Circular 140 1974

Papers Presented at

ENERGY CRISIS SYMPOSIUM

Albuquerque, New Mexico, 1973

Compiled by
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John W. Shomaker

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
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Symposium sponsored by:

New Mexico Chapter—Soil Conservation Society of America
New Mexico Section—Society for Range Management
Southwest Section—Society of American Foresters
New Mexico Geological Society
Albuquerque Geological Society
New Mexico Soil Science Society
New Mexico Section—American Society of Agricultural Engineers
Technology Application Center—University of New Mexico

1974

First printing, 1974

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University New Mexico Printing Plant, Albuquerque, January 1974

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 $2.50

FOREWORD

The Energy Crisis Symposium was organized as a joint effort by the seven professional societies listed on the title page.

The aim of the Symposium was to provide information on the effect of the Energy Crisis upon New Mexico, including the state's energy potential, options in energy sources and uses, and the impact of the development of energy resources on each of the fields represented by the sponsoring organizations.

The Symposium was held at the Holiday Inn - Midtown in Albuquerque, New Mexico on May 3 and 4, 1973, and was attended by 220 society members and others.

The following persons also presented papers at the symposium but did not submit manuscripts for publication in this volume: Marshall Reiter, New Mexico Tech (geothermal energy), Jerry Plunkett, Materials Consultants Inc. (wasted energy), Frank DiLuzio, governor's office (energy policy), and Frank W. Trainer, U. S. Geological Survey (geothermal source in Jemez Mts.).

The symposium planning committee especially appreciates the offer of the New Mexico Bureau of Mines & Mineral Resources to publish these proceedings. To hasten publication of this timely information authors were asked to submit camera-ready copy — hence, the variation in appearance of individual papers. Thus, authors were their own editors.

Albuquerque
Nov. 12, 1973

John W. Shomaker
Conference Registrar

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"THE ENERGY CRISIS"--TRUE OR FALSE?

Jack M. Campbell
former Governor of New Mexico

The answer, of course, is "True." I think everyone from hard hats to hippies would agree on that, even though President Nixon prefers to call it an "energy challenge". I am reminded of the country politician asked to define "status quo", who replied, "Son, status quo is Latin for the mess we is now in."

The dictionary defines a crisis as "a critical moment, a crucial turning point in the progress of an affair or a series of events." From the standpoint of the energy industry, the government, and the ordinary guy enjoying the benefits of the world's most affluent society, the next dozen years are going to be critical. A whole flock of political, ecological and economic chickens have come home to roost at the same time. Someone once said that depressions wouldn't be so bad if they didn't come when so many people were out of work. We might paraphrase that bit of wisdom by noting that energy crises wouldn't be so bad if they didn't come when we seem to be running low on gasoline, oil and electricity.

There is little doubt that the current energy crisis--or challenge--is, in the words of author James Ridgeway, "the most important political and economic issue of the last quarter of the Twentieth Century."

However, I would like to assure you that the sky is not falling; the lights are not going out, and the stagecoach is not going to replace the jet plane. We have the natural resources and the technological potential to provide the necessary energy to maintain a modern, industrial economy without destroying our ecology. But, we cannot accomplish this with a "business as usual" approach. We are going to have to rethink some of our assumptions about government regulations, private transportation and power priorities. We must recognize that the immediate energy crisis is somewhat artificial in that it is caused more by political and administrative restraints than by resource limitations. If public policies can be adjusted promptly, there are adequate resources to meet energy requirements beyond the year 2000 with current technology. But, that energy won't come as cheaply as it used to.

It does seem amazing that a country as technically advanced as the United States should face the threat of an energy shutdown. Surely, the system that has produced the computer, the transistor and the marvels of space flight could come to grips with its energy problems. But, the economics and politics of fuel extraction and distribution are incredibly complex. The energy equation includes industrial competition, import quotas, depletion allowances, delicate international relations and growing environmental concerns.

Until now, Washington simply hasn't had a comprehensive energy program. Fuel policy emantes from everywhere, from the Bureau of Mines, from the Atomic Energy Commission, from the Environmental Protection Agency--from 64 different agencies in all.

The government has clung to the low-cost, maximum-usage policy launched in the 1930's. The oil, gas and electric companies have advertised relentlessly to sell more and more of their output. With but 6 percent of the world's population, the United States consumes 30 percent of the globe's energy. On any given day, the average American household uses up the energy equivalent of 46 pounds of coal, 9.5 gallons of oil products and a half-pint of nuclear energy, among other fuels.

Ever since Malthus, mankind has been concerned from time to time by the fact that the earth's natural resources are limited. A 1921 report on the American Chemical Society meeting noted that "the best papers were devoted to the ever-recurring question...as to how the coming generations will secure the needed energy for light, heat, transportation and the thousand and one other requirements of human life. Resources considered (with deep concern for adequacy of supply) were coal, oil, natural gas, wind, tides, and solar power." The report added, "none of these options is as attractive as atomic energy."

Today, more than 50 years later, we are gathered here to discuss that same question, although I hope with a sharper focus. Since 1850, when firewood supplied nine-tenths of our energy needs (exclusive of draft animals), our sources of fuel and power have shifted several times. Coal supplanted wood, and then petroleum and natural gas became dominant. By the end of this century, nuclear power may meet nearly a fourth of our needs, although at the present time it accounts for less energy than firewood.

Historically, energy has been an inexpensive and readily available commodity in the United States. In fact, the cost of energy in most forms declined relative to overall price indices in the 25 years following World War II. As a result, U.S. energy consumption per capita has almost doubled since 1940

The massive East Coast blackout of 1965 indicated something might be amiss with our energy system, but a private, White House study in 1968 concluded that "the nation's total energy resources seem adequate to satisfy expected requirements through the remainder of the century at costs near present levels." With energy apparently so readily available, little thought was given to efficiency. It is estimated that the U.S. wastes 50 percent of all the energy it burns. Automobiles shoot 87 percent of their energy intake out of the exhaust pipe, and the pilot light on a gas range may consume one-third of all the fuel the appliance burns. As recently as three years ago, the President's Task Force on Oil Imports predicted that the U.S. would have to import no more than 27 percent of its oil by 1980. As you probably know, the total already has reached that level and is growing steadily.

It appears that a new energy era is beginning in this country, ushered in by growing shortages of the traditional fuels and characterized by rising prices for energy. Last year, for example, marked the first time that the average price of electricity (measured in constant dollars) has increased since 1946.

Federal Power Commission officials scoffed a few years ago at warnings about natural gas shortages. Now there really is a problem, provoked at least in part by FPC regulated low prices at the wellhead that (1) discouraged exploration, and (2) made gas cheaper than competing fuels, thereby stimulating wasteful use.

U.S. natural gas consumption is nearly six times what it was in 1945, and natural gas has accounted for half of the increase in the nation's energy consumption. Manufacturing has accounted for nearly half the total increase since 1945. Many industrial consumers could get along without gas, but burn it because it is cheap and convenient. Demand has outrun supply. In 1960-1971, consumption nearly doubled, while reserves increased hardly at all. They actually diminished in 1968, 1969, and 1971.

In January 1970 the government asked the National Petroleum Council to undertake a comprehensive study of the U.S. energy outlook through the end of the century. The final NPS report issued this past December noted there are substantial undiscovered oil and gas reserves in this country, but that most of these deposits are believed to be located in less accessible areas and will be more costly to recover than past discoveries.

Domestic supplies of energy now

provide 88 percent of U.S. requirements but if current trends continue, they would supply only 62 percent by 1985. Oil imports could climb to as much as 65 percent of total oil supply by that time. Imports of natural gas could reach 29 percent of total gas supplies Domestic oil and gas would contribute only 30 percent of the nation's energy needs in 1985 if present trends continue.

As the United States becomes increasingly dependent on crude supplies from the Eastern Hemisphere, it will be competing with sharply expanded petroleum requirements in Western Europe and Japan. Also, increased dependence on the political and economic policies of a relatively small number of North African countries could have important consequences for the security of the United States. Balance of trade pressures would increase. The dollar drain resulting from trade in energy fuels could range up to $32 billion annually by 1985.

The energy crisis also involves the conflict between the desire for more energy and the desire to cleaner air. We are currently witnessing one of those rare events in history when there arises a head-on conflict between a line of technological development and a new social attitude.

Mining, transporting and processing of fuels lead to various forms of pollution. Any technological measures to dilute this pollution will inevitably add to the final cost of the product. On the one hand, we have a vigorous growth in energy consumption, closely related to a rising standard of living. On the other, we see a widespread public concern with preservation of the environment and this concern has been translated into restrictive standards and regulations.

All aspects of energy use have a direct or potential environmental impact. Coal mining creates acid mine drainage, earth subsidence, and destruction of landscapes in stripping operations. Oil production carries the risk of marine pollution and the less-publicized problem of salt water disposal from wells on land. Oil refining can lead to air pollution when volatile hydrocarbons are not carefully contained. Oil transportation carries the risk of large spills from tanker grounds and collisions. Combustion of any fossil fuel creates air pollution and electricity transmission can cause "scenic pollution" through the intrusion of power lines on the landscape. Nuclear fuel at every stage, from mining through "burning" and reprocessing, involves radiation hazards if adequate safeguards are not installed.

