly equal to Btu's) varies across the country. This includes both the direct radiation obvious on a sunny day and usable sunlight diffused by clouds, dust, and water vapor.

Flat-plate collectors can convert 30 to 40 percent of the kilojoules that strike them into heating energy. It takes about 55,000 kilojoules to heat water for a family of four for a

THE SUN'S POTENTIAL

Average daily total radiation falling on a horizontal surface



day. For a typical house in Washington, D. C., ten square meters of rooftop collector space can provide half that family's hot water even in winter. In the same area, a 40-square-meter greenhouse, or 33 square meters of masonry walls or floors behind south-facing windows, can provide half the space heating if well integrated into the design.

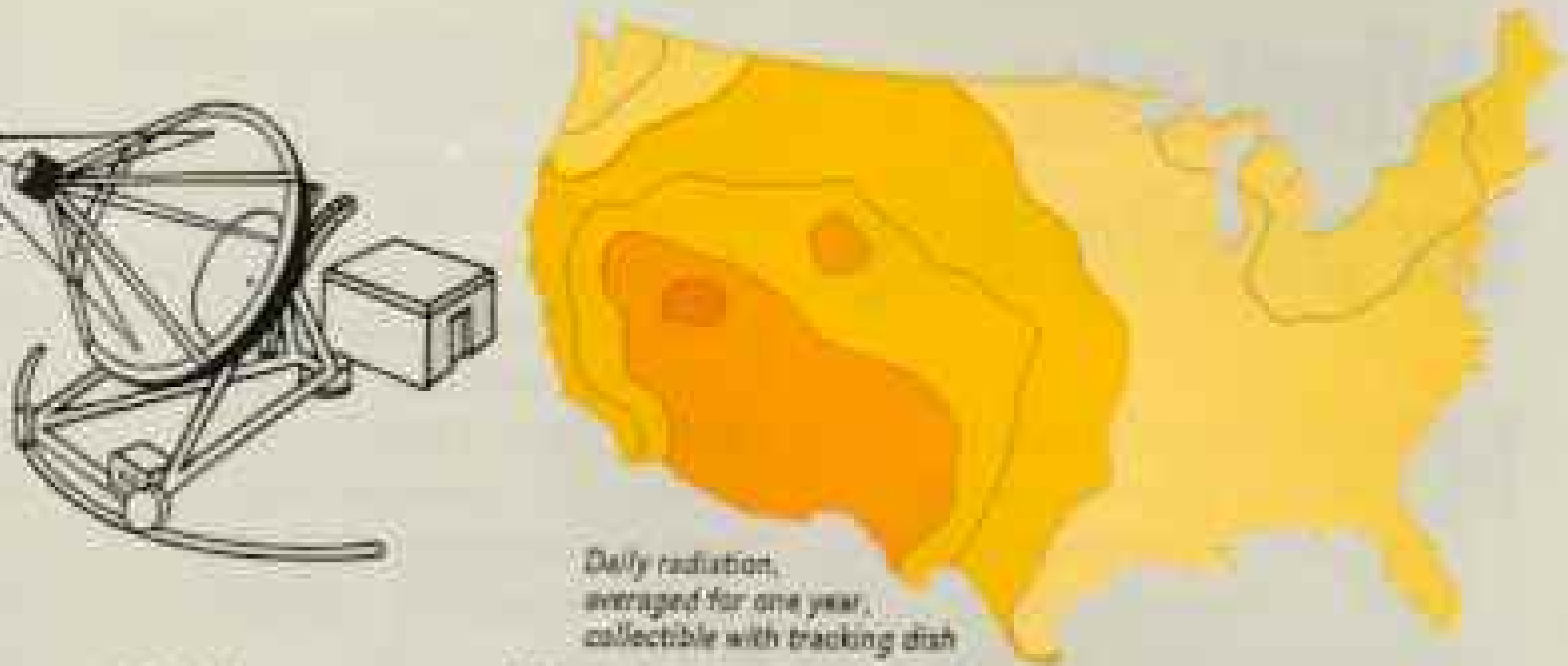
But annual performance can vary as much as 20 percent because of changing weather conditions. And figures differ, of course, from house to house and from region to region. The maps at right illustrate the potential of four leading collection techniques.

Some solar devices use concentrators (1) to reflect sunlight striking a large area onto a smaller surface, which gets hot enough to boil water and create steam to generate electricity. The concentrators track the sun continually in order to stay in direct sunlight.

Solar energy is also used to heat water or air in flat-plate collectors (2), which normally face south on rooftops. Hot water can be used for household needs. In so-called active solar systems, warmed water or air can heat buildings when aided by pumps and fans. Water for many industrial processes also can be heated with these collectors.

Windows, greenhouses, and other forms of passive solar architecture (3) can often collect as much solar heat as an efficient building needs. Even in December in Seattle or Vermont, the sun can warm buildings significantly. Photovoltaic, or solar electric, cells (4) have considerable promise across the country.

Some proponents say solar could meet even more of our energy needs than the official goal of 20 percent by the year 2000.



1 Tracking concentrators follow the sun on its course. The reflective dish concentrates solar radiation to produce electricity directly through photovoltaic cells, to turn water into steam for turbines or to heat other liquids. Production is limited by intermittent clouds and shuts down when the sky is overcast.

2 Flat-plate thermal collectors carry tubes filled with air, water, or other fluids. In the Northern Hemisphere, collectors are most effective on roofs and when facing south at an angle equal to the latitude of the site plus 15° (e.g. Denver, 40°N + 15° = 55°). They utilize direct, reflected, and diffuse radiation.

3 Passive solar designs require no mechanical systems or solar cells. South-facing vertical windows or glass walls admit shortwave solar radiation that is absorbed and converted to heat inside. Insulating glass can retard heat loss on cold nights. Roof overhangs shade windows in summer when the sun is more nearly overhead.

4 Solar-cell arrays should be situated for maximum exposure to direct solar radiation. Banks of fixed photovoltaic cells are set at the same angle as the latitude of their location (e.g. Denver, 40°N). As with all solar systems, the energy produced depends on changes in the cloud cover, day to day and season to season.

What six experts say

HOW should the energy problem be handled? A former government official, a research economist, an environmentalist, a professor, an oil executive, and a physicist present their views—and demonstrate that even experts disagree.

John F. O'Leary

JOHN F. O'LEARY ASSOCIATES, INC.

THE United States has been slow to recognize the basic nature of its energy problem—undue dependence on the Middle East. It has been even slower to take actions that can, within time, restore some order to our energy economy and prevent the recurrent crises and open-ended price increases of the 1970s.

NATHAN BENN

The single most important factor contributing to the global energy dilemma is a consequence of the geologic accident that deposited enormous volumes of oil in the Persian Gulf region. Today the world consumes energy equivalent to about 100 million barrels of oil per day. Of this, some 60 million barrels per day is oil, a third of which comes from the Persian Gulf area. We use oil in this volume because it is convenient and cheap: During the 1950s and '60s Middle East oil became the world's least expensive and most prolific source of supply.

The risky consequence of this dependence has been to subject the economic future of the United States and, to an even greater extent, that of its allies, to the fortunes of the various governments in the Middle East. That arena, chronically unstable, has become ever more so as the wealth associated with oil production and the temptations associated with its control have grown in the past decade.

Instability in that region will almost certainly continue to increase in the years ahead, with interruptions to supplies more frequent, and oil prices increasing at rates that will pose an even greater threat to the stability of the world economy than today.

The United States has, in the past seven years of groping for solutions, finally made a start on most of the purely domestic actions possible to deal with the energy dilemma. It has begun, haltingly, to provide for management of oil supplies during supply crises. It has, after too much delay, launched us on a course of energy conservation. And, with the notable exception of nuclear power, it has finally put in place programs aimed at expanding both conventional and unconventional energy resources.

A final element of action, however, has not been effectively addressed, and that is bringing the United States' enormous capital and technical resources to bear more directly on the global energy equation. We must view the world's energy economy as a single complexly interrelated system, one now unduly burdened by its emphasis on Persian Gulf oil. In turn we must grasp the potential for reducing that emphasis by increasing supplies at other points within the system. Thus the development of heavy oil or tar sands in Canada or Venezuela, the opening of a new coal mine in Poland, or the completion of a hydroelectric project in the Amazon can provide an additional supply in the global system and thus temper the capacity of the Middle East to disrupt that system.

Enormous opportunities exist for expansion of conventional as well as unconventional resources in this hemisphere and in other parts of the world, if the technology and funding can be made available. The major remaining task of the U. S. is to find the political and financial mechanisms that will permit these resources to be applied to resolving the global energy dilemma.

Hans H. Landsberg

CENTER FOR ENERGY POLICY RESEARCH, RESOURCES FOR THE FUTURE

HOW OFTEN we hear it: "What this country needs is a crash program for energy independence—something similar to the Manhattan Project, which produced the atomic bomb, or the spectacular Apollo space program. We need an energy moon shot!"

Would that it were so simple. But the headlines tell us differently.

Take those that blared from the front page during only the past two years—the Iranian revolution, the accident at Three Mile Island, the Iraqi-Iranian war. All affect the U. S. energy situation. They also show that it is not a simple crisis that lends itself to a dramatic moon-shot solution. Instead, it is a continuing set of problems that will be grinding out for decades. They present us with two undramatic choices: We cope well, or we cope poorly.

This is not to say that good news will be wholly absent. Energy efficiency will continue to rise with improved motor vehicles and building construction. Pollution will lessen with improved technology and institutions. New energy sources will replace conventional ones, but slowly.

Interspersed will be setbacks and near disasters—the tanker spill, the nuclear mishap, the discovery of a new toxic effluent, the jolting loss of an oil-supplying nation.

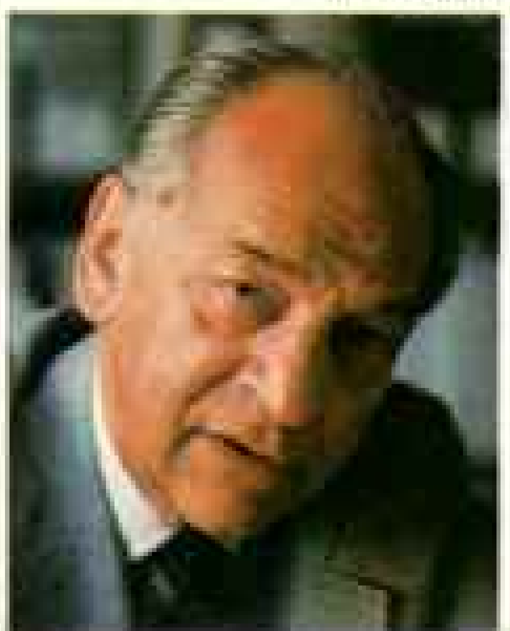
Coping with such problems involves four basic tasks:

- Adjusting to high and rising energy prices.
- Moving to a different mix of energy sources, in which oil, and after a while gas, will decline in importance. Coal and, if we are lucky, nuclear energy will rise, and in the longer run nondepletable sources will come to play an ever increasing role.
- Accomplishing the above tasks with the least damage to the economy, the environment, and world peace.
- Adopting measures that will enable us to withstand the inevitable shocks and new stresses that lie ahead.

These formulations look straightforward and achievable. But within each issue nests another. Adjusting to higher prices involves coping with increasing inflation. Higher prices hit different segments of the population with differing degrees of severity. And inequitable policies would cause rampant divisiveness.

Moving to new energy sources such as synfuels raises complex questions of government's role regarding open or hidden subsidies, regional rivalries, and poorly understood environmental and health hazards.

NATHAN BENN



A word about those who wish to participate in shaping energy policy: If they insist on seeing all their goals accepted, policy will continue to be made in agony and frustration, and at a snail's pace.

To the extent that we relearn the forging of consensus, energy policy too will benefit. Without it, energy policymaking will continue as the major battleground for opposing philosophies, life-styles, and perceptions of the national destiny. That perhaps is the hard core of the energy problem.

Steven C. Wilson

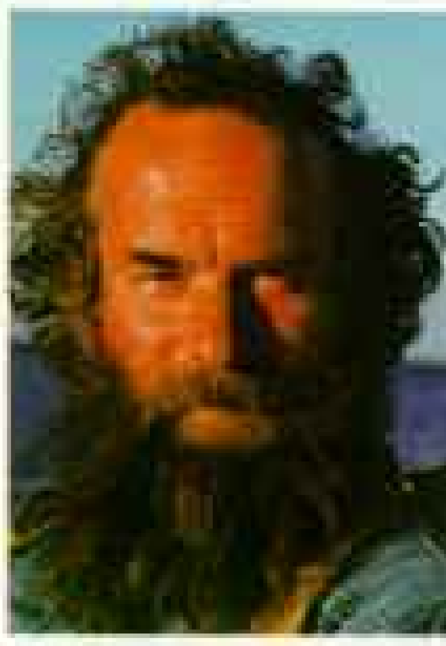
ENTHEOS MOUNTAIN
AGRICULTURE INSTITUTE

I GREW UP unfettered by energy concerns—left them to the gas and electric companies, Big Oil, the government. They coped with the problems. I consumed. But after the 1973-74 oil embargo, Karen and I changed our life-style.

Our response to the national nonresponse to the oil embargo was to become personally energy self-reliant. Our days are no longer splintered by the clock, our weeks no longer defined by calendar, our activities no longer fractured by commuting. Work and annual leave merge together, tuned to season and sun.

There is a satisfying honesty to the daily immediacies. We like the rhythm, the pulsebeats of our planet responding to its sun: spring planting when the soil temperature reaches 43°F, fuel-wood cutting when the sap is down, digging carrots and potatoes before the fall rains, pruning fruit trees in the winter . . . discovering, then maintaining the harmony of the land, water, and seasons.

Organic gardens, home-preserved foods, woodlots, simple work in a place of beauty, and a clothesline by a home not connected to the commercial power grid—these things are real. I know that most of what we eat, the warmth in our home, our hot water are all solar powered. Our tools are selected for work enhancement rather than labor saving.



ENTHEOS

And so our perception of the "energy crisis" is different from many. We feel that Americans have had too much fuel available, that less will be better. I see it as the "effects of too much energy" crisis.

With our bigger-is-better, disposable, nonrenewable energy past, I wonder if, in squandering fuel, we have not also subverted self-reliance, neighborly concern, the active appreciation of balance and harmony. I think confronting this legacy of too much, too soon would be the proper response to the energy crisis.

Robert B. Stobaugh

HARVARD GRADUATE SCHOOL
OF BUSINESS ADMINISTRATION

THE most important energy problem facing the United States is the need to reduce dependence on imported oil while maintaining an adequate level of economic growth.

Reducing oil imports is imperative to lessen the strain on the international oil market, to moderate future oil price rises, and to avoid costly recessions. It would improve political relations with our allies and enhance our national security.

Unfortunately, geology limits the outlook for domestic oil and gas. Prospectors have so picked over the giant fields that the likelihood of finding additional huge fields is much less than in the past. Four times as many oil and gas wells have been drilled in the United States as in the rest of the world put together—yet oil and gas reserves have been declining.


NATHAN BENN

Coal and nuclear power face political barriers. They inflict penalties or side effects paid for not directly by utility customers, but by the general public: air pollution caused by burning coal, unsightly damage caused by strip mining, fear of a nuclear accident, and the dislike of passing nuclear wastes along to future generations.

Controversies about these side effects must be solved politically. This inevitably means a slower solution than if the issues could be decided in the marketplace.

Still, some increases in coal and nuclear output will occur, perhaps enough to offset probable decreases in oil and gas output. The likely result: zero growth in energy supply for at least a decade.