The automobile industry is involved in a struggle with air pollution control authorities over the control of exhaust emission levels. I understand that Detroit has decided in view of its failure to produce a clean engine that it will offer next year's car buyers tighter windows.

This is a new world for increasing numbers of businesses caught in the conflict. The Council on Environmental Quality estimates that increased capital and operating costs related to pollution control will amount to some $287 billion by 1980.

An electrostatic scrubber for a large industrial plant requires as much as 50,000 kilowatts of capacity. The Federal Water Quality Administration estimates that in 1973 the U.S. will consume close to five million kilowatt-hours for sewage treatment. Electric furnaces use more than ten billion kilowatt hours each year to reclaim scrap iron and steel.

The demand for a clean environment has hobbled the energy industry's efforts to keep up with demand. The Clean Air Act of 1970 is forcing Midwest utilities to find a substitute for 200 to 300 million tons of high-sulfur coal a year. Clean-burning, low-sulfur coal is plentiful in the West, but proposals to strip-mine the land to get at it have triggered complaints from ecologists throughout the nation. Experts believe there are massive basins of oil off U.S. shores--the Interior Department says 5.5 billion barrels off the Atlantic shelf alone--but protests that oil spills might ruin the coastal playlands have held up development.

Delays of authorizations for the Alaskan pipeline system are depriving the nation of at least 2 MMB/D of crude oil and about 3 TCF/year of natural gas. Nuclear reactor plant siting and licensing postponements could cost the electric utility industry an additional $5 billion to $6 billion for each year's delay during the early 1970's. This could reduce installed nuclear plant capacity by up to 135,000 megawatts in 1985. Banning of surface mining would essentially eliminate western coal production for making synthetic liquids and gas. Environmental regulations already have restricted the fuel options available to electric utilities so that, in many parts of the country, they have no choice but to use imported low-sulfur fuels.

Even if the businessman is not directly involved in the conflict, he can expect an increase in his energy bill as gas rates rise to reflect the reduction in oil's sulfur content; coal prices rise to reflect the impact of the Coal Mine Health and Safety Act and restrictions on strip mining; electricity rates rise to reflect all of these things plus the cost of cooling towers and other environmental facilities.

The American standard of living, the envy of the world, also contributes to the energy resource problem. Air conditioning and space heating accounted for a 28 percent increase in the use of household electricity in the past decade, according to the American Public Power Association. Replacing a black and white television set with a color unit, or an old refrigerator with a frost-free model requires twice as many kilowatt-hours.

Another input into the energy crisis is the increasing non-energy uses of fuels such as petroleum. The percentage of oil used for petrochemicals is expected to climb from only 2 percent in 1965 to 35 percent by the year 2000.

I'm afraid my remarks are beginning to sound like one of those "bad news - good news" jokes which were so popular a couple of years ago. You know the kind. The pilot of the airliner comes on the public address system and announces to the passengers: "Ladies and gentlemen, I have some bad news and some good news. The bad news is that we are lost; the good news is that we are making very good time."

Well, now for the good news. As I mentioned at the beginning of my talk, the initial problem is one of failure in planning, comprehensive research, and national leadership. In this regard, I believe President Nixon has made an historic move in the right direction with his recent energy message to Congress. The President warned the Congress and the public that "in the years immediately ahead, we must face up to the possibility of occasional energy shortages and some increases in energy prices."

He called for elimination of price regulations on newly discovered natural gas to encourage the development of new supplies of the nation's cleanest fuel and asked that Interior Secretary Morton be empowered to impose a ceiling if prices get too high. He urged increased research and development to produce new sources of energy such as more efficient nuclear plants. The President suspended all oil import quotas and he lifted tariffs on oil, but imposed license fees. Morton was ordered to triple the amount of federal offshore lands available for oil and gas leasing and to study leasing in the Atlantic Ocean. The President urged greater use of coal, the most plentiful domestic energy source, consistent with "reasonable" environmental requirements. He asked Americans to be more conservative in their use of electricity and gasoline, and he directed the Federal Housing Administration to raise insulation standards to reduce the energy required to heat or cool homes. He proposed efforts to conserve present fuel supplies in part by increasing prices to be more reflective of true costs.

Some compromises on environmental standards will be needed, the President noted, to keep the costs of energy at reasonable levels. To stimulate domestic oil production, he proposed extending the investment tax credit to exploratory oil drilling., The credit would be more generous for successful wells than for dry wells, in his words, "in order to put an additional premium on results." He pledged to seek much more spending for energy research in such advanced areas as solar, geothermal and thermonuclear fusion. The President repeated his previous call for approval of the Alaska pipeline to permit development of the rich North Slope oil fields.

Several of the President's directives favor producers but they also will open the petroleum industry to greater public review. Since the giant oil and gas companies will be the primary beneficiaries of the higher prices, they will be operating in a political fishbowl as never before. There could be demands to break up the major oil combines, which among them control about 84 percent of U.S. refinery capacity, about 72 percent of natural gas production, more than 50 percent of uranium reserves and 20 percent of coal production.

The next dozen years will be the crucial ones. Our requirements for energy will almost double between now and 1985. During that period the nation must continue to rely heavily on its overburdened supply of fossil fuels -- coal, oil and natural gas--and on imports. Internationally, the crisis could force a new order of priorities in American diplomacy as the U.S. tries to improve relations with the Arab nations that control most of the world's oil reserves. Increased purchases by Western Europe and Japan as well as the U.S. could create major new centers of financial power in the producing countries, particularly Saudi Arabia and Iran. By 1985 the oil producing countries could be collecting revenues of almost $50 billion annually. A large portion of these oil tax revenues could move into the money markets of the Free World in ways which are difficult to predict. One possibility is that these countries could become large equity holders in the financial institutions and industrial companies of the United States, Western Europe and Japan. Overdependence on foreign sources could make the U.S. vulnerable to the military and political interests of Middle-Eastern nations.

On the other hand, accelerated development of domestic energy supplies should benefit all segments of American society. Employment would increase, individual incomes would rise, profit opportunities would improve, government revenues would grow, and the nation would be more secure. However, increased government restrictions on energy demand growth could prove disruptive, requiring unrealistic changes in the American way of life. They would adversely affect employment, economic growth and consumer choice.

American oil and gas resources are sufficient to support a substantial increase in production if the producer can be assured of a fair rate of return. To find, develop and process the primary energy supplies needed through 1985 will require capital investments of more than $200 billion, with an equal amount needed for electric generation and transmission. Thus, total capital requirements probably will exceed $400 billion, according to the National Petroleum Council study. Higher prices for energy will be required to attract the large sums of capital needed to expand supplies above current levels.

The chief mission of a national coordinating agency should be to establish priorities and guidelines and to eliminate delays, conflicts and confusion.

Protection of the environment will require higher energy use to achieve cleaner air and water. Standards for a better environment must be compatible with such other important national goals as full employment, reduction of poverty, and assurance of adequate energy supplies for health, comfort, and national security.

It is important to continue enforcement of the Federal Coal Mine Health and Safety Act of 1969 equitably throughout the industry. However, any features which reduce productivity but have little bearing on health and safety should be eliminated.

The government should support President Nixon's proposal to accelerate the leasing of lands for exploration and development of energy resources in a manner consistent with environmental goals. Such a leasing system also should provide acreage at more frequent intervals so industry can deploy its skills to develop needed energy supplies. The NPC study indicated the largest potential for new domestic reserves of oil and gas before 1985 is located in the offshore areas and frontier regions of the north.

Federal leasing policy also is important to the development of oil shale land in the Rocky Mountain West. The Mineral Leasing Act of 1920 now limits a company to one lease of a maximum of 5,120 acres. A policy that would (a) make government reserves available in adequate quantities, (b) permit individual companies to have initial holdings of at least 10,000 acres, and (c) allow additional acreage to be obtained as commercial operation proceeds, would provide a spur for oil shale bidding and development.

Any new time limits placed on federal claims or leases held for uranium should take into account the long lead times associated with uranium exploration and development.

Import policies for uranium also should be designed to encourage the growth of this American industry during the transition from supplying primarily a government market to meeting the demands of a mature commercial market. In the long term uranium will become not only the major fuel for electric power generation but also a major source of energy for the United States. The program proposed by the AEC last year for operation of government enrichment facilities and disposal of the government-owned stockpile is reasonable in conjunction with present import policy if adequate economic incentives can be developed.

President Nixon's call for relaxation of FPC regulated gas prices is another necessary step. Natural gas prices and the prices of gas manufactured from petroleum liquids or coal and liquified gas imported from abroad should be freed eventually to reach market clearing levels. This would (a) encourage exploration for new reserves, (b) stimulate development of new sources of supply and (c) discourage the consumption of gas in low priority uses.

Supplies of clean, secure, energy fuels will become increasingly tight over the next three to five years. This condition will become more severe in the longer term if traditional policies continue. Additional intensive research is required in such fields as exploration methods and equipment, the production of synthetic fuels, and development of new energy forms.