Synthetic fuels—perhaps important by the end of the century—face barriers including uncertain environmental effects, commercially unproven technologies, multibillion-dollar investments for each of dozens of facilities, and long times required for design and construction. Like solar energy, their contribution by 1990 is uncertain.

This leaves only two alternatives: slow economic growth interspersed by recessions—a very costly solution—or a substantial increase in energy efficiency—by far the preferred route.

To achieve economic growth without increasing energy consumption requires heavy energy-saving investments. These are discouraged by present regulations that keep energy prices below world levels and thus give consumers an annual subsidy of 150 billion dollars.

Though political oppositions will be formidable, we should let oil prices rise to world levels, to reflect the desirability of reducing oil imports. We should decontrol the price of all natural gas and encourage electricity pricing that reflects the cost of building new power plants. Meanwhile, the government should give financial incentives to investments that improve energy efficiency.

Fred L. Hartley

CHAIRMAN AND PRESIDENT, UNION OIL COMPANY and PRESIDENT, AMERICAN PETROLEUM INSTITUTE

AMERICA suffered a series of energy shocks in the 1970s that reverberated throughout our economic system. We suddenly were faced not only with dramatically higher prices but also with uncertain oil supplies—supplies subject to the goodwill and political stability of a few nations. Cheap imported oil, which we had permitted to become our lifeblood, had become an economic weapon.

No longer does our nation have a choice. We cannot continue down the careless path of past years. We must pursue a course of action that will reduce our dependence on imported oil supplies.

The United States has the resources to achieve a higher degree of self-sufficiency in a comparatively short time. We have ample sources of oil, natural gas, coal, uranium, and geothermal energy available within our borders, more of each than has been produced so far in the history of our nation. These energy sources will be able to carry us not only until synthetic oil and gas are available in large quantities from oil shale and coal, but also until solar power and other nontraditional energy forms are developed. Geothermal production already is well established in California, and a number of companies are proceeding with projects to produce oil from our vast shale deposits.

The Congress also has taken some positive steps, and the framework for an appropriate energy policy is in place. If we are to win back control over our energy future, however, the nation must accept a program of regulatory consistency and balanced environmental law, put greater reliance on free-market forces for pricing of energy, provide access to public lands for energy exploration while preserving the great wilderness areas, promote use of coal and nuclear power without sacrificing health and safety considerations, and continue a vigorous stress on energy efficiency. Higher prices, more efficient energy-consuming machines, and greater dedication to the total conservation ethic have resulted, incidentally, in a 20 percent drop in oil imports in 1980 from the previous year.

With continued encouragement, this nation could halt the decline in domestic oil and gas output and stabilize it near current levels or higher. We could cut oil imports in half. We could double our use of coal. We could triple nuclear power by finishing plants that already have government permits. We could get synthetic fuels and renewable energy sources on a faster track. We could

NATHAN BENN

strengthen the dollar by keeping tens of billions of dollars in the U. S. We could make our personal life-style more secure by providing assured energy for jobs, homes, and cars.

In short, we could strengthen both our military security and our economic security.

In the development of synthetic fuels the need is for government promotion, not preemption. The government can help by supporting research and demonstration projects. The private sector alone should undertake commercial-scale plants, with the chance to succeed or fail at its own risk.

The energy industry confronts a bold challenge. Given the opportunity to invest responsibly, we will provide America with energy enough to keep her strong and secure.

Our national objective must be increased energy self-sufficiency without environmental retreat or economic dislocation. Given the determination, the courage, and the vision, the people of the United States can continue to enjoy the advantages of an industrialized society.

Amory B. Lovins

FRIENDS OF THE EARTH

HOW MUCH energy do we need? Just enough to do each task, balancing the cost of getting more energy against the cost of wringing more work from what we already have. Investing in this way over the next 20 years could reduce energy use in the U. S. by a quarter and nonrenewable fuel use by nearly half—with a two-thirds increase in gross national product, unchanged life-styles, and more jobs.

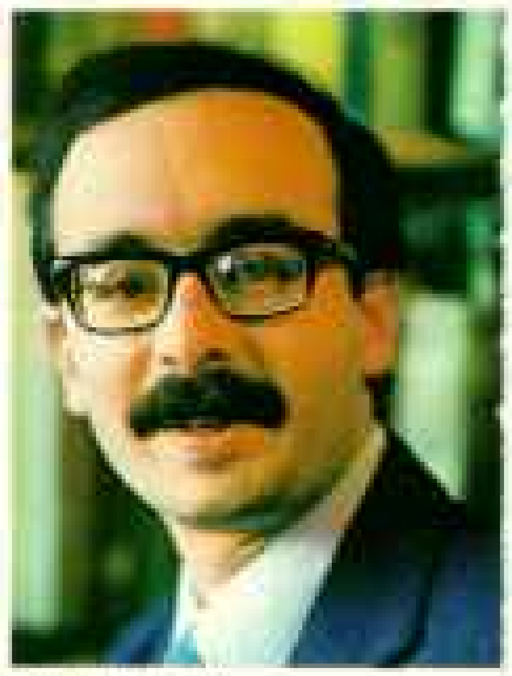
Like someone who cannot fill the bathtub because the hot water keeps running out, we need not a bigger water heater but a plug. Cost-effective plugs can double the efficiency of industrial motors, triple that of lights, quadruple that of household appliances, quintuple that of cars, and increase that of buildings tenfold or more by making them so heat tight (but well ventilated) that they need little heating or cooling.

What kinds of energy do we need? The kinds that will do each task at the least cost. The special tasks that justify using electricity—the costliest form of energy—are only 8 percent of all energy uses, but are met twice over by today's power stations. Still more electricity would be grossly uneconomical for the other 92 percent of our needs (heating and vehicular liquid fuels).

Thus debating which electric power station to build is like shopping for brandy to burn in your car or Chippendales to burn in your stove. Compared with efficiency improvements, any new power station is so uneconomical that we would save money by never operating it! No wonder the marketplace has rejected nuclear power.

Where can we get our energy? Active and passive solar heat, passive solar cooling, liquid fuels from biomass wastes, existing and small-scale hydro power, and wind can meet virtually all long-term energy needs for the United States, Great Britain, West Germany, France, Japan—indeed, every country yet studied. Available renewable sources are not cheap, easy, or instant, but they are cheaper, easier, and faster than synfuel plants or still costlier power stations.

These best buys—efficiency improvements, followed by "soft technologies" (renewable sources)—are also the fastest oil savers. Just weatherizing buildings and replacing inefficient cars could eliminate oil imports by about 1990. Consider: During 1973-78 we got twice as much energy capacity, twice as fast, from efficiency improvements as synfuel advocates claim they can provide at ten times the cost. In 1979 about 97 percent of U. S. economic growth was fueled by energy savings, only 3 percent by new supply. Nuclear power, after three decades and vast subsidies, is delivering about half as much energy as wood. Millions of individual actions in the marketplace are outpacing centrally planned supply programs by nearly forty to one.



ALBERT MOLDVAY

Economic and political advantages have already spurred thousands of communities to start implementing a soft-energy path from the bottom up: Washington will be the last to know. Energy is neither too complex nor too technical for ordinary people to understand—although it may be too simple and too political for some technical experts.

In short, as Lao-tzu advised: "Leaders are best when people scarcely know they exist, not so good when people obey and acclaim them, worst when people despise them. Fail to honor people, they fail to honor you. But of good leaders who talk little, when their work is done, their aim fulfilled, the people will all say: 'We did this ourselves.'" □

SYNFUELS
Fill 'er up! With what?

To help free this nation on wheels from its precarious dependence on foreign oil, the United States embarks on a massive program to develop alternative fuels. In this quest for energy independence we plant the seeds of enormous opportunity —and pose new perils to an already stressed environment.

The challenge finds a symbol (facing page) in lumps of abundant U. S. coal inside a plastic gas can—energy aplenty, but a problem to pour.

By THOMAS Y. CANBY
NATIONAL GEOGRAPHIC SENIOR WRITER

Photographs by
JONATHAN BLAIR

YOU ARE DRIVING your car in a year yet to come, into the sunset of a century fast fading. A glance at the fuel gauge shows you're nearly empty. A service station looms, and you veer in.

What will your car be using in that decade of the 1990s? The same superb gasoline or diesel fuel it now gulps with such gusto? A blended brew of gasohol, or even straight alcohol? Or one of those unlikely synthetic fuels wrung from rock? Perhaps your car is electric, and simply needs a charge-up. Or, perish the thought, maybe the station is closed, with weeds growing up around the pumps.

These questions, so vital to us behind the wheel, also burden those high in government and industry. They reflect the fact that the United States is at the end of the road of abundant petroleum supplies on which transportation is dependent. This means that we must not only conserve but also, in the opinion of many, detour in the direction of crude-oil substitutes, known as synthetic fuels or synfuels.

Today we produce no synfuels, except for a welcome trickle of gasohol. But we have a choice of many new avenues to take, some potentially as broad as the road we have traveled. For no other nation possesses our vast resources for making synthetic fuels.

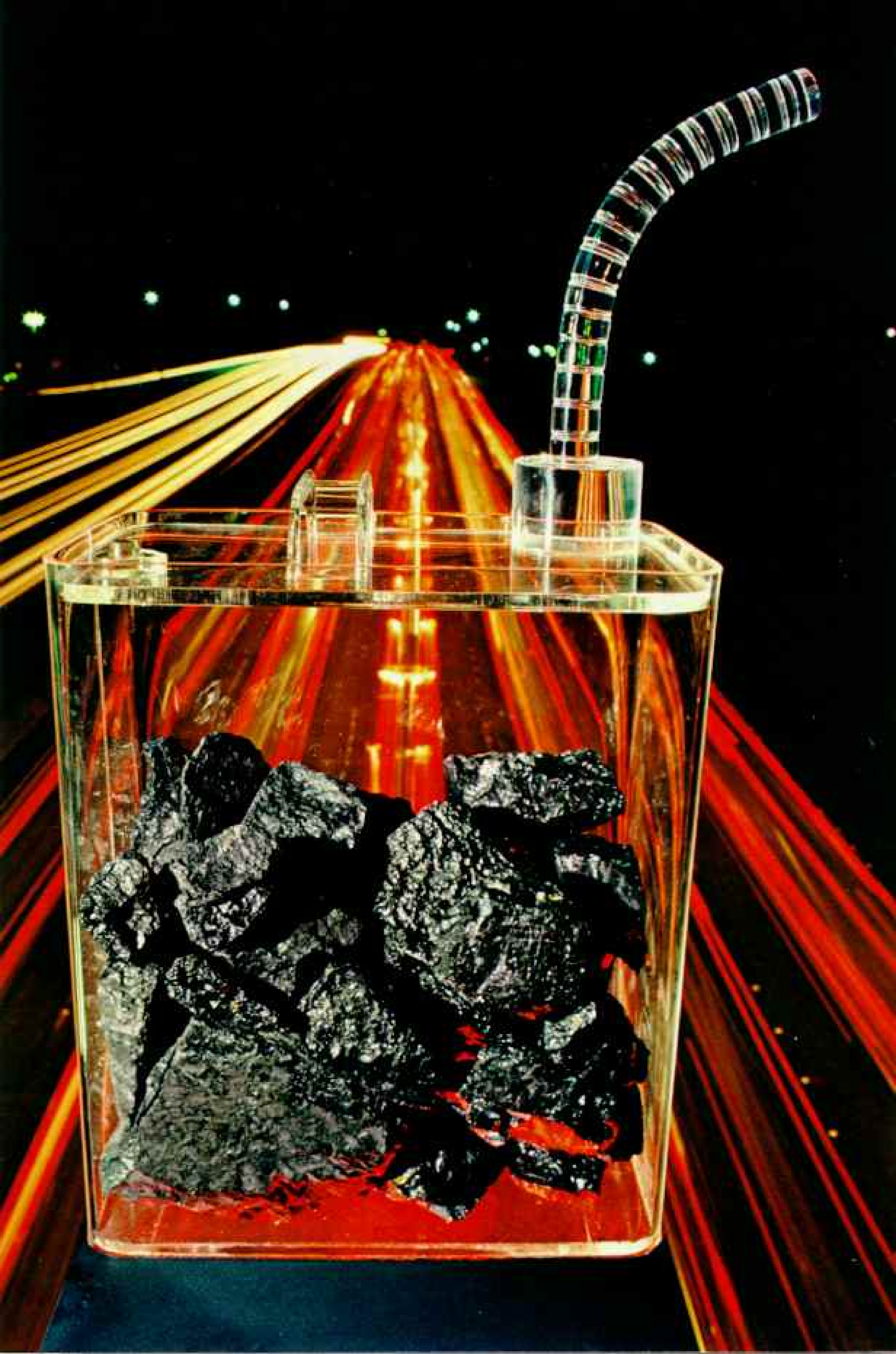
Synfuels can be made from coal, and we claim more than a quarter of all reserves—enough for a trillion barrels.

Liquid energy lies locked in rock formations known as oil shales, and we harbor an estimated 600 billion to a trillion barrels recoverable. We have deposits of tar sands that contain more oil than our conventional petroleum reserves. Our farms and woodlands can produce millions of barrels of alcohol, a renewable resource that we can tap year after year.

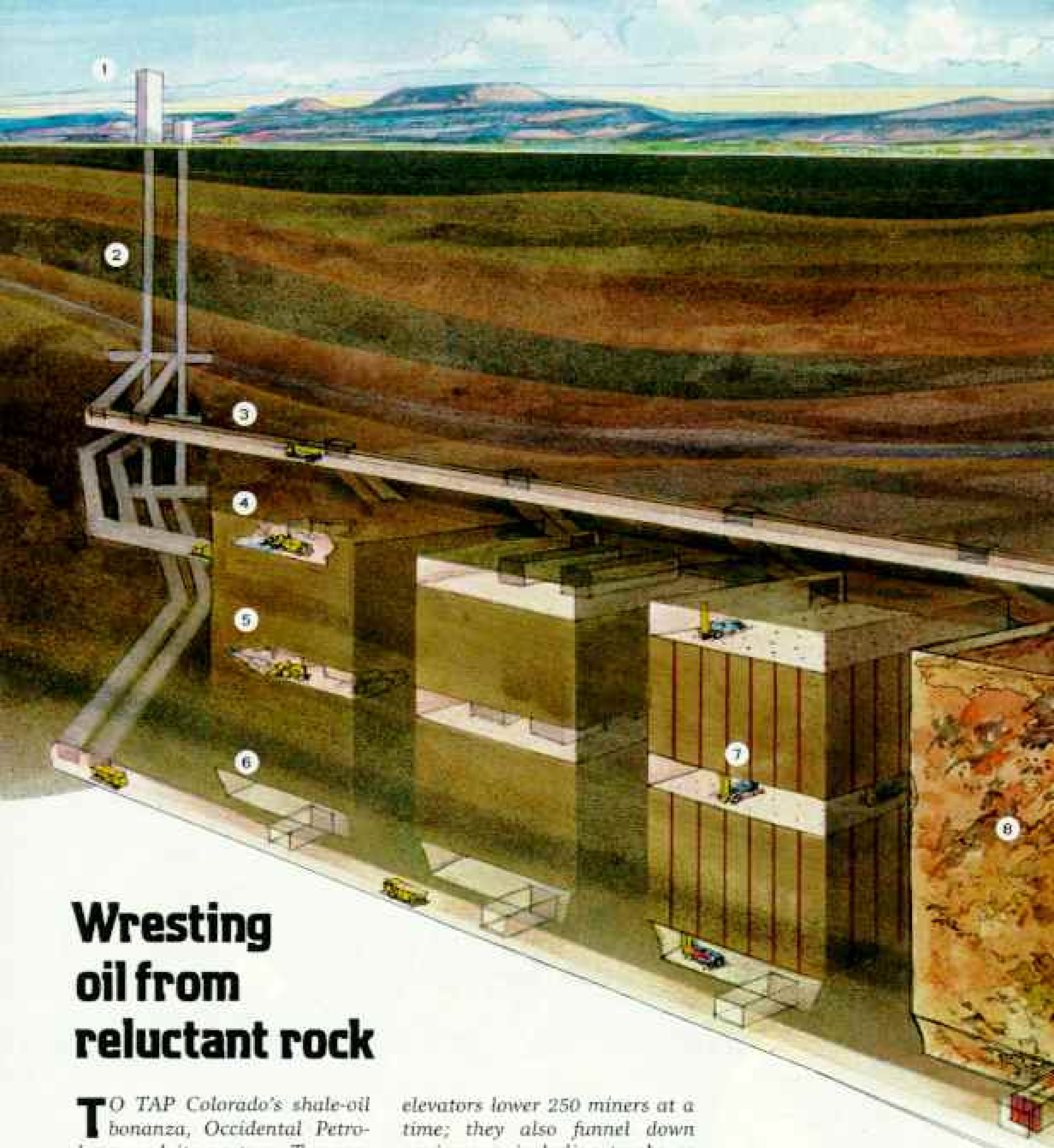
Why, in this fuels paradise, do we face a fuel famine?

Part of the answer lies in lack of effort. The seven million barrels of oil we import each day at disastrous expense is almost the amount consumed by our cars, trucks, and airplanes. Only now do we begin to show determination to spend this money at home by making use of our alternative resources.

Also, synfuels are expensive and often dirty. "Oil can be *(Continued on page 80)*



BURROWING *for oil, miners probe Colorado shale deposits that hold hundreds of billions of barrels. Western shale, with 25 gallons per ton of rock, could be the first major synfuel to supplement petroleum.*



Wresting oil from reluctant rock

TO TAP Colorado's shale-oil bonanza, Occidental Petroleum and its partner, Tenneco, are excavating the world's most unusual underground mine. When it starts producing in about 1985, it will miraculously extract oil from ore still deep beneath the surface—a sharp contrast to most shale operations, which will process the rock in surface plants.

Beneath skyscraper headframes (**1**) that hold ventilators and elevator hoists, mammoth mine shafts (**2** and preceding pages) penetrate the ores. Giant elevators lower 250 miners at a time; they also funnel down equipment, including trucks so large they must be lowered in sections, then reassembled in subterranean machine shops—never to see the surface again. A thousand feet down, where the richest ore begins (**3**), the miners blast miles of horizontal tunnels, known as drifts. Along these they carve the mine's vitals, a vast honeycomb of chambers called retorts, each thirty stories high and half an acre in size.

To prepare each retort, a crew excavates three cavities (**4, 5,** and **6**), trucking the ore to a shaft to be hoisted for processing on the surface. Working in the cavities, blasting experts plant thousands of pounds of explosives in the retort's remaining ore (**7**). On detonation, the fractured ore expands to fill the cavities, a step known as rubbling (**8**).

With the retort a column of

*rubble, pipes are inserted at the top. These bring in diesel fuel to ignite the ore, air to aid in combustion, and steam to control the rate of burn. When the fuel is lighted (**9**), it heats the surrounding ore to about 900°F. This drives oil from the rubble, leaving behind a carbon residue that sustains the fire. As the burn smolders down through the columns (**10** and **11**), the retreating oil migrates to the bottom of the retort. There it gathers in a collecting drift and is pumped to the surface as synthetic crude.*

*Burning out in about 300 days (**12**), a retort will produce some 175,000 barrels of oil. Sixty retorts burning simultaneously, along with surface processing, will yield 95,000 barrels a day.*

Environmental monitoring parallels every step of the mine's development. Yet uncertainties remain. One concerns pollutants that might be leached by groundwater as it percolates through burned retorts—a problem the companies hope to minimize by sealing the retorts with injections of grout.

(Continued from page 74) extracted easily and relatively cleanly," noted Dr. Kenneth Cox of the Department of Energy's (DOE) Los Alamos laboratory in New Mexico. "But coal and oil shale, our most promising synfuel sources, are solids. This means handling enormous quantities of ore and building incredibly complex processing plants. These make synfuels much more expensive and more damaging to the environment."

Despite their sudden popularity, synthetic oil and gas are not new. An English document of 1694 describes the making of "oyle out of a kind of stone"—the first known patent for shale oil. By the 1850s the Scots had developed a shale industry that lasted a century.

Europeans also learned to convert coal into flammable gas, and by 1817 Marylanders completed a coal-gas plant to light Baltimore. Other eastern cities soon set up plants, each managed by a "gas-house gang." Not until the 1940s did many give way to electricity or natural gas. Thus little more than a generation separates the death of one synfuel era and the birth of another.

A pioneer in the synfuels boom, *Dr. Armand Hammer, Occidental's chairman, holds flaming shale from his company's mine. Exxon, Standard Oil of Indiana, Mobil, Union, and other petroleum giants pursue shale ventures. Most will process the ore on the surface instead of underground like Oxy.*

Ghost of boom times past, *this Colorado retort* **(opposite)**—*a "new experimental oil still"—illustrated a 1918* NATIONAL GEOGRAPHIC *story on shale deposits.*

U. S. GEOLOGICAL SURVEY

It will be a big baby. Last year Congress approved an ambitious synfuel goal of 500,000 barrels a day by 1987, and two million barrels daily by 1992. "A national effort on this scale in peacetime is unprecedented," asserts Dr. Ruth Davis, DOE's assistant secretary for resource applications. By 1992 this means between 30 and 40 mammoth coal and shale-oil plants costing from one to six billion dollars apiece.

Observes W. T. Slick, Jr., senior vice president of Exxon Company, U.S.A., "We are looking at a once-in-a-lifetime phenomenon—the creation of a major new industry on the scale of the railroads and aerospace."

Most experts believe that the first major flow of synfuels will come from western oil shale. At least four commercial projects already are under way in northwestern Colorado and another in Utah. Rich ores also lie in adjacent Wyoming.

Early settlers in the region were dismayed when their stone hearths burst into flame. Soon they learned how to cook out a black oil from this abundant "rock that burns," and their furnaces, known as retorts, provided them with lubricants. With the sinking of the nation's first oil well in Pennsylvania in 1859, the shale boomlet went bust—the first of several such cycles.

Geologists mapping shale country found that it encompassed a geologic region known as the Green River formation, an area twice the size of Massachusetts. Long-vanished lakes had deposited plant and animal sediments that later formed a rubbery hydrocarbon known as kerogen. Heated, kerogen releases oil, often 25 gallons and more per ton of rock. Today geologists calculate that the formation holds enough to meet the nation's energy needs for decades—if obstacles to exploiting it can be overcome.

"Shale's time has come," declared its most daring advocate in his Los Angeles office. Dr. Armand Hammer, 82-year-old chairman of Occidental Petroleum Corporation, peered over his desk with oil-burner eyes. His company was one of the first to charge ahead with a bold and costly commercial shale operation.

How much would shale oil cost when his plant begins producing in 1985?

"Cheaper than petroleum," came the optimistic reply. "Oil's getting expensive to find. With oil shale you never hit a dry hole."

I headed off for Dr. Hammer's bonanza, hidden away in Colorado's Piceance Creek Basin, an outback of piñon and sage and fleeting mule deer.

Three skyscrapers reared from a piñon plateau. Beneath them plunged three mine shafts, the largest as big around as a house, and all eventually reaching 2,000 feet deep. From those shafts, miners soon would dig outward, creating a network of tunnels between towering blocks of standing rock, each half a city block in size (pages 78-9).

A Labyrinth Built to Be Destroyed

About 1985, when miles of tunnel carve a subterranean city of rock, engineers will systematically charge each block with high explosives and shatter it to rubble. After each block is blasted, they will ignite the top of the rubble. As the kerogen in the rock smolders downward like the fire of a stubby cigar, the heat will drive off oil, and pumps will draw it to the surface to be transported to refineries and then blended with conventional gasoline and diesel fuel.

Will this strange-seeming technique work? "The key," said a DOE official who monitored Occidental's years of experimentation, "is in the blasting—obtaining the right-size rubble to get a uniform burn. It's a new and difficult art." If and when Occidental and its new partner, Tenneco Oil Company, hit full stride, each day 95,000 barrels of oil will flow from underground retorts and from excavated ore processed on the surface.

At least two dozen other shale venturers, including Exxon, Gulf, Union, and Standard of Indiana, have taken the plunge into shale oil, or stand ready to leap, many with their own extraction processes. Most will employ conventional mining and cook out the oil in surface retorts that resemble oil refineries. This technique is expected to produce the bulk of our shale oil. Union Oil Company, which has experimented with shale for 40 years, already is erecting the first unit of a plant that by 1983 will produce 10,000 barrels a day, and ultimately 50,000.

"We'd have more activity," said Paul Petzrick, director of DOE's Shale Resource Applications Office, "except that about 80 percent of western shale is federally owned,

and government leasing has moved slowly. Further, federal laws restrict the number of projects a company can be involved in—a case of government's left hand impeding what the right hand is trying to do."

Opponents of these claims observe that existing leases are sufficient to meet national production goals, and that restraint is advisable until shale development's environmental effects are known.

A "Little Guy" Vies With Big Oil

In this high-stakes game, is there room for what started as a mom-and-pop outfit? To find out, I drove deep into Utah's shale land, to the small trailer camp of Geokinetics Inc.

"Anita and I first came out with our young sons, two helpers, and our tents," recalled Mike Lekas. "Good shale lies close to the surface here. We devised a way to rubble it without sending men underground.

"Winter caught us that first year, but we finally rubbled a small area a few feet down. We drilled a fire hole at one end and a shallow well at the other for bailing out oil, if there was any. Then we dropped in some burning coals and stood by with a bucket.

"Oil began to trickle into the hole, then flow. We dipped out a bucket of it, partly mixed with melted snow, and then filled another and another—an incredible success."

Supported by DOE grants during its experimental work, Geokinetics already has fired its first small commercial retort.

Worries about shale's environmental impact loom large. So isolated is this fastness, so pure is its air, that the hand of man inevitably leaves a scar.

Air pollution is a big concern. Mining and transport will create dust; ore processing will emit hydrocarbons, arsenic, mercury, particulates, and nitrogen and sulfur compounds, with drift ranges yet unknown.

Plant and animal life will be affected. Here lives the nation's largest herd of mule deer, and it will face habitat destruction and the threat of passing vehicles.

Water scarcity causes national concern for this semiarid region that drains into the much used and abused Colorado River. Large amounts will be necessary for ore processing, land reclamation, and the thousands of laborers and families who converge to build shale plants. Development could also aggravate the river's salinity problem. Unsurprisingly in this controversy-ridden watershed, estimates on water availability vary widely, from enough to sustain a production of 500,000 barrels a day to as much as 2,000,000.

The amount of shale mined would be enormous—100,000 tons a day for an average plant. Complicating the problem of disposal, processed shale expands about 20 percent in volume—the so-called popcorn effect. Plans call for these voluminous tailings to be pushed into canyons, compacted to prevent leaching, and revegetated. Other types of seals are planned for underground retorts to prevent leaching of toxins by water percolating through the burns.

From the outset, the boom has been monitored by the Environmental Protection Agency, DOE, and state agencies; on federally leased lands this scrutiny has been coordinated by the Area Oil Shale Supervisor's Office in Grand Junction, Colorado. Occidental submitted 74 volumes of environmental reports during years spent in obtaining various permits. Observes Thomas Ten Eyck, a former state director of natural resources and now vice president of Rio Blanco Oil Shale Company, "This will be the first major industry on earth to be plugged into environmental concerns since the day of its conception." Yet uncertainty will remain until commercial operations actually begin.

Coloradans in Rifle, Meeker, and other small towns fringing shale country brace for the "boomtown syndrome," the inevitable influx of thousands of construction workers and families demanding water, sewage facilities, homes, roads, and schools.

"Above all," I often heard, "we've got to avoid another Rock Springs."

The sufferings of this Wyoming mining town lodge like a bur under the saddle of western consciousness. A decade ago crews flocked to Rock Springs to work mines and build the huge Jim Bridger Power Plant. With facilities strained beyond the bursting point, families were forced to live in tents, crime and suicides soared, police became demoralized.

"Communities need help at least two years before the first wave comes," I learned from Dr. Camilla Auger, director of the

Tosco Foundation in Boulder, Colorado. "If they don't get it, it's almost impossible to undo the damage."

A second huge oil-shale deposit lies in the eastern U. S. Known as Devonian shale, it sprawls in a great U-shaped formation from Michigan and Pennsylvania south to Alabama. Although eastern shale yields less oil per ton than western, the enormous deposit is believed to hold a trillion barrels.

A retort designed for lean eastern shales has been developed by the Institute of Gas Technology in Chicago. Known as the Hytort process, it extracts the oil in a hydrogen-rich atmosphere that coaxes as much as 25 gallons from each ton of shale. Both eastern and western shales may someday be extracted by heating the rock with radio waves or microwaves until the oil liquefies.

In remote north-central Alaska, the nation boasts a third oil-shale deposit. Sketchy geologic reports show it to be vast, and tentative assays indicate a wide range of oil content, from a few gallons a ton to saturated ores that test at 102 gallons.

How much oil can shale deliver and when? DOE's Paul Petzrick believes that, with luck, western shale could meet the 1992 shale quota set by the government—400,000 barrels a day—and that its cost would not exceed that of conventional crude. By the year 2000 some see a possibility of millions of barrels a day, the limit being set by water and environmental considerations.

Coal Liquids Fueled War Machine

When German planes roared aloft late in World War II, they burned gasoline made from coal. Even German "butter" was a synthetic made from coal.

Behind this technology lay nearly a century of intensive research in Europe and America. In the 1800s chemists discovered that coal's complex molecules of carbon, hydrogen, and oxygen contained the building blocks of nature, capable of being rearranged into thousands of useful products.

German scientists observed that coal differs from oil primarily in that it contains less than half as much hydrogen. Working with catalysts at high temperatures and pressures, chemist Friedrich Bergius succeeded in adding hydrogen to coal until it liquefied. He won the 1931 Nobel Prize in Chemistry.

Two other Germans, Franz Fischer and Hans Tropsch, discovered a catalytic process for converting familiar coal gas into liquid fuel. A dozen Bergius plants and a smaller number using the Fischer-Tropsch technology provided Germany's smorgasbord of coal products in World War II.

At war's end the U. S. government organized a team of more than a hundred scientists, headed by Dr. Wilburn C. Schroeder, to uncover the secrets of German synfuel technology. Probing bomb-damaged plants and laboratories, they brought back 175 tons of documents, now under study at Texas A & M University. The Bureau of Mines built two coal-liquefaction plants at Louisiana, Missouri. Supervised by Dr. Schroeder, they made a costly fuel that successfully powered a diesel locomotive. When the tide of Middle East oil began its surge in the early fifties, the Missouri plants shut down.

In 1950 South Africa sought to ease its dependence on foreign oil by building a 10,000-barrel-a-day plant based on the Fischer-Tropsch method.