The old bromide "waste not, want not" may be in for a comeback. Ancient kings showed their affluence by having their carriages drawn by 10 to 20 horses. The modern American who might sneer at such a display of conspicuous consumption, gets into a 200-horsepower car to drive to work.

History may mark the last quarter of this century as the time when mankind first came to grips with the natural constraints on growth: growth in population, in demand for energy, and in the amount of waste and pollution generated by the mechanical accessories of the good life.

It is essential not to lose sight of the potential trade-offs between increasing fuel efficiency and decreasing the environmental impact of fuel consumption. It very often may be the case that we cannot do both at once. Occasionally we may have to delay stringent controls in order to conserve our fuel supplies and to provide time for research on radical fuel use alternatives.

Improved efficiency is almost certain to benefit the user economically. However, it is not always true that the environment will benefit. A classic example of this dilemma is found in the attempts to decrease automobile emissions. The 1975 emission standards can be met only at the price of a decrease in engine efficiency and consequently a 35 percent increase in average fuel consumption.

A corollary to this quandary is that the volume of fuel used and the volume of pollution generated are not necessarily proportional. Transportation is by far the most serious source of pollution, accounting for 69 percent of the total air pollution measured in tons, even though it consumed less than 25 percent of the fuel. Therefore, major improvements in the efficiency of fuel use in the industrial and commercial sectors may lead to only modest decreases in the total tonnage of emissions. Nevertheless, these decreases may result in very significant air quality improvements in certain locations, particularly urban areas.

Further, if we consider only stationary sources and separate fuel used by utilities from that used directly by industry, we encounter another dilemma. For a given amount of fuel used, utilities contribute far more than their share of pollution. This means that in considering fuel use alternatives for an industrial or commercial user, we cannot glibly recommend conversion to electric energy without considering the integrated impact on the environment due to pollution generated at the power plant.

The advent of extensive nuclear generating capability at the end of this century will change many of these conclusions, but in the meantime, it is essential to consider carefully all of the ramifications of any decision to increase the use of electricity as an energy source for industrial or commercial applications.

We should launch a major new effort to construct the equivalent of at least 280 nuclear emergency plants of 1,000 megawatts each during the next 15 years. Today we have the equivalent of only ten such size plants in operations and only 46 actually under construction.

In looking toward the future energy needs of this country, we can see that the most critical period will be from now until 1985, when we should begin feeling the impact of new technology in the production of fuel. Taken in the aggregate, our potential resources have an energy content sufficient to meet our needs for at least 200 years under favorable marketing conditions.

Beyond 1985 we shall look increasingly to such technological supplements to the conventional fossil fuels as nuclear energy, solar energy, geothermal energy, and the use of atomic fusion to utilize the virtually limitless quantities of hydrogen isotopes in seawater. Shale oil, synthetics and the Canadian tar sands also will be available.

Projections for the year 2000 already indicate a very significant trend toward the use of electric energy--from less than 25 percent of energy consumption in 1970 to perhaps 50 percent in 2000. Both coal and nuclear power are by their nature oriented toward electricity generation.

It is unlikely that large-scale use of solar energy would occur until close to the end of the century because of the high cost of energy production, the intermittent nature of solar energy, and the need for significant technological advances in such areas as the utilization of solar energy from orbiting satellites. However, the National Science Foundation and the National Aeronautics and Space Administration have turned their attention to this field. Last December they sponsored a top level meeting of scientists interested in solar energy. The National

Science Foundation has initiated a national competition for the design of a solar-powered home heating and air conditioning system, along with the specifications for mass production.

Geothermal energy is generated in the earth when molten rock comes in contact with underground water. When the resultant steam is within a few miles of the earth's surface, it might be tapped to produce electricity. Some interesting research is taking place in this area.

Methyl alcohol made from coal probably could be developed into an economical transportation fuel after 1985, partially compensating for the dwindling supplies of petroleum.

The utilization of hydrogen as a major energy source after the year 2000 could provide the economic incentives for the use of fuel cells for the localized generation of electricity.

All of these ideas are appealing, but it will require an extensive investment in human and financial resources to translate the concepts into practical, economic technologies. Our speakers this afternoon and tomorrow will give us a more expert and detailed analysis of their energy potential.

We can be certain that any new technological developments will excite both great expectations and great fear. Many years ago the introduction of alternating current was condemned, largely by competitive direct-current interests, as "the killing current." When automobiles first came into use in England, a British ordinance required that each car be preceded by a man on foot carrying a red flag. And before that, the bicycle was at one time banned from public use in New York. Too dangerous.

We have learned, perhaps overlearned, in recent years that science and technology can have unforeseen, harmful consequences. The resources of our small, blue planet are not infinite. The film of life which surrounds the earth could be endangered by energy-related pollution and heat. Man has the power to alter the natural cycle which makes life possible in our obscure corner of the universe.

Scientific research must go on. Political decisions affecting our physical, cultural and economic lives cannot be postponed indefinitely. It is important that the men and women who make these decisions have the benefit of the best technological information and the broadest human concern.

No one in this country can be immune from the effects of the energy crisis; no one can escape the pressures of the counter-thrusts of exploitation and conservation. This is especially true in New Mexico and throughout the Rocky Mountain region. As the nation's last frontier, we offer more than any other section of the country in mineral wealth and ecological health. We have a great deal to be shared or plundered. The states of the Mountain West not only have all of the known reserves of uranium and oil shale and tremendous potential for geothermal and solar energy, but also more public land, more wilderness and more forests than any other part of our nation.

Take New Mexico for an example. It is the largest uranium producer in the United States. We rank third among the states in production of natural gas liquids, fourth in the production of natural gas and sixth in crude oil. We have large coal deposits in the northwest and northeast. Petroleum accounts for two-thirds of the total value of all minerals in New Mexico and is the greatest single source of state revenue for education and governmental services. Almost a third of New Mexico's total land area is under lease for oil and gas exploration. Yet, in per capita income, New Mexico ranks among the poorest of the 50 states.

The development of our energy fuels is the key to future growth patterns in the Mountain West. We want to share our energy treasures but for a reasonable return economically and not at the loss of our other priceless assets of scenic beauty and ecological harmony. As a single state, we may not carry a great deal of political clout. But if all the states in the Rocky Mountain region will pool their political, scientific and economic resources, we can affect the direction of our national energy policies. With the interest and support of organizations such as the Soil Conservation Society and with the research capabilities of our universities, we can help provide the intellectual and technological power our nation needs to survive as leader in human values as well as in gross national product.

If we are to become part of the solution to the energy crisis, we must avoid the allure of easy and emotional responses to the hard questions which face us. We can preserve both our economy and our ecology if we are willing to pay the price in self-discipline and higher fuel costs.

IS THE NATIONAL ORIGIN OF THE OIL WE BURN IMPORTANT?

James E. Wilson, President
The American Association of Petroleum Geologists

One of the last places one would expect a fuel crisis to occur would be in the State of Texas. But during the severe and prolonged cold spell last January you perhaps read that is just what did happen. A few weeks ago in a conversation with Judge Jim Langdon, Chairman of the Texas Railroad Commission, he told of a call he had from the President of the Association of Rendering Plants of Texas. The allocation of gas for critical use was imminent and the Rendering Plant Association President was asking that they be put on a high priority as critical to public health. My first reaction was something of amusement as Judge Langdon admitted his was. But Judge Langdon said the Rendering Plant Executive calmly pointed out that perhaps their products weren't so critical, but that it was against the law for slaughter houses and poultry-dressing plants to operate unless their offal was picked up and processed by the rendering plants. That gas was the only fuel the plants were equipped to use and if the rendering plants had to shut down because of lack of fuel, so would the meat packers, poultry houses, etc. In short order there would be no fresh meat in the grocery stores, hospitals, etc. The rendering plant appeal was unique and compelling. I believe Albuquerque itself had a tight gas situation a year or so ago. Almost every paper I pick up across the country today has a story about shortages or predicted shortages of fuels and energy whose supply we have for so long taken for granted.

Up until this past winter I had avoided the term crisis in reference to the energy situation. But the prolonged and severe cold period this last winter and continued delays in start-up of critical facilities has now brought us to a crucial period — the most crucial period perhaps — in our nation's history.

In the days ahead there will be fuel shortages in varying degrees in various sections of the country. It may happen in different ways at different times, but a fuel or energy crisis in one area triggers a reaction that propogates itself very rapidly into other sections of the country. This is how the impact will reach back to New Mexico — a state well endowed with energy raw materials.

These crises were not unexpected nor unpredicted. The peaking of oil and gas production has been forecast for eight to ten years or longer by industry, but we were rudely accused of being self-serving and alarmists and some still insist that the crisis is a fiction promulgated by the oil industry just to get prices up.

I want to illustrate for you some of the facts, forecasts, and problems connected with our energy fuels that we face as a nation. These charts and graphs are based on studies made by Shell Oil Company, and I want to thank them for permission to make use of these data.

There are a number of assumptions on which these forecasts are based which I won't go into, but the underlying problem is, of course, population. There are those who advocate zero population growth as a solution to our problems. I don't know very much about this concept or lack of conception — but zero population growth wouldn't help much even if it could be invoked tomorrow for the big energy users for the next 15 years are already born. They are the ones who are in or will be moving into the 25- to 35-year-old age groups. These are the big energy users. These are the ones for whom the new houses will be built. They will expect those new houses to be lighted, heated, and cooled. They, along with the rest of us, will be requiring transportation to go places and carry on the world's work.