Half a pint of oil *lies locked in shale bookends polished by a Colorado lapidary. Dark bands indicate rich ore.*

Alchemy on an awesome scale *converts coal into 55,000 barrels of transport fuel and other products each day at a South African plant known as Sasol Two* (**following pages**)*. Several United States companies plan similar facilities, while the Department of Energy focuses on development of three competing coal-liquefaction processes.*

Three years went into construction, and five more into ironing out defects in the complex refinery, known as Sasol.

When the 1973 Arab oil embargo struck, South Africa launched Sasol Two, with five times the capacity of its predecessor. Covering more than a square mile of treeless high veld near Johannesburg and just now beginning operations, it is one of the largest complexes ever built.

A rising sun was turning back the covers of the African night when I saw this colossus of industry. Set amid fields of corn and cattle, it seemed a surrealistic cityscape, planted by advanced beings from another planet. An 840-foot exhaust stack towered over turretlike cooling towers with hourglass waists and a phalanx of huge gasifier vessels that stretched a quarter of a mile. A thousand miles of piping enmeshed Fischer-Tropsch reactors. Truly, here stood the citadel of the great god Energy.

Today the Fluor Corporation, U. S. contractor for Sasol Two, is building yet a third one. When all are on line, they will yield a major part of South Africa's transport fuel. A steady procession of energy pilgrims from industrial nations—oilmen, coal men, and government officials—visits these awesome temples to behold a vision of the future.

In contrast to South Africa's bold march, the U. S. government until recently directed its effort toward research. This focused on three techniques that convert coal without passing it through a gaseous state—adaptations of the Bergius technology.

One process, developed by Gulf Oil and others, soon will be tested in two gigantic demonstration models, each designed to produce the equivalent of 20,000 barrels of oil a day. A model under construction at Newman, Kentucky, will convert high-pollutant coal into liquid and solid boiler fuel that will be low in ash and sulfur. If successful, it will scale up in 1990 to a giant fuel factory producing an equivalent of 100,000 barrels a day. The second, at Morgantown, West Virginia, will convert coal into synthetic crude oil for refining into gasoline, diesel, and boiler fuel.

A second process undergoes tests at a pilot plant in Baytown, Texas. Developed by Exxon, it includes among sponsors two other oil firms, DOE, Japanese and German interests, and the Electric Power Research Institute in Palo Alto, California.

The third process on which DOE pins its hopes originated at the Dynalectron Corporation. Harnessing Germany's World War II experience, a Dynalectron subsidiary developed a catalytic process that forms the heart of a large pilot plant operated by Ashland Oil in Catlettsburg, Kentucky.

Catalysts and coal still make magic. In a landmark discovery a Mobil Oil Corporation process transmutes methanol, an inexpensive alcohol that can be derived from coal, into water and high-octane gasoline. A pilot plant to test the new Mobil M process is now being built in Germany, and New Zealand has selected the technique for converting immense reserves of natural gas into gasoline via methanol.

Hazards of Coal Are High

Far more than shale, coal causes concern about effects on human health and safety.

Each year U. S. coal-mine accidents claim more than a hundred lives. Further, many hydrocarbons can cause skin cancer upon prolonged contact, and these agents are especially prevalent in coal. A coal-liquefaction pilot plant in West Virginia, operated in the 1950s by Union Carbide, experienced a high occurrence of employee skin cancer. A DOE survey contends that the risks, though real, are controllable.

What of coal's threat to air and water? Coal emissions contribute to emphysema, lung cancer, and other respiratory diseases, to a degree that still challenges accurate calculation. Sulfur compounds emitted by burning coal are one cause of acid rain, which kills aquatic life, stunts vegetation, and corrodes structures.

Coal burning is a major culprit in pumping carbon dioxide into the atmosphere, which, some experts maintain, is creating a greenhouse effect. They fear a planetary warming that will change weather and agricultural patterns and melt polar ice caps enough to raise the ocean levels. The federal government has launched a five-year study to define the threat.

As to whether a coal synfuels boom will magnify these hazards, scientists still lack enough information for a judgment. Inevitably, areas in which plants are located will feel their impact. But the use of coal synfuels could have positive effects for the regions in which they are burned.

"The making of coal synthetics," explained Dr. Joseph Yancik, vice president for research of the National Coal Association, "requires the capture of almost all pollutants; otherwise they 'poison' the catalysts. To the extent that the nation's coal-burning facilities switch to synfuels, air pollution will be reduced."

Why haven't synfuel plants moved from the drawing boards into coal country?

A major roadblock is cost. While many experts believe shale oil can be cooked from rock for roughly the price of crude, coal's elaborate alchemy raises the cost to levels no one is quite sure of. Most estimates place it at one and a half times to twice the cost of oil.

With investments so high, industry leaders often raise the specter of "predatory pricing." What if they invest billions and then OPEC lowers prices in an attempt to snuff out the infant industry? No firm, no matter how large, could survive a synfuel plant sitting idle, producing no revenue to help pay back the colossal costs of construction.

Recognition of these problems led Congress to create the Synthetic Fuels Corporation, with its production goals and assortment of financial inducements and cushions. To the tune of 20 billion dollars spread over four years, with as much as 68 billion more to follow, the SFC will offer loan and market guarantees as well as arrangements for cost- and profit-sharing.

Other obstacles surround the process of permitting—obtaining the permits required at every level of government in order to locate a plant. Permits are designed to protect the public, and for most industrial projects they can be obtained in one or two years. But permitting can get out of hand, as was the case when Sohio oil company sought to build a needed West Coast tanker port and pipeline.

With Alaskan oil glutting West Coast refineries, Sohio proposed to pipe this oil to Texas, with its vast refining and distribution system. After five years of bureaucratic struggle, Sohio had spent 55 million dollars and secured nearly 700 permits, but still lacked approval. In 1979 it abandoned the project, ironically provoking a torrent of criticism from government officials.

Despite this daunting array of obstacles, a few companies are at the starting gate to launch coal synfuel plants. Several have plans for gasification plants, less risky and expensive than those for liquefaction.

Kentucky, with abundant coal and water, and a welcome mat for job-producing industry, is attracting liquefaction plants. Texas Eastern Corporation plans a Sasol-type facility. Ashland Oil is forming a consortium for a 50,000-barrel-a-day plant, and W. R. Grace & Co. plans a giant facility using the Mobil M process.

Action also is stirring among a powerful coalition of western Indians. Members of the Council of Energy Resource Tribes own 15 percent of the nation's minable coal. Already Montana's Crow Indians are considering a gasification facility.

What can we expect in the way of production? With no commercial plants yet under construction, the flow cannot start for almost a decade. Projections for 1990 range widely, from a modest 150,000 barrels a day to as high as a million.

Tar Sands Abound

Scattered about the continent in ages past, ancient lakes and inland seas left deposits of organic materials encased in beds of sand. Over the eons these formed hydrocarbon deposits known as tar sands.

"About 550 deposits have been identified in the United States," explained Leland C. Marchant, tar sands project manager for the DOE Energy Technology Center in Laramie, Wyoming. "Significant deposits occur in California, Kentucky, New Mexico, Texas, and a few other states. But 80 percent of our tar sands—about 29 billion barrels—occurs in Utah."

That's where most of the action is. Though it will never be overwhelming, tar sands have a future. "We've extracted bitumen, the hydrocarbon in tar sands, using two experimental methods," said Mr. Marchant. "One used an underground burn similar to shale retorting. The other injected steam underground to liquefy the bitumen. We might see 60,000 barrels a day by 1990, and maybe 200,000 by the year 2000."

Immense tar sands deposits, holding an estimated trillion barrels of oil, lie in the

***Fields sprout fuel tanks** in Brazil (**right**), where soaring petroleum costs spur the conversion of sugarcane into ethyl alcohol for making gasohol. In the U. S., gasohol made largely from corn spreads rapidly as a gasoline extender.*

*With $1,100 in parts and labor (**below**), the president of California's Future Fuels of America converts a Ford to run on straight methyl, or wood, alcohol.*

Canadian province of Alberta. Two large facilities extract the oil. They, together with South Africa's coal-converting Sasols, are the vanguard in the measured march toward synfuels.

When experts talk of synfuels, they often include two sources of oil that are extracted much like tar sands.

One is heavy oil, petroleum so thick it must be liquefied underground, usually by injecting steam. The U. S. resource is huge—about 75 billion barrels—with the major portion in California.

Today California fields yield 500,000 barrels a day of this costly oil, and rising prices could see the level climb to 800,000 by 1985. Production could soar with the introduction of experimental submergible steam generators able to tap deep-lying deposits.

The second source is conventional oil left behind in abandoned wells. Normally, primary and secondary extraction recovers only 30 percent of the oil. The residue holds promise, with new and expensive technology known as enhanced oil recovery. This includes sending down detergents or liquid carbon dioxide to dislodge and mix with the oil; in a year or two the oil-rich mix can be pumped to the surface for separation. Another approach under study is oil "mining"—digging shafts along the bottom of formations to drain the residual oil.

Delay and frustration may plague most synfuels, but one has bounded off to a jackrabbit start. Gasohol, a mix of unleaded gasoline laced with one-tenth alcohol, offers a tonic both for the auto and the farmer.

"Alcohol is sunshine in liquid form," claim enthusiasts. Thousands of gasoline stations now sell gasohol. Idle breweries and whiskey distilleries find new markets; onetime moonshiners respectably advertise their expertise; and scores of companies—many woefully short on experience—offer to build plants of all sizes.

Sunshine aplenty baked the corn belt when I touched down in central Illinois. In rows of rich green plants, solar energy worked the silent miracle of photosynthesis, transforming water and carbon dioxide into carbohydrate, channeling it to growing ears. Soon some of that corn would be trucked to a brown building I visited on the outskirts of Springfield. Inside, exhaling a saccharine aroma, a still was ingesting corn of a previous season and extracting stored sunshine as ethyl alcohol, or ethanol.

"This is a community-size distillery," boomed Alvin M. Mavis, president of the National Gasohol Commission. "It makes 800 gallons a day. It also leaves a mash that contains every ounce of the corn's original protein, for use as livestock feed supplement. There's room for a thousand of these

distilleries in the state of Illinois alone.

"To understand the alcohol movement," said the man who is one of its mainsprings, "you must understand its economics. Run a bushel of corn through a still, and you get two and a half gallons of alcohol, plus by-products, that almost double the corn's value—and help provide energy independence for America."

These economics are warmly disputed. To make alcohol profitable for distillers large and small, federal and state tax incentives create a hefty subsidy. New, fuel-efficient distilleries should reduce costs and also end the argument that alcohol is "energy negative," requiring more energy to make than it delivers.

An acre of corn yields about 250 gallons of alcohol, an acre of sweet sorghum or sugar beets twice that, and sugarcane even more. This year the nation's distilleries will produce about 200 million gallons of this renewable resource, enough to convert only 2 percent of our gasoline into gasohol. By the mid-eighties the government hopes to see ten times this capacity.

How much is possible? At what point does farming for fuel compete with farming for food, causing inflated grocery prices? A study by the Office of Technology Assessment finds that food prices could feel inflationary pressures when alcohol production from farm crops reaches two billion gallons a year. Proponents claim that by using wood, food-processing residues, and surplus and diseased crops, the nation can provide the 11 billion gallons of alcohol a year needed to convert our gasoline to gasohol.

Brazil Switches to Alcohol

Meanwhile, Brazil has boldly committed itself to an alcohol-fuel economy. Distilleries there ingest endless servings of sugarcane, cars burn gasohol made with 20 percent ethanol, and auto plants turn out models to run on straight alcohol—a growing trend in this oil-shy country.

Another promising synfuel is methanol, the alcohol that wears the skull and crossbones and fuels your fondue burner. It also is the fuel of the racing car, a high-octane fluid that accelerates autos with neck-jolting speed. Methanol is so versatile, so available, and relatively so inexpensive and environmentally acceptable that it could someday end up in your car.

Testing one for the road, a scientist at the University of Santa Clara in California **(far left)** monitors a lobster's heartbeat to determine the ecological effects of spills of ethyl and methyl alcohol. Findings indicate far less damage than from petroleum spills. The alcohols also cause less air pollution than do petroleum products, although they emit aldehydes whose effects are still unknown.

Common weeds yield crude oil at Native Plants, Inc. **(left)**, *a biological laboratory in Salt Lake City, Utah. Glass extractors help measure yields of two promising petroleum producers: milkweed, foreground, and gopher plant.*

Behemoth with fangs of steel *scoops oil-rich sand at Syncrude Canada Ltd.* **(following pages)**, *one of two immense facilities processing Canada's famed Athabasca tar sands. U. S. tar sands deposits, largely in Utah, hold more oil than our reserves of crude.* KENNETH GARRETT

Today methanol is made from natural gas and used largely for making plastics and solvents. But the technology exists to make it from biomass and coal, two of our most abundant resources.

If methanol finds a birthplace as automotive fuel, it probably will be California.

"I became interested while looking for clean-burning fuels to relieve the smog problem," recalled Professor Richard K. Pefley at the University of Santa Clara. "For a decade now we've successfully run a small fleet on methanol.

"Converting a gasoline-powered car to methanol isn't complicated—a few changes in the carburetor and manifold plus a handful of corrosion-resistant seals. As for performance, methanol is way ahead—more power and faster acceleration. The main drawbacks are difficulty in starting in cold weather, which can be cured with fuel additives, and a low energy content—about half that of gasoline—which is partly offset by methanol's high octane.

"The problem is the old chicken-and-egg syndrome. Nobody's going to make methanol automobiles until there's methanol in the fuel pumps, and nobody's going to put it in the pumps until there are cars to use it."

A vicious cycle indeed. I found a Californian, however, who is setting out to be both chicken and egg.

"That's the idea," said Charles L. Stone as the onetime aerospace engineer wiped grease from his hands in his workshop near Sacramento. "I'm approaching people who operate vehicle *fleets,* firms like Bank of America, Pacific Telephone, and McDonnell Douglas that store their own fuel and that depend on mobility even in the worst gas crunch. I contract to provide them with methanol cars converted here in the shop, and with methanol at 79 cents a gallon. And I warrant that each car will go as far on three gallons of methanol as it will on two gallons of gasoline, although I expect them to perform much better soon."

How can he, when methanol has only half the energy content of gasoline?

"Remember methanol's high octane," Mr. Stone replied. "We can raise the compression ratio for more power. We also machine our parts to extremely fine tolerances. Soon we'll have methanol cars getting the same mileage they did on gasoline."

Chuck Stone also has plans for producing

methanol. He turned toward the distant Sierra, its snowy peaks holding a tattered white banner on the horizon. "Between here and the mountains lies a belt of hardpan and gravel that you can't plow—good only for grazing. It could grow enough eucalyptus trees to provide methanol for every car on the California highways, and the cattle could graze beneath them. But we don't need all that wood. The waste from our forest operations and our cities—these can provide a large chunk of our methanol. The same can happen all across America."

Another methanol plan comes from Dr. Thomas B. Reed, senior scientist at the Solar Energy Research Institute in Colorado. "We're developing small plants capable of producing 30,000 gallons of methanol or ammonia a day. They could be installed almost anywhere, say by a local farm cooperative. Farmers and others within 15 miles would bring in cornstalks and other crop residues, municipal wastes, trash thinned from forests—anything organic. A plant could produce enough ammonia in 15 days to fertilize the surrounding farmland. The rest of the year's output would be methanol to run tractors, cars, and boilers. It's a clean, manageable, self-renewing system."

A small handful of gaseous fuels could also contribute to running our cars.

With a few engine adjustments, cars can be converted to run on propane gas, a by-product of oil refining. Methane, which occurs as natural gas, sewer gas, and gasified coal, becomes a liquid transport fuel when stored under refrigeration. Modesto, California, is converting its city fleet to run on methane made from municipal sewage.

Hydrogen, the fuel of the sun, could be a fuel of the future. Wherever there is water—H_2O—there is a source of hydrogen. But freeing the hydrogen molecules by electrolysis requires costly amounts of electricity. Further, bulky hydrogen is difficult to store on board a vehicle, a problem scientists are beginning to solve.

The winding down of the petroleum era could also mean the rebirth of the clean, low-maintenance electric vehicle, or EV.

For almost a century this appealing auto has been hobbled by the limited performance of the batteries that store its electric energy: heavy, expensive, short-lived, capable of trips of only 40 or 50 miles.

Last year both Gulf + Western and General Motors announced breakthroughs with batteries that may double today's driving range and greatly increase the number of recharges possible. General Motors plans to be producing EVs by the mid-eighties.

The Department of Energy is encouraging research on vehicles known as hybrids. These electrics carry a small gasoline engine to increase the EVs range.

Synfuels Future Still Uncertain

In an emerging industry with the almost limitless possibilities of synfuels, can anyone foretell the future?

Some environmentalists fear they can, and they object. Says Kevin Markey of Friends of the Earth: "Synfuels are not a good investment, environmentally or economically, compared with conservation, and should be approached cautiously."

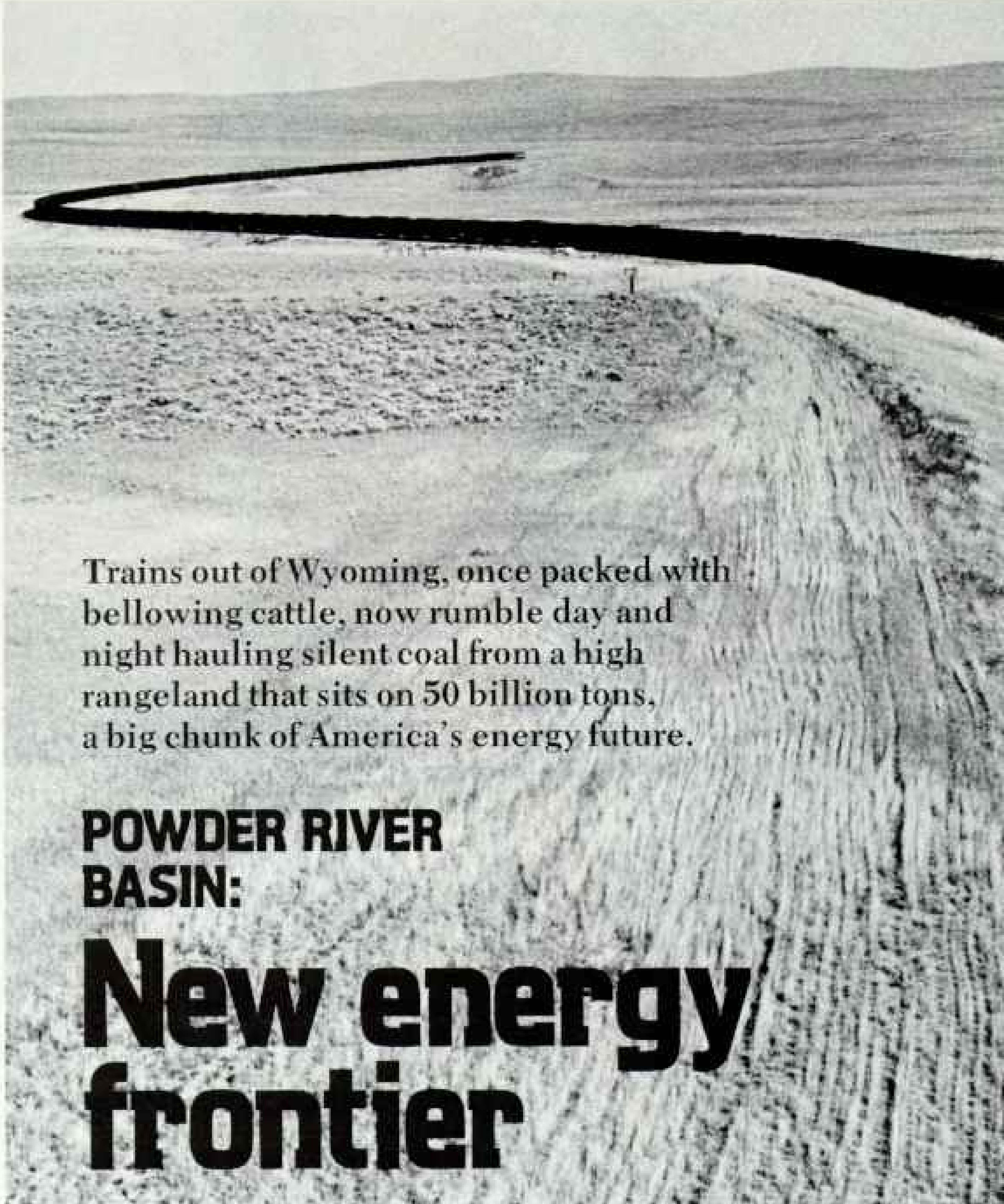
From the opposite direction, strong voices cite the nation's dollar-draining dependence on oil imports and the strategic need for greater energy independence.

Others see pitfalls in too hasty a plunge. "If we go too fast," says Edward W. Merrow, an energy analyst for the Rand Corporation, "plants will cost more, they'll be late, and they'll have problems. And if this happens, we fail to signal OPEC that there's an upper limit to what it can charge for oil."

As to how many barrels will be produced when, and of what, the crystal ball obviously is too cloudy to tell. But shale oil, coal liquids, and alcohol seem to be on the way.

In Brazil, a knowledgeable manager of the giant Volkswagen works observed that America's energy future is complicated by the confusing variety of choices that lies before us. It's not a bad problem to have. □

Designed to be as scary *as a scarecrow can be, an apparition sets sail on an oily tailings pond at the Athabasca tar sands. At its feet rides a propane cannon that booms twice a minute. This rig and a hundred replicas successfully deter birds from alighting on water polluted by processed sand. Environmental threats pose a primary obstacle to synfuels.*



Trains out of Wyoming, once packed with bellowing cattle, now rumble day and night hauling silent coal from a high rangeland that sits on 50 billion tons, a big chunk of America's energy future.

POWDER RIVER BASIN: New energy frontier

By BILL RICHARDS
Photographs by LOUIE PSIHOYOS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QUESTION: Why do the ranchers here go around in tennis shoes?

Answer: So you can tell them apart from all the coal miners wearing cowboy boots.

This cynical explanation for the profusion of fancy tooled leather boots and other cowboy gear in Gillette, in the heart of Wyoming's Powder River Basin, reflects a revolution. Gillette, once a cattle-loading stop on the Burlington Northern railroad, is now a steamed-up energy boomtown, rapidly shedding its cow-town past.

But out in the lonely reaches along the Powder River, ranchers are trying to hold to old ways and values in spite of stunning change. On his 11,000-acre ranch, shirt off but with sweat-stained cowboy hat on the back of his head, Ed Swartz tugged, pulled, and finally yanked a calf into the world.

"We were touch and go there for a minute," he said over his shoulder, as the calf lay panting next to its mother on the barn floor. "He's an awful big critter to squeeze out of such a little heifer."

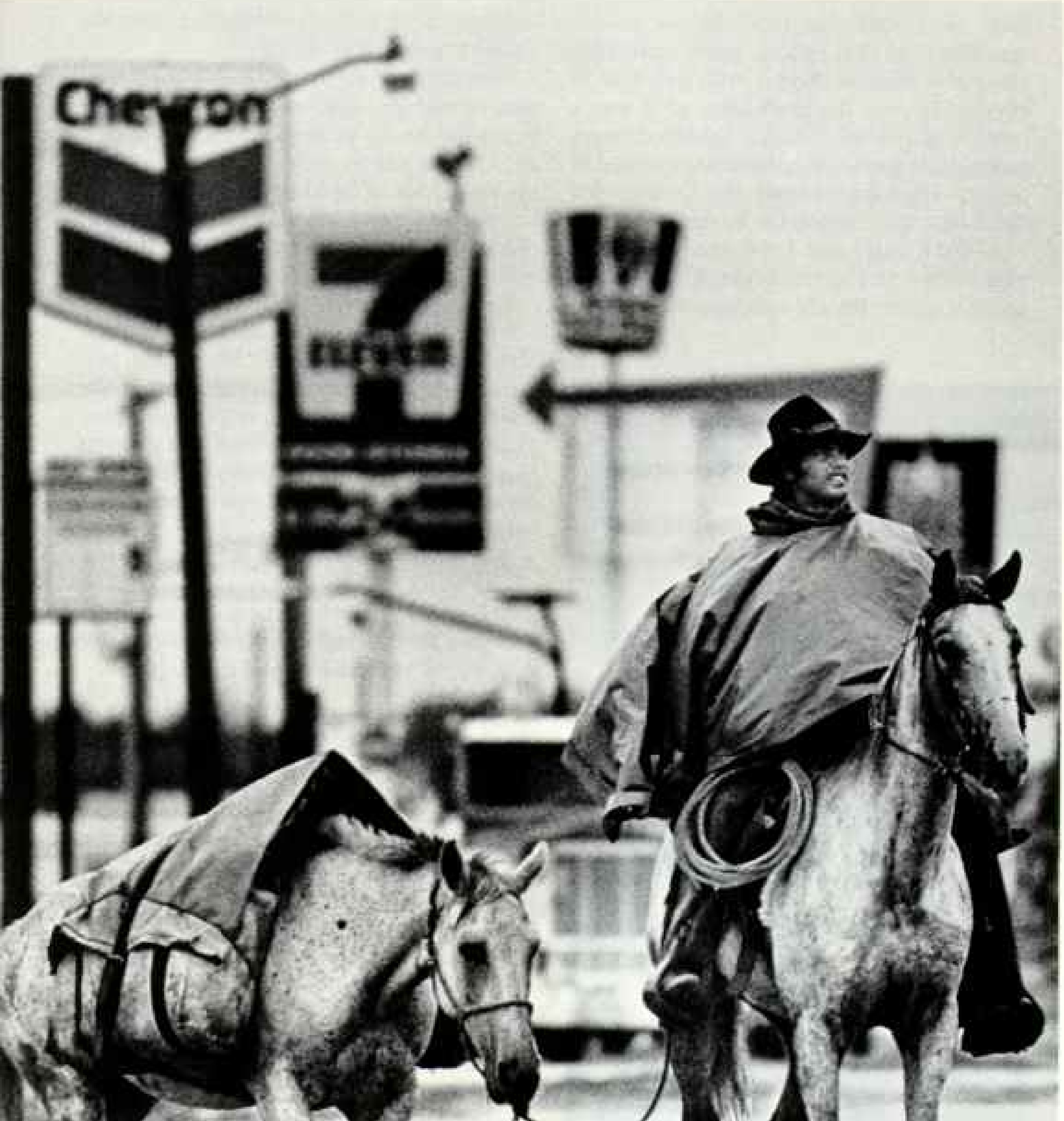
It had been several years since I last saw Ed, a 39-year-old, third-generation cowboy. At first glance not much had changed. Other heifers, swollen with their first calves, watched from their pen. But the peacefulness of Ed's ranch, with its tiny drama of new life, made a sharp contrast with the larger drama taking place around us.

After a century of comfortable isolation, walled off by the Bighorn Mountains on one side and the Black Hills on the other, the rumpled, lonely plains of the basin's cattle country have been caught up in a massive energy boom. A dozen strip mines gape new and raw against prairie dusted blue with flowering lupine. A mile-long coal train cuts through grassland where no track existed two years before. Once sleepy ranch towns swell with thousands of miners, construction workers, railroaders.

And more, much more, to come. Another 20 coal mines are planned, waiting for the call for more coal from Chicago, Houston, Tokyo. Slurry pipelines may use billions of gallons of precious basin water to carry that coal south and west. Half a dozen billion-dollar synthetic-fuel plants may rise to convert Powder River coal to oil and gas.

All this is about to transfigure a land as

"Nothing to do there" *and three days of rain send Chuck Voglewede out of Gillette, Wyoming, capital of the coal boom. On a ride that had begun in Los Angeles, he worked spring roundups, got his dog G. L.*



(Good Luck) in Utah, and kept moving. With traditional western openness, ranchers let him cross their lands, but told him that energy companies would not. Why? "Just the way they are, I guess." Coal, the fourth boom, after cattle, oil, and uranium, has brought the area some fast money, but has also brought problems such as heavy drinking, divorce, and violence—the darker side of life on new frontiers.

large as Connecticut and Massachusetts combined: 12,000 square miles stretching along the Powder River. And yet it is as empty now, for the most part, as it was a century ago, when Texas longhorn drovers and restless midwestern farm boys drifted in to stay after discovering the protein-rich shortgrass that carpets the basin floor.

As Ed Swartz and I thumped across his pasture in a pickup truck, checking cattle, I asked whether the old ranching ways could continue here without conflicting with the nation's new energy demands.

"I'm not sure any more," he said. Not long ago, he told me, a big eastern coal company suggested he fly to Nevada to look over a 39,000-acre ranch—more than three times the size of his. If he liked it—and agreed to let the company mine a 55-foot-thick seam of coal under his Wyoming ranch—the 5.5-million-dollar Nevada place was his.

He turned it down.

"This is my home," he said. "My grandfather homesteaded here. My father survived years like the 1936 drought, when the government bought cattle at $15 a head because nobody else would, then shot many of them. I want to give my kids something with history attached to it, not just some place a corporation bought for us."

But others have yielded to the pressures. "Look quick," Dorothy Reno told me. "The next time you come back here, the ranch life you see now could all be gone." She had just sold half of her ranch to coal developers.