New Mexico is an exporter of energy raw materials. *Neuvo Mexico es un pais muey simpatico y encantadores.* Tourism is a significant item in the state's economy and you hope that some of your exported energy raw materials will be used to bring people to visit this "Land of Enchantment." Petroleum products will be the principal fuel for our transportation for a long time to come, and we can have a look at the energy supply on Figure 1.

It is quite evident that oil and gas are today's mainstays of our energy diet, supplying approximately three-quarters of our requirements. These sources are expected to play — will have to play — a major role for quite some time to come. This is simply because alternative sources of energy will take a long time to develop to the point where they can make an impact on the national scale.

Coal's potential is very large, but the increasing severity of air quality standards, environmental problems associated with strip mining, and mine safety and labor problems will have a deterring effect on how rapidly the use of coal can be expanded.

Nuclear power could develop rapidly, but there are long lead times in construction as well as concerns over safety and pollution. Last week I overheard someone telling about a nuclear power plant in the Northeast that was shut down because its coolant waters were heating up the lake and it was claimed had an effect on the fish population. When the plant was shut down, the fish froze and the plant was made to start up again.

Hydropower has limits because of the availability of sites and is shown to diminish percentage-wise.

Shale oil is shown to begin making a small contribution in a few years, but I'll have more to say on shale later on.

I have not plotted *geothermal* or *solar energy* on this graph for their contribution is hardly discernible on this scale.

Because of the heavy reliance on *oil* and *gas* for the foreseeable future, I plan to talk mostly about those energy sources.

Figure 2 shows that the consumption of natural gas has grown steadily since 1955, but the supply from domestic sources has now peaked and during the next seventeen years it is forecasted to decline at about the same rate that it grew. One of the reasons for this peaking and decline is that exploration has declined steadily since the early 50's and as a consequence so have additions of new reserves. One of the reasons for decline in exploration is that the price of gas has been controlled at such a low figure that there has been little incentive to spend much money in a high-risk business.

Gas imports from Canada have been growing rather modestly and there are some who have the fond expectation that Canada will take care of our petroleum supply problems. They seem to overlook the fact that Canada is a sovereign nation and must first look after its own needs. We have already seen that the amount of oil and gas that will be permitted to be exported from Canada is going to be carefully controlled.

Canadian imports are forecasted to increase, but not in the quantities we'd like to have.

Coal gasification has some technological problems, but there are several projects underway to convert this abundant solid fuel to a gaseous form.

Deals are being made to import *liquified natural gas* from several sources, but this is going to be very expensive and has many logistical problems.

Synthetic gas from oil has fewer technological problems than does coal gasification, but it is more expensive perhaps as much as 50 percent higher. That is why it is shown to increase in the near term as a stopgap measure, then level off. Even if the process were relatively inexpensive, another problem would be the supply of oil. So let's have a look at oil, but before we leave this chart, I'd like to point out that we are going to need all the gas that can be found, manufactured and imported just to stay somewhere near present consumption levels.

Figure 3 shows that the rise and decline of domestic oil production follows a similar pattern to that of gas.

Nevertheless, demand for this product is forecasted to continue to grow and is expected to double by 1980. This forecast is based on the overall projected demand for energy and the fact that substitutes for naturally occurring gas and oil as energy sources will not be developed rapidly enough to pick up that increasing demand.

In the years up through the 50's we were essentially self-sufficient in oil and even exported supplies as late as the two Suez Crises in that decade. But today we are already dependent on foreign imports for between 25 and 30 percent of our requirements.

Oil from the Alaskan North Slope will be of great help, but this graph was prepared before the most recent court order further delaying construction of the Trans-Alaska Pipeline.

Imagine what the chart would have looked like if Prudhoe Bay production had been phased in about now as it might have been — and other prohibitions for lease sales and production had not been delayed in the Gulf of Mexico, the Santa Barbara Channel and elsewhere.

I've already commented on the Canadian gas supply, and there is projected a gradual increase of crude from that source.

Synthetic crude from oil shale, tar sands and coal hydrogenation will begin to make a slight contribution, but it will not be very significant for ten or 15 years.

Since *oil shale* has gotten quite a bit of publicity as a "fantastically rich undeveloped resource," let me expand a bit on that subject.

First, let's get the dimensions of supply in focus. If any source is going to make much of an impact on our national needs it has to be measured in millions of barrels.

Secondly, technology and pilot plant work has shown that the kerogen (or oil) can be satisfactorily extracted from the shale by various retorting methods.

Thirdly, when one scales up to commercial production from the pilot plant stage, economics and availability of acreage come very much into play. These two factors are largely — and have always been — in the hands of the Federal Government.

Now let's pursue the matter of dimension a little further together with some other facts. The richer shale runs around 30 gallons of oil per ton of shale. At 42 gallons per standard barrel this means at least a ton and a half of shale per barrel of oil. Now let's take a medium-size refinery of, say, 100,000 barrels per day. To supply this much crude shale oil and taking into account losses means mining around 200,000 tons of shale per day. This is approaching the tonnage of ore handled at the Bingham Canyon operation near Salt Lake City — the largest open pit mining operation in the country. If the mining is planned as an underground operation, this means something twice the size of our current largest underground mine.

So if oil from shale is to make a contribution to our national supply on the order of a million barrels per day, then multiply the model I've just described by ten.

Some politicians have waxed eloquent about the part oil shale is to play in our energy picture. If so, we need to forget this "give-away" threat, this "Teapot Dome Syndrome" and see that incentives for development are quickly forthcoming. Among the incentives I would suggest would be availability of leases at favorable terms, reasonable environmental safeguards, and other economic incentives such as price improvement and tax preferences.

A particularly important aspect would be to encourage insitu experimentation. Of help in this connection would be making test tracts available along with appropriate economic inducements.

The obvious and sobering fact is that in the near term of 15 to 20 years we must depend on *foreign imports* in growing amounts for oil supplies — with all that is implied by dependence on such sources for a commodity so vital to our national strength.

But let's assume for the moment that there is no problem at the source for foreign supplies and look ahead only seven years to 1980 and see what our situation is forecasted to be.

If we make the further assumption that U. S. production plus Canadian supply can bring us back to, or maintain, our 1973 level, then we would need an overseas import volume of about 12 million barrels per day.

Getting it here and putting the crude oil in a consumable form is yet another problem of tremendous and serious proportions.

(Figure 4.) A fleet of very large crude carriers will be needed. If they could carry 11/2 million barrels each, we would need 325. This is equivalent to the entire world's tanker fleet of only six years ago.

Ships of this size require deep-water ports of which we have none in the U. S. at present.

According to the logistics, approximately six tankers per day will have to arrive and since they can't unload in one day, 25 receiving berths at strategically located deep-water ports will be needed.

Only one new refinery has been completed in recent years. We will need 58 new refineries with an average daily capacity of 160,000 barrels to process the increased crude imports.

Pipelines and other transportation to move the products from these refineries will have to be doubled.

The capital requirements for these facilities plus an increased domestic exploration and production effort is estimated to require some $150 billion dollars — double the expenditure of the 60's.

(Figure 5.) A terribly important thing not realized well enough is that it takes time to do these things that I've just mentioned.

Exploration and development takes on the average five years from initiation of a program to when substantial production can be achieved — it can take a great deal longer if environmental problems arise. It borders on a national disgrace that our exploration technical capability today is absolutely superb, yet we are at an activity level comparable to 30 years ago.

It takes at least three years to obtain a plant site today. It strikes me as a curious civic conscience when certain sections of the country want their share of the energy, but they want the terminals, plants and refineries in someone else's backyard.

All of these functions and facilities take time to plan, engineer, and install — in whosoever's backyard they are done. The responsible public must come to understand that cease, desist and ban are not solutions for the problems where energy and the environment seem to be in conflict. It isn't an either/or proposition, society has already decided that it wants both.

As overwhelming as the problems may be once the oil is on top of the ground, let's go back to the assumption we made a bit ago that the supply of foreign oil for import would be available in the quantities we wished. In the real world there are other energy deficient and emerging nations that will be competing for this supply wherever it may be, so let's have a look at the rest of the world's appetite for energy.

In Figure 6 all energy forms have been converted on a BTU basis to crude oil equivalents. The number of barrels is not as important as the number of "feet in the trough."

In 1970 the U. S. used about 32 percent of the world's energy. By 1980 the world's energy consumption will have almost doubled. The U. S. is forecast to be using only 28 percent by that time — not because we will be requiring less, but because the rest of the world will be using more. You may recognize that some of these countries such as Japan may be more desperate than we for energy fuels, for they do not have a domestic resource base such as we have.

It is well known by now that the Middle East contains about 70 percent of the free world's oil reserves, so let's have a look at the world oil movements as visualized for 1980.

(Figure 7.) Don't become concerned with the bar graphs or the numbers along side the arrows, but just be aware that the width of the arrows represent fairly quantitatively the volumes of oil movements. The location of the center of gravity of oil supply is pretty obvious.