It's a blast *after driller Chris Kimbrough* ***(above)*** *sets her 25-pound explosive charges to tear coal from strip-mine seams. "I never was scared of it," she says, and works right through the hard winter at Wyodak Mine because "the coal must come down." For miner Ed Martinez* ***(facing page)*** *the answer to his T-shirt might now be "I couldn't care less." He was laid off and has since moved on.*

Energy Potential Is Enormous

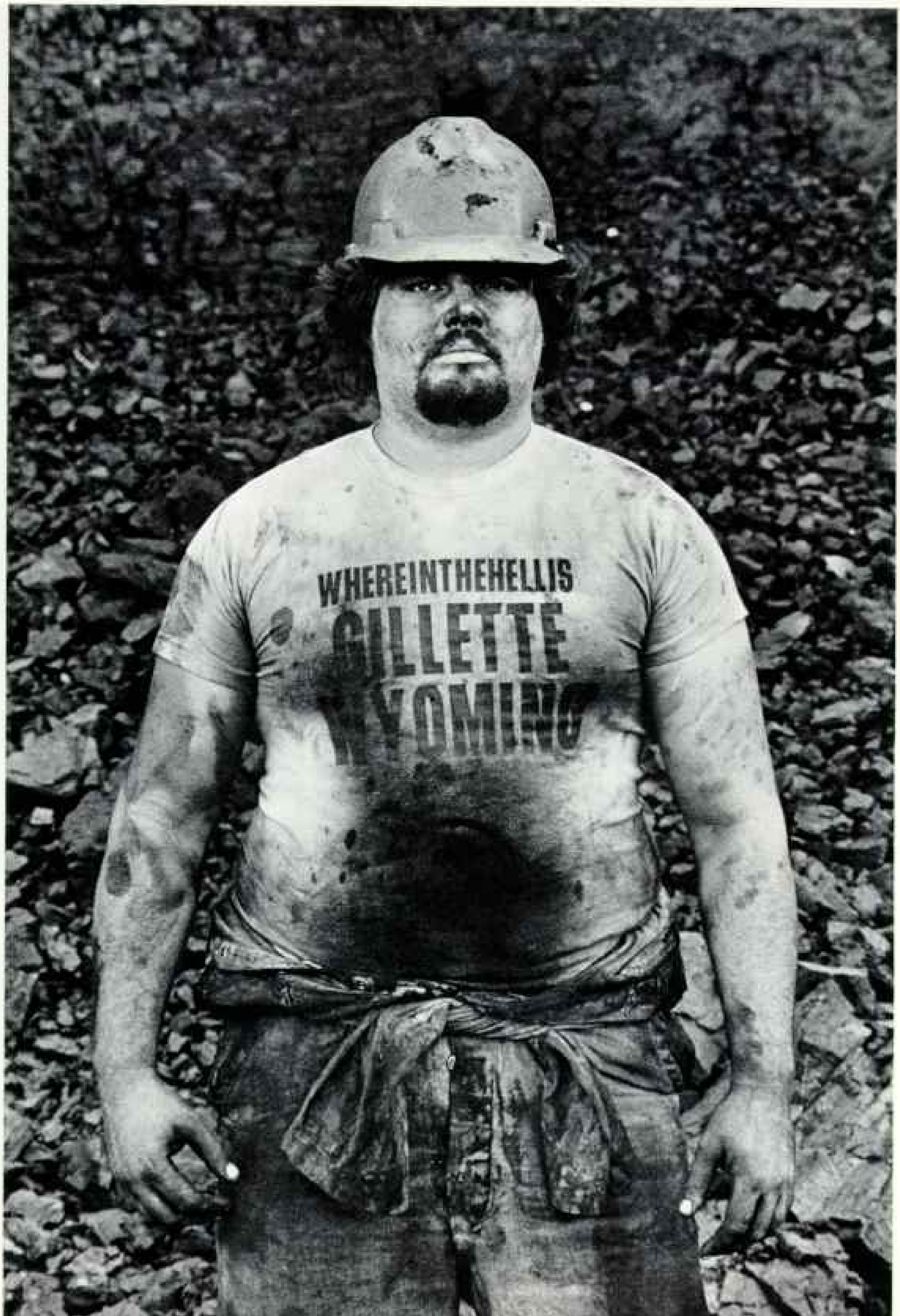
Gary Glass, deputy director of the Wyoming Geological Survey and a believer in energy development in the basin, would not contest Mrs. Reno's view. "If this nation intends to produce enough energy to shape itself up in the next ten years, then you're looking at the future right here."

There are huge reserves of raw energy in the basin. Wyoming is second in the nation to New Mexico in uranium reserves, with a third of the state's supply under the basin. There is also oil, with pumping jacks bobbing across the prairie like faraway insects that never seem to rest.

But it is coal that sets this land apart. Fifty billion tons, much of it very close to the surface in seams that sometimes run as thick as a 20-story building is high.

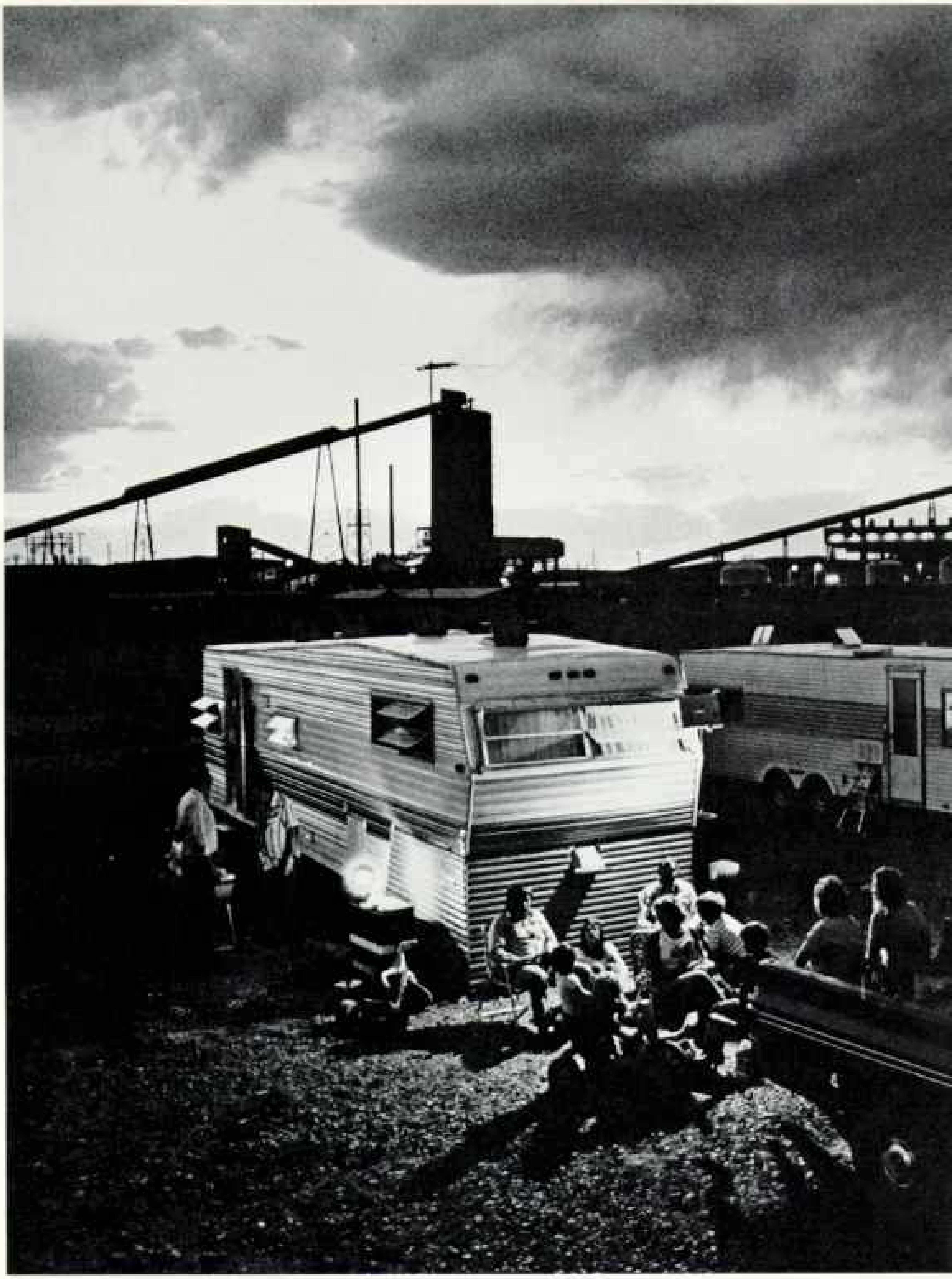
In Gillette I met the energy boom head on. Rows of trailers spilled across the valley. Road graders gnashed away, turning the two-lane state road I was on into a four-lane highway. Dust clouds rose over the local airport, undergoing its third expansion in three years. And a plastic sign on a roadside honky-tonk offered music and beer every night, Sundays included.

At night, souped-up cars and trucks filled


WHEREINTHEHELLIS

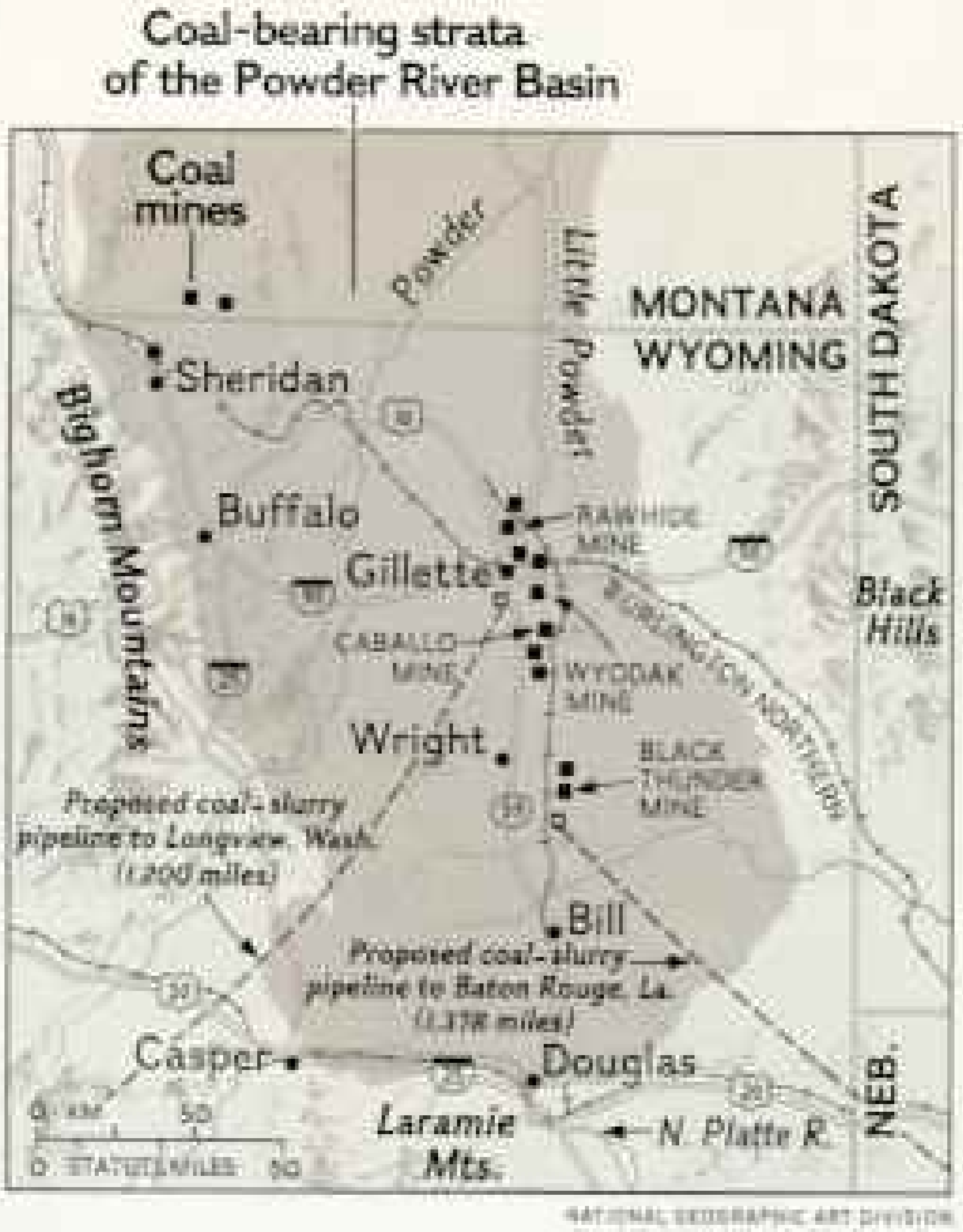
There's no bull but lots of buck as "El Toro" jolts a patron in a

Gillette bar. Even as cowboys work the mines, miners try electric rodeo.



Aluminum Conestogas *make for a circle of neighbors enjoying payday steak and beer. Transient workers follow ready wages to settle briefly, as here before the Wyodak complex. Once the largest coal strip operation in the world, the mine*

*feeds two companion power plants. Yet the region is so rich in coal (**map**) that the surface is barely scratched.*



with newcomers raced around a circuit of bars. Car radios blared country and western songs, one of which seemed a particularly appropriate dirge for Gillette's past:

This is the last cowboy song,
The end of a hundred-year waltz,
The voices are sad as they're singing along,
*Another piece of America's lost.**

Replacing the lost cowboys are the energy boomers like Marty Yuill, a young woman who drew admiring glances from the male diners in the café where we were sipping coffee.

"I came here last year," she said, "to find work that paid better and was more exciting than the jobs available back home."

"Did you find what you wanted?"

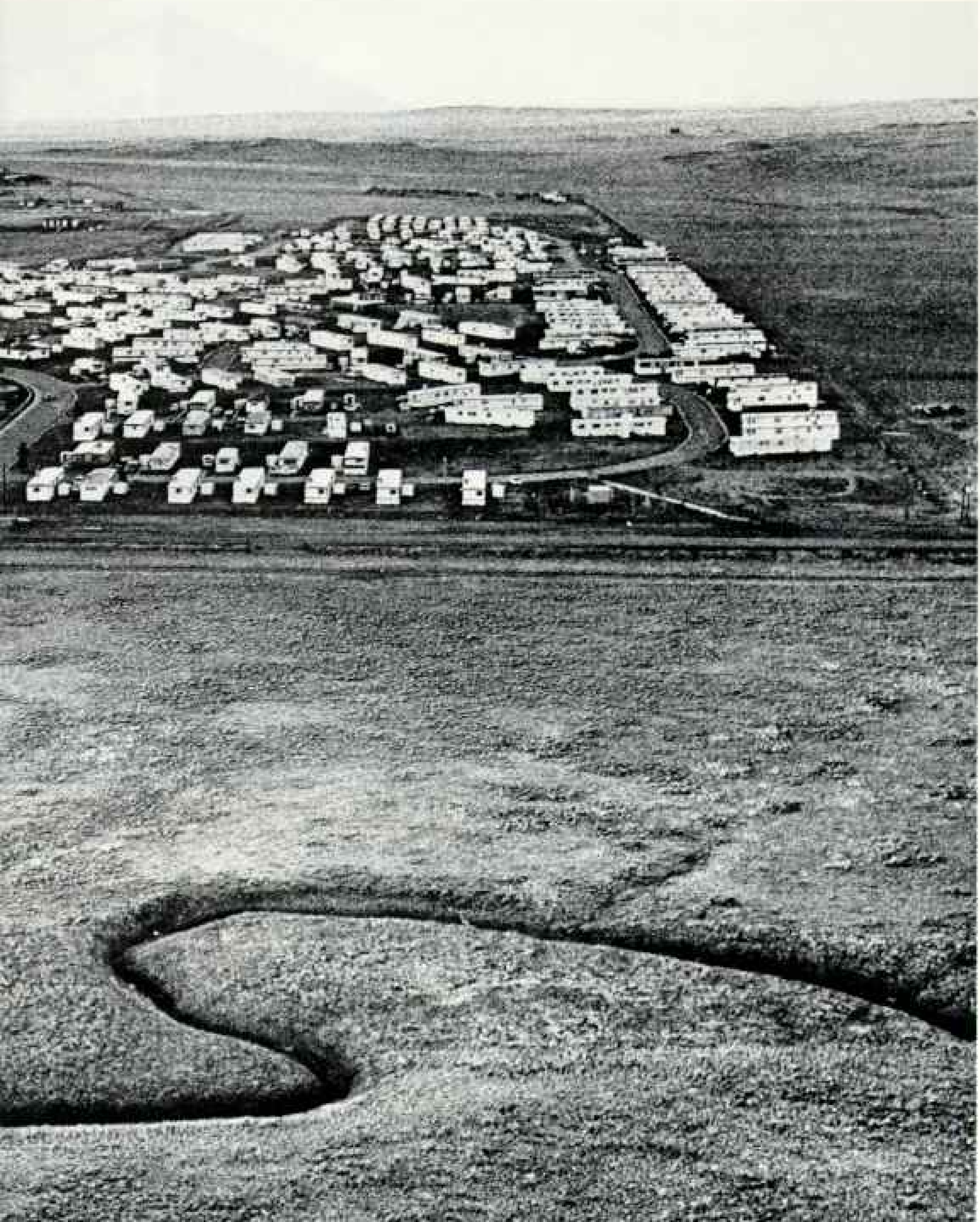
"You bet I did," Marty said with a grin.

She got a job packing 50-pound bags with blasting material for the coal mines. "I'm used to it now," said Marty, "but you ought to see how it shakes up the guys I meet."

Job seekers by the thousands have been pouring into the basin in the past few years. Most are young—the average age here is 28—and some make good money. The starting pay for an apprentice heavy-equipment

* "The Last Cowboy Song" by Ed Bruce and Ron Peterson © 1979 by Tree Publishing Company, Inc., and Gingham Music Company.

Anticipating the boom of Black Thunder, Arco's nearby mine, the



company planned the prefabricated birth of Wright, Wyoming.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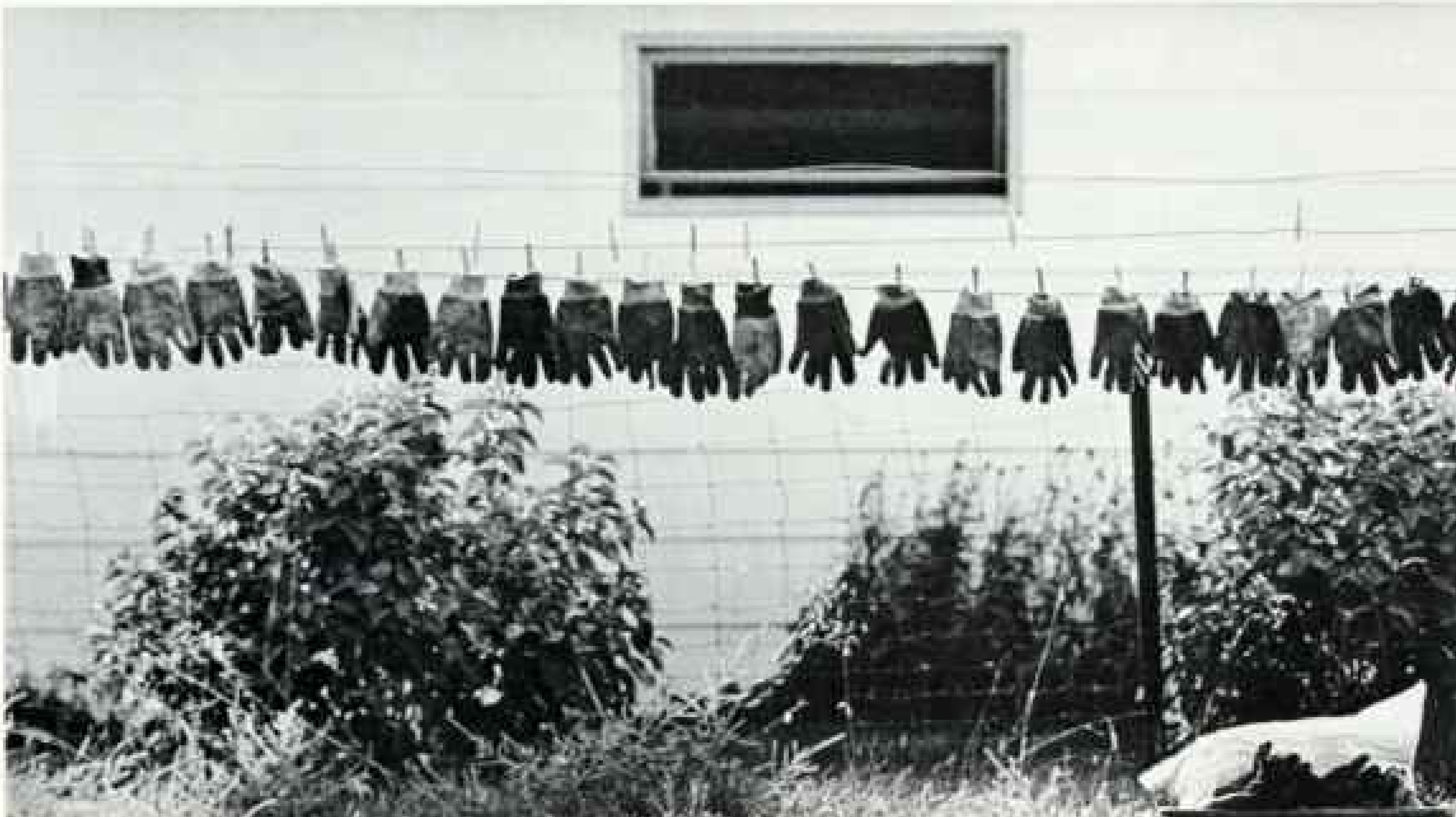


operator in a coal strip mine is more than $11 an hour, about what a cowhand can expect to earn for half a day's work on a ranch.

But there is a darker side to this boom. Loneliness, long cold winters, and a wind that screams for days on end can breed despair. According to a recent estimate, one in every 250 residents has attempted suicide.

Some observers say Gillette exhibits a "boomtown syndrome"—a pattern of social ills typical of people who come looking for the rainbow's end. At the Northern Wyoming Mental Health Center many cases involve marital conflict, wife and child abuse, and alcohol problems.

Coping With Boom Times

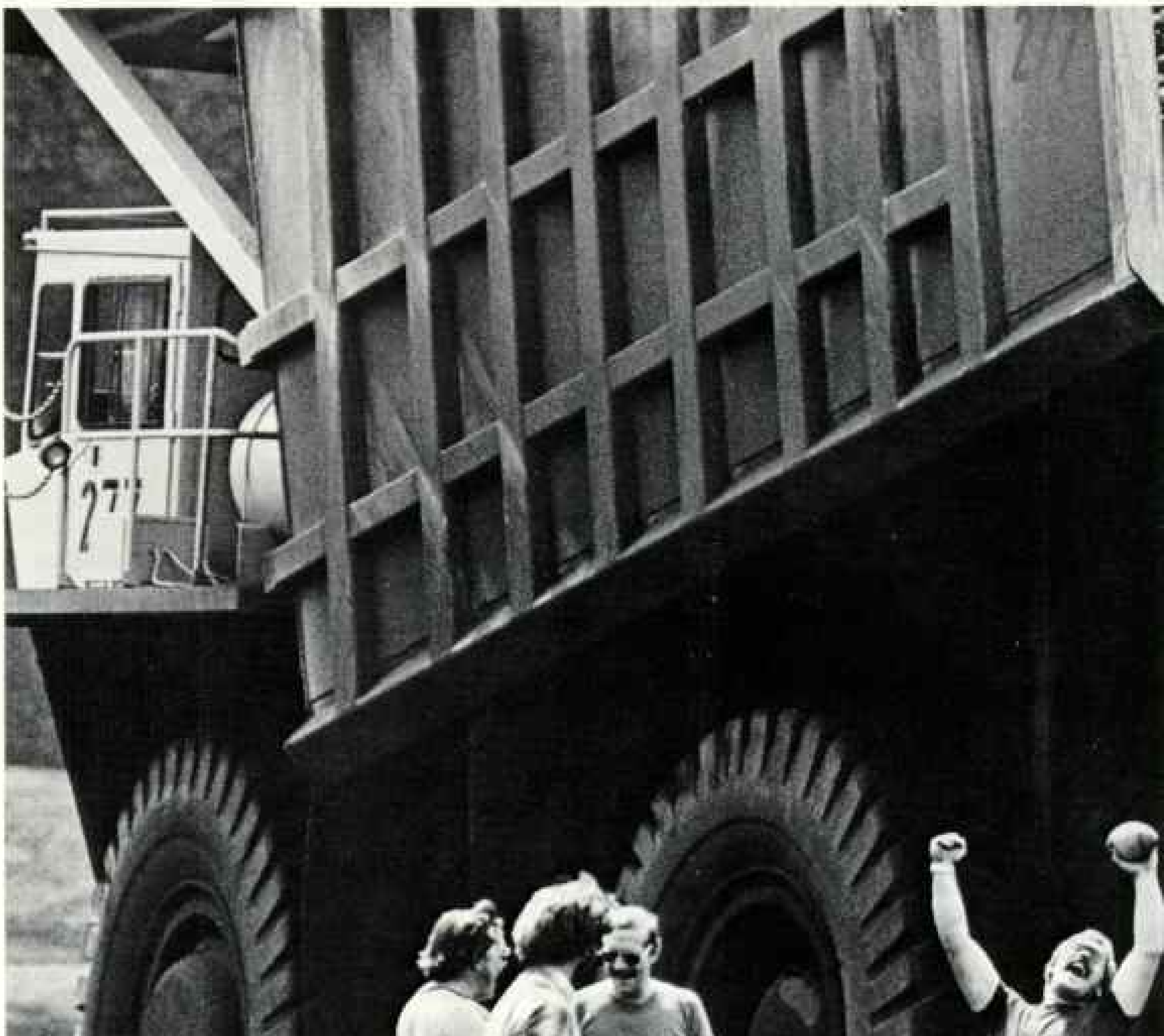
Gillette's Mayor Mike Enzi disputes that gloomy assessment. "We've got problems all right, but most have been blown out of proportion. We've been called the baby-abuse capital, which just isn't true." On the wall of his office is a plaque with the city's official—and preferred—title: Energy Capital of the Nation. Gillette has grown from 4,000 people when he came here in 1969 to 14,000. In another 20 years, he expects a population of 50,000, chiefly attributable to coal.

"I'd rather talk about present-day positive solutions than historically negative problems," Mayor Enzi continued. "Nobody ever mentions our 200 baseball teams. There are more baseball players than occupants of all the bars in the county." Furthermore, since the mid-seventies, Gillette has expanded its electrical power, sewage treatment, water supply, and roads. The ratio of new homes to mobile housing is now about even.

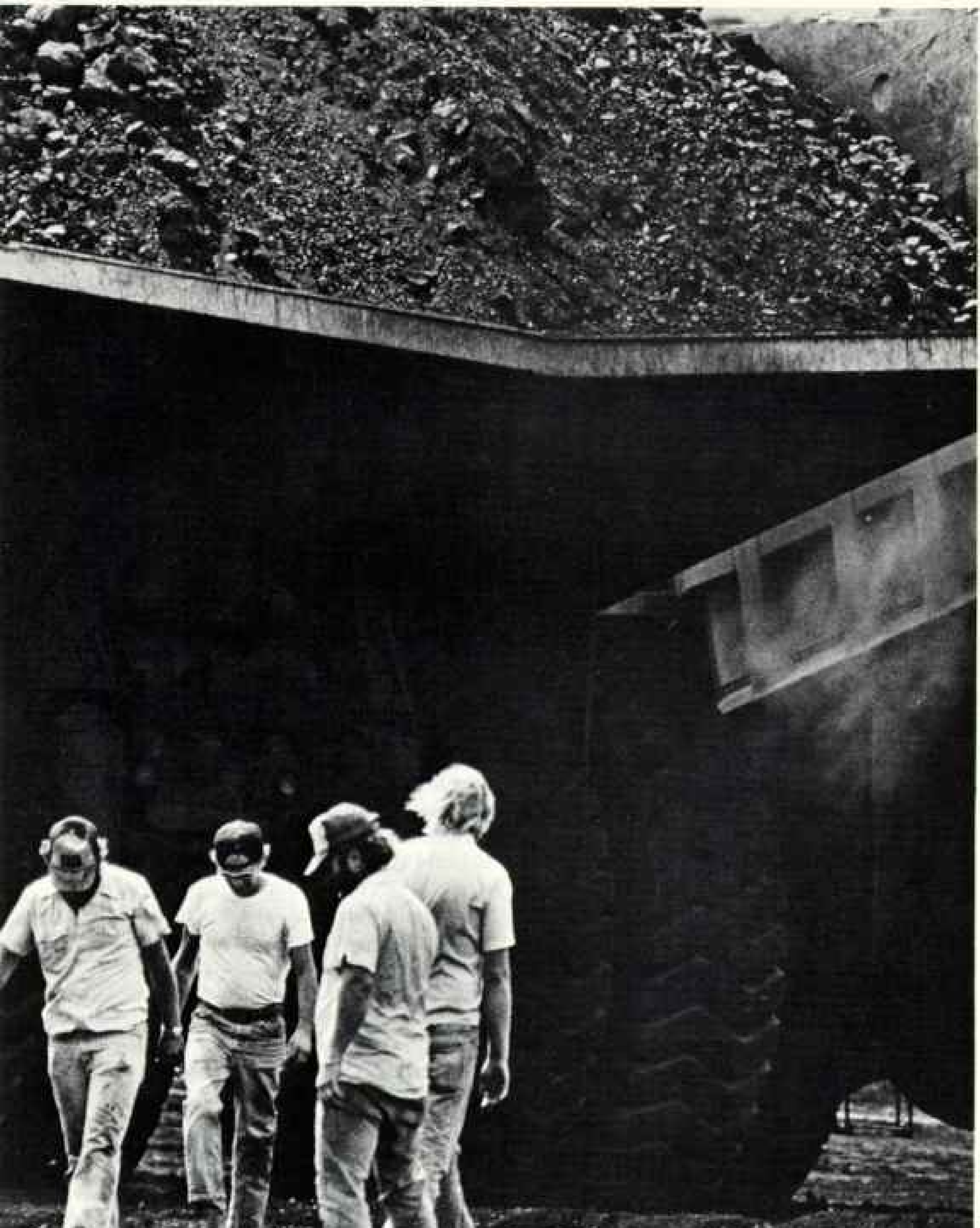
With Joe Hamner, president of the Carter Mining Company, I visited one of the basin's busiest strip mines. Carter, a division of Exxon Coal, has invested more than 140

The sofas were coming, *but nobody was roused on this day in Gillette* (**above**). *The itinerant furniture store soon moved along to the oil fields, where the young workers are the big spenders.*

On glove wash day, Karen Turner (**left**) *strings up like pelts some two dozen pairs, about a third of the supply her husband will wear out in a year working as a roustabout in the oil fields.*



Touchdown at the whistle sends the stars of two pickup teams



back to their giant trucks to haul away strip-mined coal at 120 tons a load.

million dollars in its Rawhide and Caballo coal mines. In 1979 the two mines shipped 4.7 million tons, and by 1990 could be producing 36 million.

"We tell our workers we will be here digging coal for the next 30 or 40 years," said Hamner in a deep east Texas drawl.

At the Rawhide Mine there is so much coal that the electric shovels and 180-ton belly dump trucks with their ten-foot tires are toys against that massive seam. Mine manager Pete Erickson explained that the mine will follow the coal seam across 6,000 acres of ranchland.

As the miners open up new sections of the seam, they will fill in the mined-out pit behind. "Five years from now this hole will be restored to its original condition—minus the coal, of course," Erickson said. He pointed to a gentle grass-covered slope where a couple of antelope grazed. "We reclaimed that hill," Erickson said proudly. "But some folks still argue it can't be done."

On the other side of the fence, so to speak, are ranchers and environmentalists like Roland Landry, who warn that, with a dozen operating strip mines and more to come, the large-scale disturbance of the prairie will leave a permanent scar. Landry helped form the Powder River Basin Resource Council, most of whose 600 members look skeptically at claims by Exxon, Arco, and others that mines can be permanently reclaimed.

"This is delicate country," Landry said. "The reclamation looks great—now. But after a couple of drought years and heavy grazing, it could be right back to moonscape."