Today the U. S. is importing only about 600,000 barrels per day from the Middle East — that's about the amount produced by the State of Wyoming. By 1980 it is forecasted that we will be importing over ten times that much or some 6 1/2 million barrels from Middle East sources—or a little over half our total overseas imports projected for that time.

The amount shown emanating from the Middle East is almost 34 million barrels per day. In spite of the faddish popular tune played by some political pied pipers — known as "all that cheap foreign oil" — you can be assured that nobody is giving it away. So imagine, if you will, money backflowing along the red lines. The Middle East is not only a fabulous "pool of oil," but it is going to be a "fabulous pool of money" as well.

Whatever happens in the Middle East and elsewhere in the world of oil is of more than "spectator interest" to US.

There are several obvious and compelling *conclusions* that come from what I have discussed.

1) One of the most pressing needs has been for a firm and constructive new National Energy Policy. There were some very good things in the President's energy message of April 18. Our national goals must be better defined by the Congress and they should reflect a balance between energy needs and reasonable and attainable environmental protection. It must be realized that many of our environmental goals will require more energy, not less. I'm somewhat disappointed that the message was not more specifically encouraging to our domestic petroleum exploration, and a bit surprised that he didn't give the utilization of coal a bigger boost.

I'd like to comment a bit on areas of research by industry and Government.

2) Cooperative research between industry and Government can be very helpful in several areas. Let me assert, however, that "Government" does not have a research capability superior to the total effect of the "competitive research" of industry. I've heard the suggestion that we should have a massive government effort on energy as we did in the space program.

The space program had to start from scratch, but we have a petroleum industry and a coal industry already in being today that has a tremendous capability in technological talent, know how, business experience, and in spite of some efforts to paint a picture to the contrary a social conscience and civic responsibility.

Intensified governmental research is very much in order particularly on the alternative sources — solar, nuclear fusion, coal gasification, magneto hydrodynamics, etc., but any such research — by government, institutions or industry, or a combination of all three — takes time, often an unpredictable time, for the results to be realized. Then following any successful research must come commercial application at a scale to make a significant contribution to the national need.

Meanwhile, there are compelling energy needs today, next year and for the uncertain number of years that must be dealt with.

In this meantime, we are going to have to be increasingly dependent on foreign imports.

3) This calls for an enlightened foreign policy that recognizes and deals with the implications of not only ours but the world's energy situation. We must recognize the bitter truth that this nation is in the unaccustomed and awkward posture where they and not we dominate the world of oil. An Arab friend of mine once told me "You need our oil worse than we need your dollars; we came out of the desert; we know how to live off the desert; we could go back, but you can't go back."

4) The power of public opinion is going to have a great influence on what happens in government at the federal, state, and local levels, as they deal with the problems of energy and the environment. There are "frontiers of leadership" for legislators, government officials, educators, information media, and scientists and technologists. We all have a vital stake — you and I, our children, labor, the environmentalists, the disadvantaged, all of us.

A symposium such as yours which brings together such a variety of natural resource professionals is indeed impressive and heartening.

Energy problems and environmental problems each require multi-disciplinary attacks. Where energy and the environment interface — and they seem to inevitably do the multi-disciplinary cooperation is an absolute must. Everyone loses in a stalemate. Emotionalism, intransigence, and plain bullheadedness are not scientific and technological methods. I think our energy and environmental problems call for the "best effort" of every scientist, lay leader and politician in the country. But I'd like to leave you with the question: *How important do you think is the national origin of the oil we burn?*

Figures 1-7 follow on pages 14 & 15

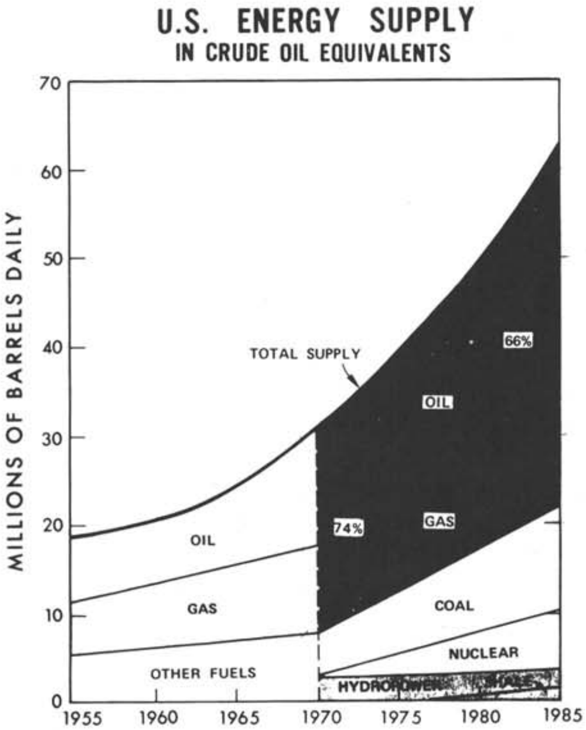


FIGURE 1

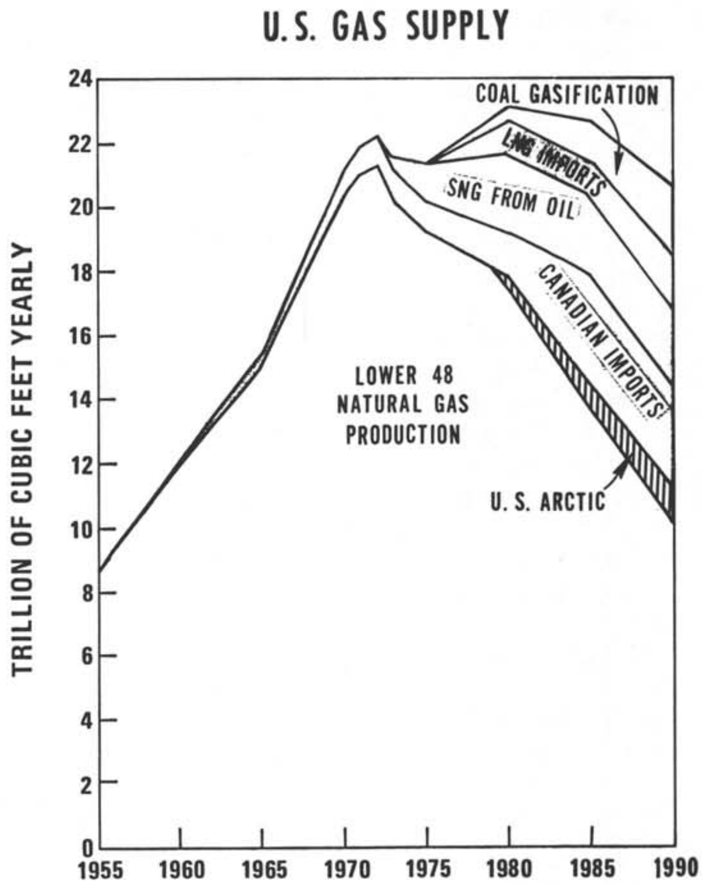
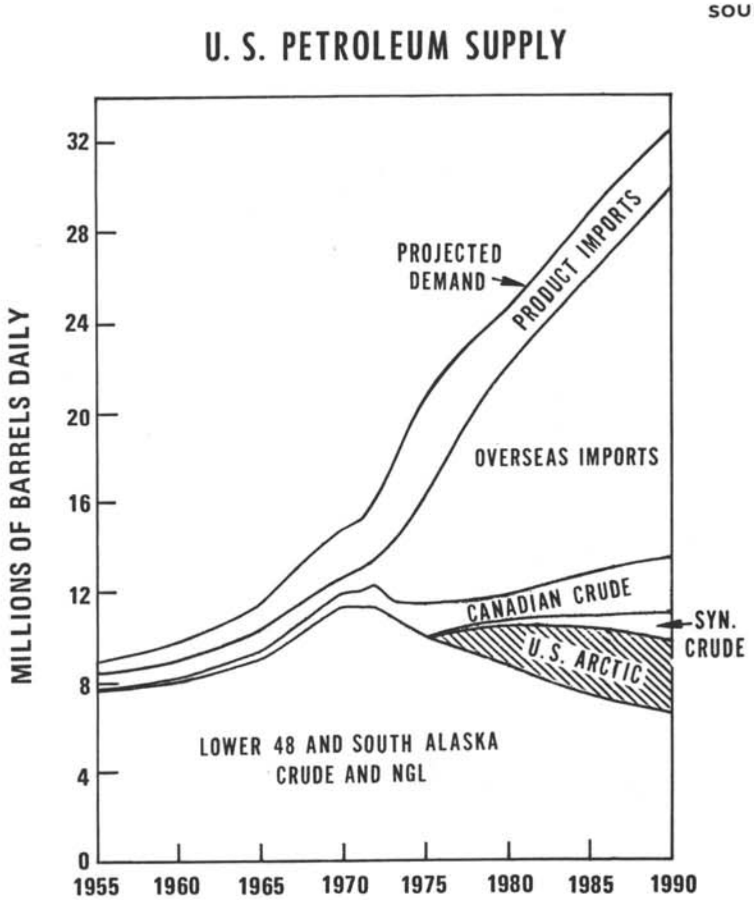


FIGURE 2

SOURCE: SHELL OIL CO.