The basin's coal was ignored until recent years because the basin itself was ignored. Westward travelers in the 19th century skirted it and the treacherous Bighorns when they could. Those who did pass through—mostly along the Bozeman Trail toward Montana's goldfields—noted fine, dark sand resembling gunpowder along the riverbank—thus the name Powder River.

It was not until 1892, when a railroad crossed the basin, that the importance of its coal was recognized. The railroad tapped deposits near Sheridan to fuel its engines. Mining camps sprang up filled with Poles, Italians, and Irish, whose descendants mingle with the children of English and Scottish ranchers on the streets of Sheridan today.

The Burlington Northern burns diesel fuel today, but it hauls a lot of coal—about 80 million tons in 1979. I swung aboard coal train number 50-48, a line of 110 orange-and-black hopper cars, each holding 105 tons, stretching out of sight around a bend three-quarters of a mile back. The train, pulled by six engines, was bound for Houston; its 11,550-ton load would provide as much electricity as that city uses from all sources every ten hours. By 1985 this stretch of track could be one of the busiest in the country, carrying 30 coal trains daily.

Opposition or Control?

Such booming prospects alarm old ranching families. Near the quiet community of Buffalo (population 3,800), Texaco and Mobil want to build synthetic-fuel plants. One evening I spent several hours in the basement of the Buffalo Congregational Church listening in on a strategy session called by opponents of the proposed plants.

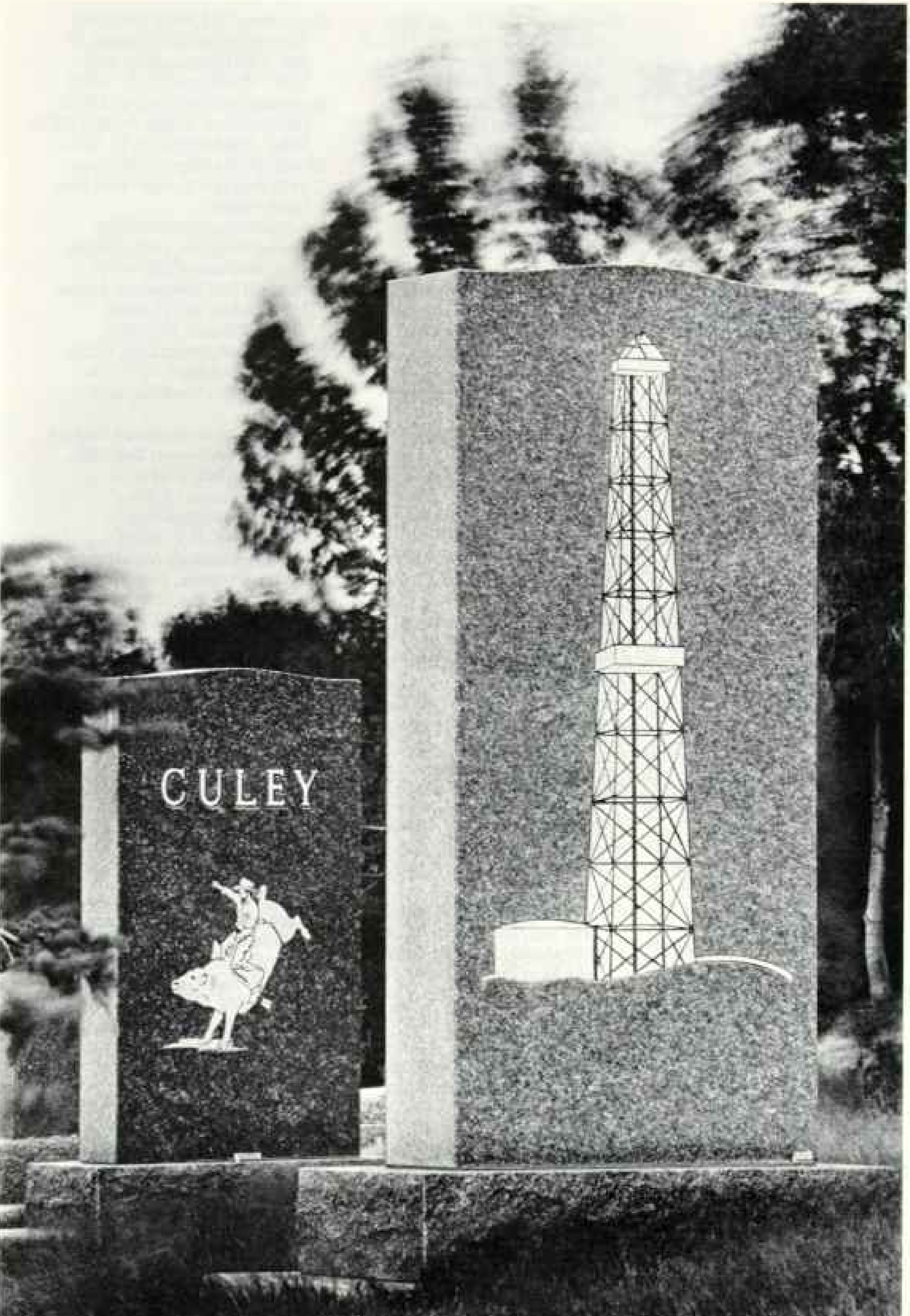
A schoolteacher, a forest ranger, several ranchers, and perhaps three dozen other people attended the meeting. The impact of the energy projects on the area would be enormous, they said: a work force of 10,000 to build the two plants, several billion gallons of water to run them, and potentially serious pollution that could drift into the nearby unspoiled Bighorn Mountains.

Still, I wondered, what chance did 40 people have of halting a project of this magnitude? I asked Wyoming's U. S. Senator Malcolm Wallop, whose ranch sprawls into the foothills of the Bighorns a few miles from the site of Texaco's proposed project.

"I doubt there's much that can be done," he said. "Sadly, the time spent trying to stop development is perhaps wasted. It could be better used to control the impact.

"People of Wyoming have never given ground happily. But today we have to give ground because irresistible changes are coming to this part of the West." □

The paths of glory*—cattle glory or oil or coal glory—still lead but to the grave. Generations of boomers will pass before Powder River coal lights its last lamp.*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National Coal Association, Public and Media Affairs, 1130 17th Street N.W., Washington, D.C. 20036.

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HUNDREDS OF CARLOADS OF COAL, AMERICA'S MOST ABUNDANT ENERGY RESOURCE, WAIT FOR SHIPMENT AT HAMPTON ROADS, VIRGINIA; LOUIS PSIHOYOS

OUR WORSENING energy situation of the past decade reminds me of the farmer whose mule wouldn't budge. A helpful neighbor struck the animal a jarring blow between the eyes with a post, explaining, "First you've got to get his attention."

The 1973-74 oil embargo by the Arabs was the blow that got our attention. OPEC quadrupled the price of crude oil, and the price of gas shot up—when we could find a station open and had the time to wait in line.

We were inconvenienced then. But the long-range effects have been devastating. Unemployment is up. The dollar is down. Our automobile industry is in convulsions.

Being from Missouri and familiar with mules, I know all too well that getting their attention doesn't mean you can get them moving.

Likewise we will need more than a shock to get our economy moving ahead and overcome our dependence on foreign energy. This will require more concerted effort than our entire moon program. Conservation and increased efficiency offer the only reasonable immediate relief, but this must be accompanied by an imaginative and thoughtful development of new and alternative energy sources and a massive retooling of an aging industrial complex.

It will not be easy. It will not be cheap. We have the know-how. We have the raw materials. As with a successful mule skinner, the most important thing is, do we have the will?

Wilbur E. Garrett

EDITOR

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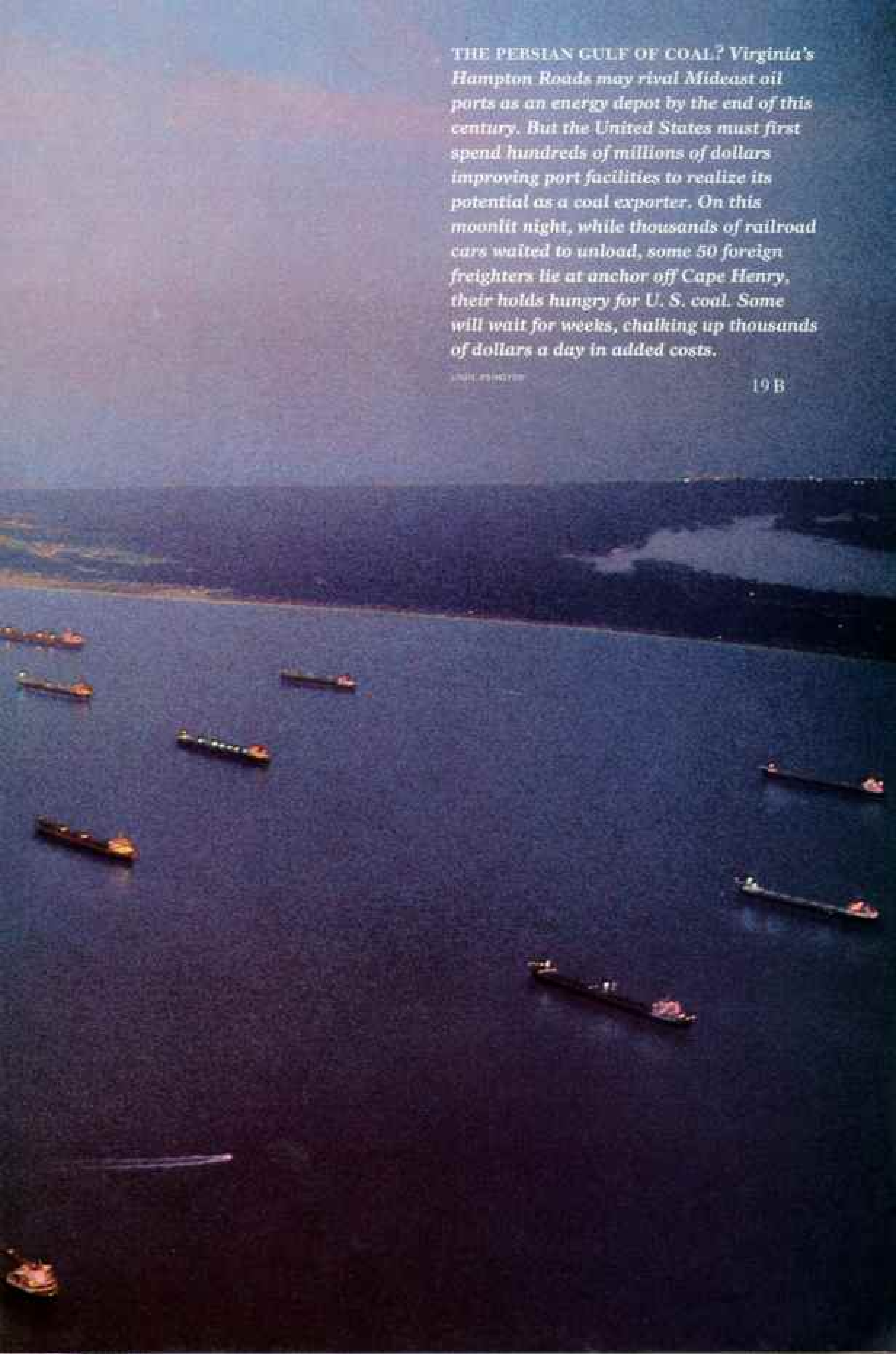

THE PERSIAN GULF OF COAL? *Virginia's Hampton Roads may rival Mideast oil ports as an energy depot by the end of this century. But the United States must first spend hundreds of millions of dollars improving port facilities to realize its potential as a coal exporter. On this moonlit night, while thousands of railroad cars waited to unload, some 50 foreign freighters lie at anchor off Cape Henry, their holds hungry for U. S. coal. Some will wait for weeks, chalking up thousands of dollars a day in added costs.*

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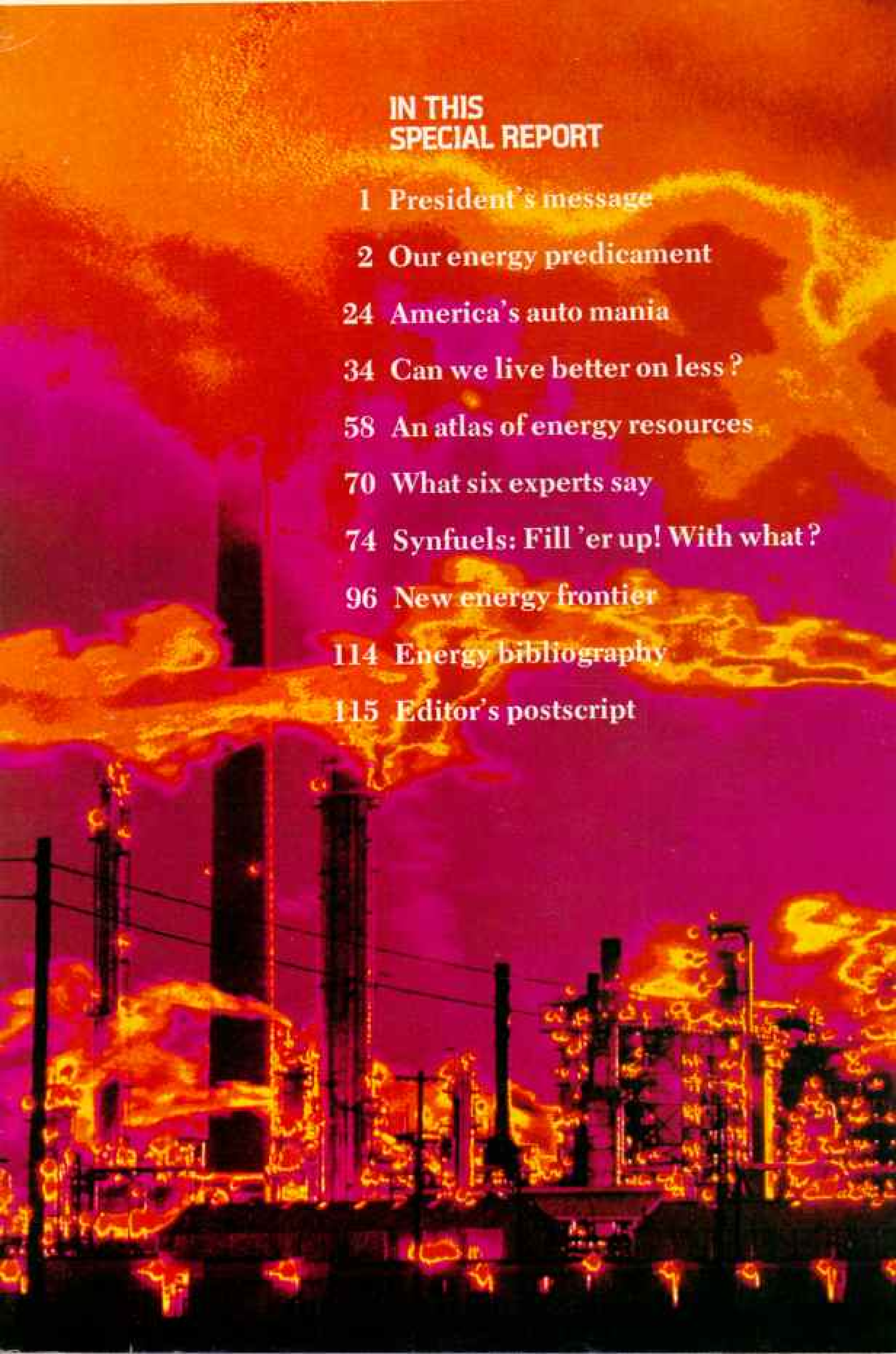

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