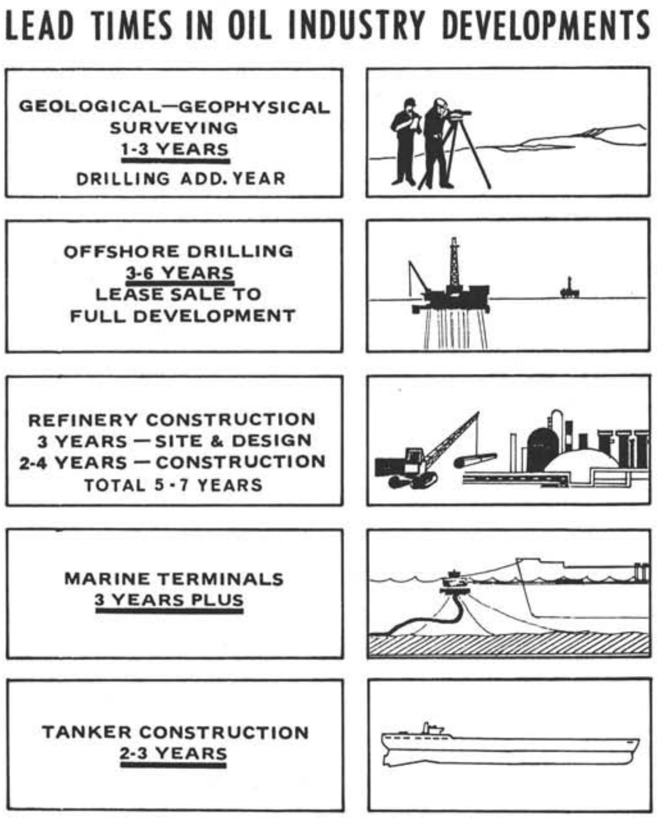


SOURCE: SHELL OIL CO.

FIGURE 3

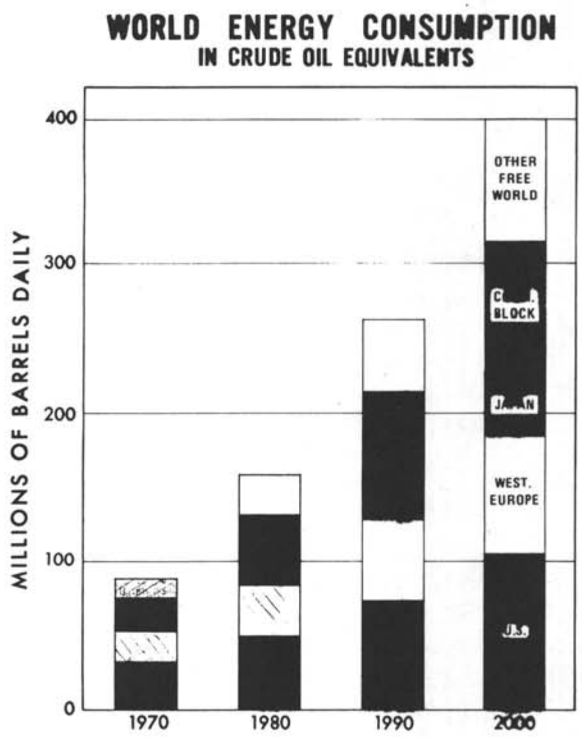
— NEEDED — BY 1980	
325 SUPER-TANKERS (1½ MIL. B)	EQUIV. TO ENTIRE WORLD TANKER FLEET 1967
25 BERTHS (6 ARR. PER DAY)	NO U.S. PORT CAPABLE HANDLE
58 NEW RFY. (AVG. 160,000 B/D)	TODAY 262 RFY. AVG. CAP. 49,000 B/D
PRODUCT PIPELINE MOVEMENTS — DOUBLED	
CAP. REQ. — $150 BILLION	2 X EXPEND. FOR 60'S

FIGURE 4



SOURCE: SHELL OIL CO.

FIGURE 6



SOURCE: SHELL OIL CO.

FIGURE 5

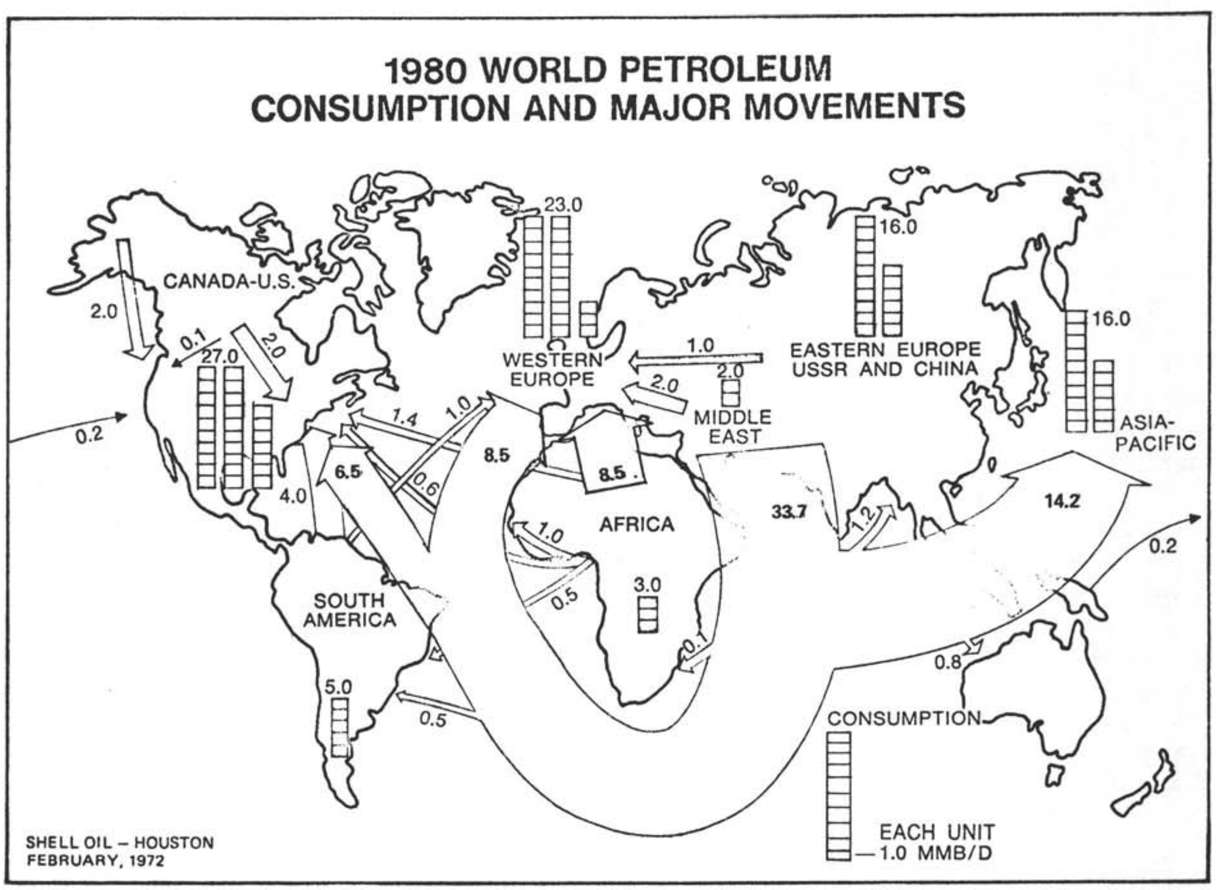


FIGURE 7

VEGETATION AND THE ENERGY CRISIS

Donald A. Jameson
Colorado State University

Most of the alarm about energy concerns the declining supplies of non-renewable energy. By definition, the availability of non-renewable resources must be diminishing (Figure 1). Technological advances can reduce the rate of decline, but basically nothing can be done to overcome the eventual problem.

In contrast, renewable resources are continuously being replenished. Although there may be short run declines during periods of heavy utilization, there is also a constant resupply; the resupply will result in an increased amount on hand if the utilization rate is sufficiently reduced. It is this area that we can classify such resources as water power and vegetation.

A subset of renewable resources is that which is renewed at a constant rate regardless of utilization. Solar energy for our purposes is a constant rate resource as it cannot be stored (in solar form at least) and nothing in our actions of utilization will significantly influence the supply.

Some renewable resources are biological in nature and some are non-biological. Non-biological resources will recover during periods of lesser utilization, rapidly at first, then at a decreasing rate. Water is an example of a non-biological renewable resource (Figure 2).

A biological renewable resource has a slightly different recovery pattern because the rate of recovery depends on the amount of biological material. In these cases the initial recovery rate is low, a maximum rate occurs later, and as the recovery rate approaches zero as a maximum amount of material is accumulated. This is the basic sigmoid growth curve of biology.

The sigmoid curve of plant responses results from an integration over time of photosynthesis (an addition process) and respiration (a process of subtraction). With low amounts of plant material photosynthesis may exceed respiration (Figure 3) and net plant growth results. Eventually, however, photosynthesis becomes limited by some limiting factor such as light. Thus respiration eventually becomes as great as photosynthesis, and zero net growth results.

By referencing the photosynthesis curve to the respiration line of figure 3, we obtain a parabola of net growth (Figure 4). Maximum plant material occurs at the point of zero growth, and maximum growth of necessity must occur at something less than maximum amount of plant material. Thus maintenance of maximum plant material, such as in a wilderness area, cannot be efficient in energy capture.

In cultivated systems this natural growth parabola is elevated upward by additional inputs (Figure 5). These inputs are often considered to be water and fertilizers, but very appreciable inputs of energy in the form of petroleum has long been used in agriculture of developed countries.

In an economic system the amount of each input is determined by its cost relative to output (Figure 6). The greatest output/input occurs where the graph of the relationship is the steepest; if an input is worth using at all it will be used at least in this amount. A greater input may also be used, depending on the benefits and costs, but in no case does it make any economic sense to exceed the point of maximum production.

If an input is being used at the point of maximum rate of return, and the prices of the input is then decreased, the amount of input used will be increased. Conversely, if an input is being used at a level near maximum production, and the price of the input is increased, less will be used.

If the price of petroleum for example, is increased, the amount used in agricultural production will be decreased. Total agricultural production must therefore be decreased, and the price of agricultural products will increase.

Of course it is possible that other factors will also be involved. Instead of reducing total agricultural production, there may merely be a shift away from less efficient users of the petroleum to more efficient users.

There is particularly an opportunity to save as is pointed out by the elementary behavior of a ecological system (Figure 7). Each feeding or "trophic" level of the system retains about 10 percent of the energy on which it feeds. Thus crops fed to animals are only about 10 percent as effective in terms of human nutrition as crops fed directly to humans. Beans rather than beef thus becomes economically more attractive. In the long run the only plant material which will continue to be fed to animals rather than directly to humans is that which is not suitable for human use; particularly this includes cellulose which is not digestible by human, but is broken down by ruminant animals such as cattle and sheep.

With continuing cost increases of energy inputs into agriculture, grazing of lands not suitable for cultivation becomes particularly desirable since it is the only widespread form of agriculture in developed countries which has a net gain in energy, i.e. there is more energy trapped in the production process than is used (Figure 8). This net gain is later reduced by transportation and processing costs, but other intensive advanced cultivation has, at the outset, a very significant net loss of energy. Estimates of cultivated crops as an energy trapping system range from 5 to 20 percent efficiency. Combining this already inefficient system with the 10 to 1 trophic level handicap discussed earlier leaves us with only one-half to two percent efficiency for a cultivated crop-feed lot combination.

These same considerations are also apparent in many other situations where a high energy using synthetic has replaced a natural product. For example, aluminum building material uses many times as much energy as wood, synthetic fibers use much more energy than cotton, etc.

Thus a shortage of energy gives a strong economic advantage to renewable resources in comparison to the strong disadvantage of the past several years. Not only do beans appear relatively more desirable than beef, but woods begins to look better than aluminum, and cotton better than nylon.

Another significant change, which relates back to figure 4, is that use of renewable resources begins to have very significant advantages over nonuse such as occur in wilderness areas. Vegetation used for man, as the most efficient energy system we have, will be an increasingly valuable asset.

Figures 1-8 follow on pages 18 & 19

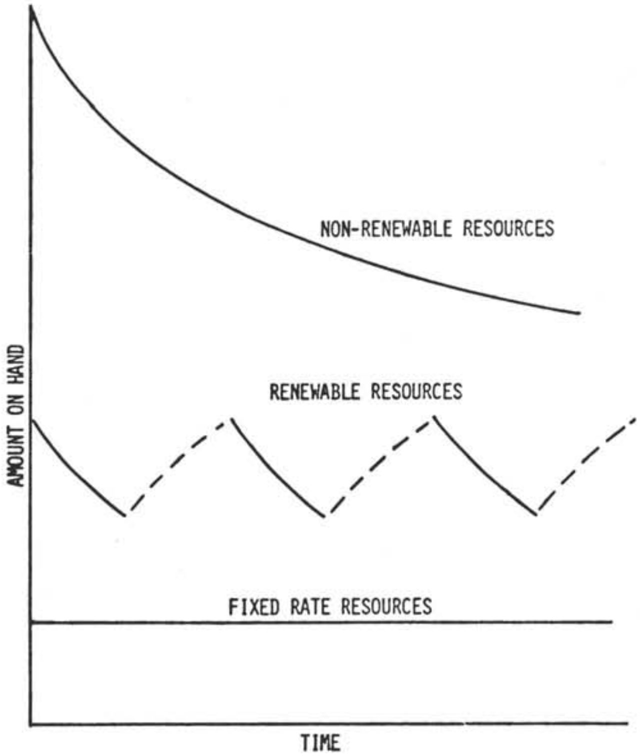


Figure 1 – Amount of renewable and non-renewable resources as a function of time.

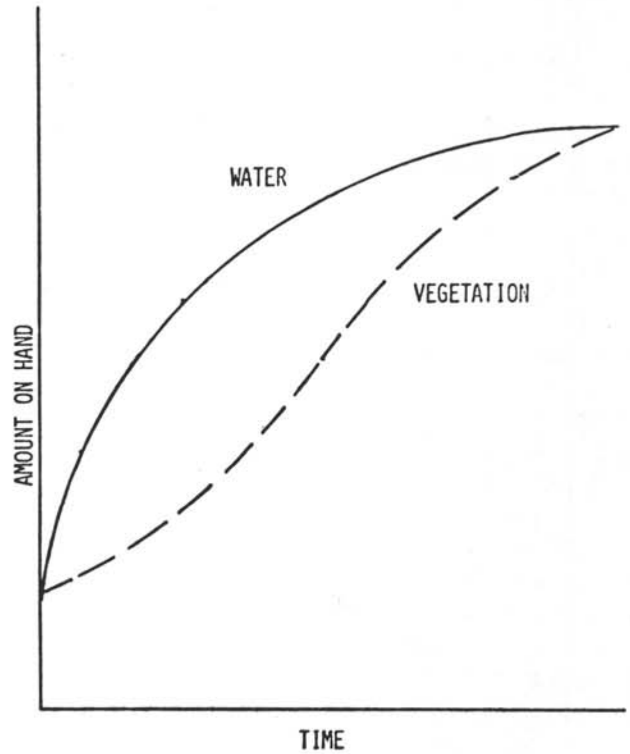


Figure 2 – Response rates of non-biological (water) and biological (vegetation) renewable resources.

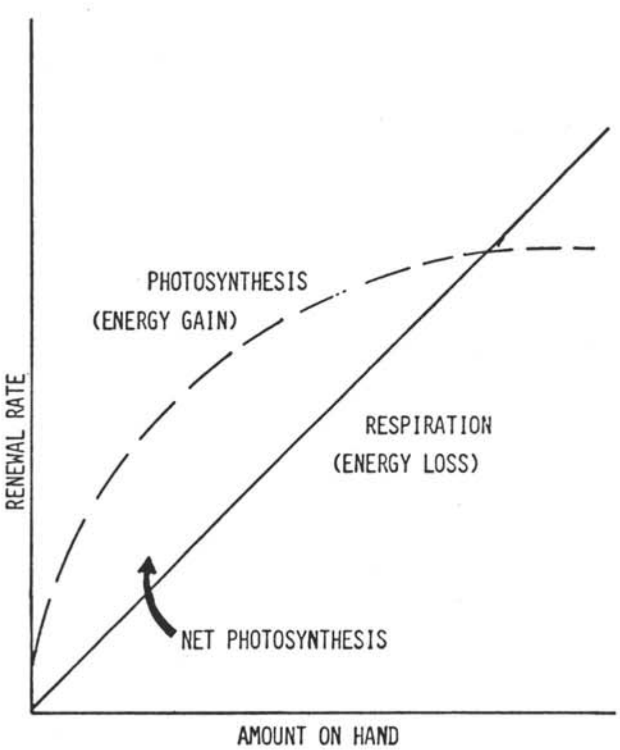


Figure 3 – Relationship of photosynthesis and respiration.

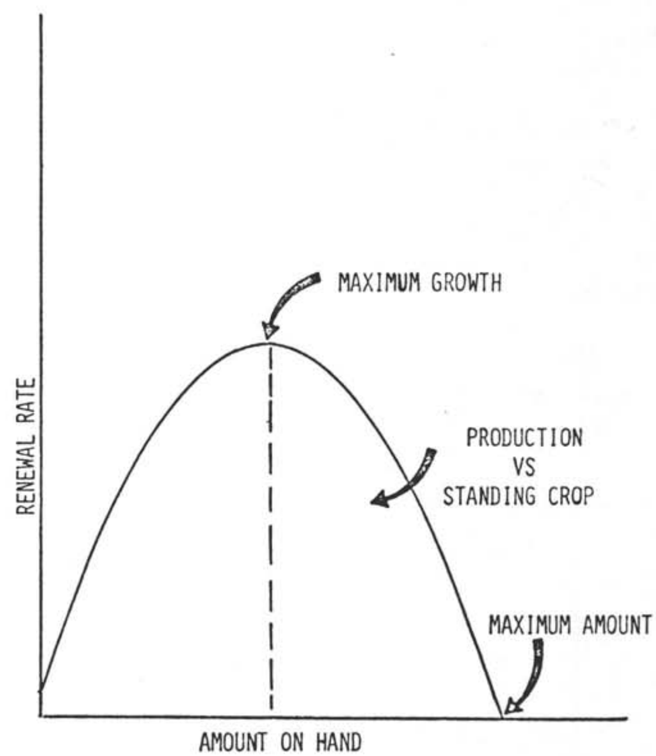


Figure 4 – Relation of production to standing crop.

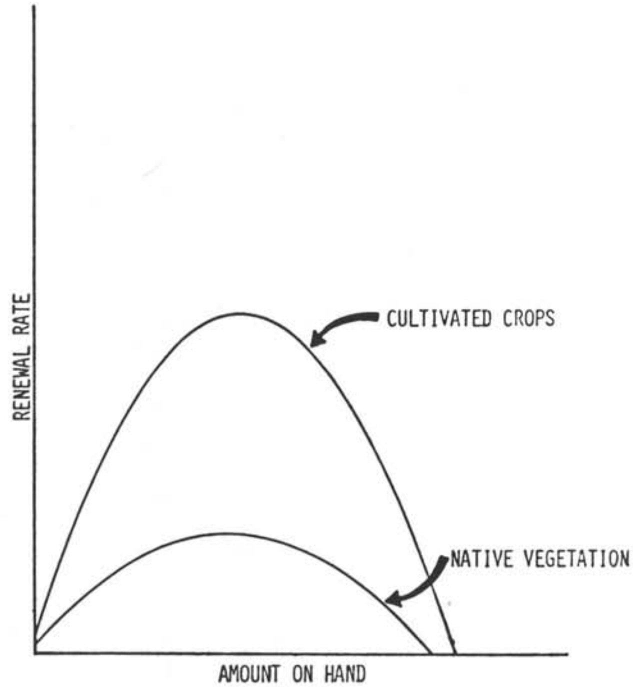


Figure 5 – Renewal rates of cultivated and native vegetation.

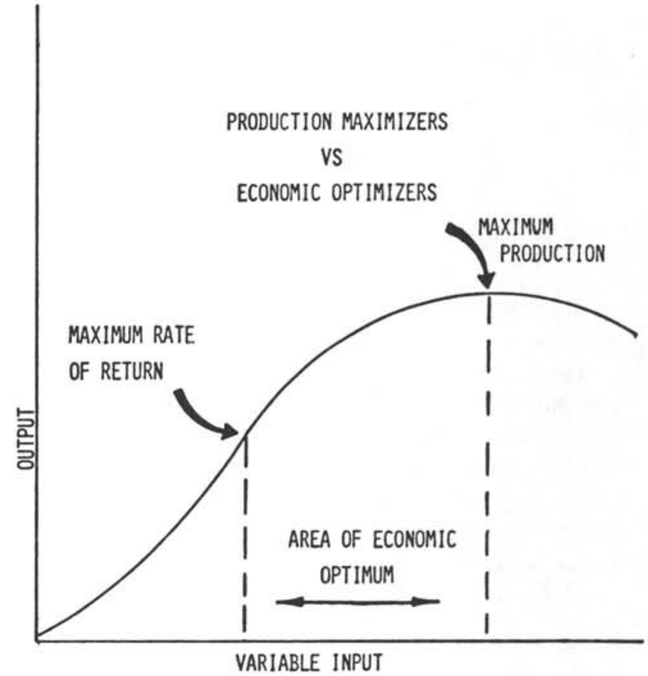


Figure 6 – Optimal output in relation to input.

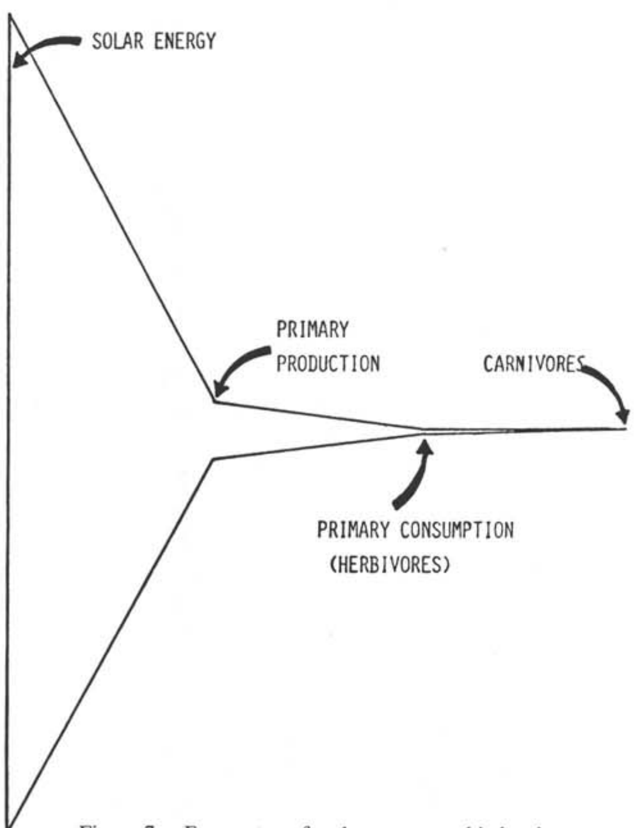


Figure 7 – Energy transfers between trophic levels.

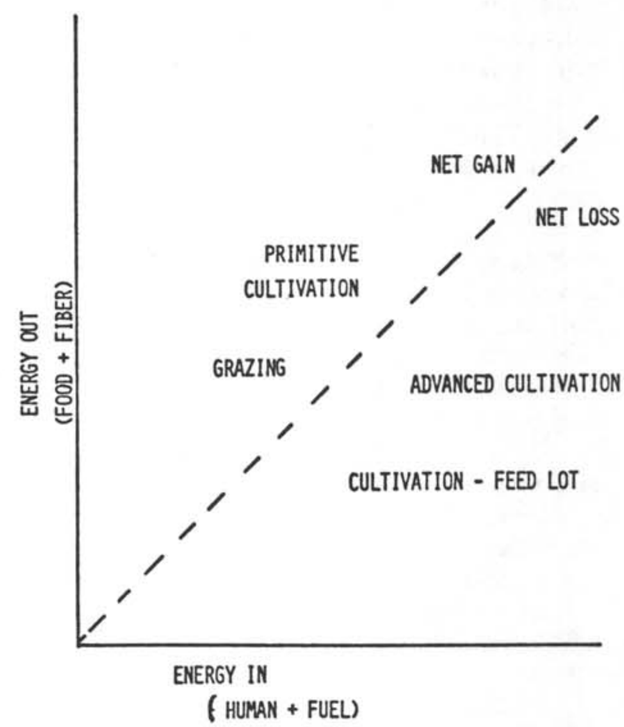


Figure 8 – Energy efficiency of various agricultural practices.

COAL, THE ENERGY CRISIS, AND NEW MEXICO

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New Mexico Bureau of Mines & Mineral Resources
in cooperation with
U.S. Bureau of Mines

The first requisite for an understanding of the position of coal in the energy budget of the next few years, and decades, is to know what needs have been projected on a national and regional basis. As is well known, such projections are subject to great errors, and must be considered with a good deal of skepticism, but let's examine some of them.

On a national level, estimates of energy consumption have been made by the Interior Department, the National Petroleum Council, Chase-Manhattan Bank, the Federal Power Commission, and many others. Just for a general look at this matter, let's take the Interior Department's breakdown published in early 1973 (fig. 1). For 1971, in terms of British thermal units consumed, oil represented 44%, natural gas represented 33%, coal 18%, and hydroelectric and nuclear power amounted to something under 5%. In 1985, by contrast, nuclear power is expected to supply some 10% of the total energy consumption, oil about 44%, gas 23%, coal 18%, and hydroelectric power about 4%. It is important to note of course, that we will have, according to this particular projection, about 1.7 times the total 1971 consumption of energy. Coal consumption, while holding steady in percentage terms, would rise about 70% in terms of actual energy required. It's worth noting that these new figures fall considerably below previous Interior Department projections. Nineteen eighty-five is only 12 years away. The real takeover of the energy market by nuclear power is not likely to be until sometime toward the end of the century. Thus, energy demand is likely to be borne largely by fossil fuels for a long time to come. These latest Interior Department figures indicate coal consumption in 2000 A.D. of about 2.5 times the 1971 level, and overall energy consumption about 2.8 times that of 1971.

Some recent work by a group at Cornell (Chapman and others, 1972) indicates that most of the published projections are too high. This work suggests that demand for electricity, at least, will about double by 1985 (instead of 1980 as projected by the Federal Power Commission), and that it will increase to about 3 times 1971 demand by the end of the century. This is far less than FPC's estimate, which would have demand at almost 4 times the 1971 level shortly after 1990, and somewhat less than the new Interior Department guesses.

These rather encouraging projections are based on the notion that scarcity will engender higher prices and thus curb demand, rather than upon the usual extension, ad infinitum, of population and per capita demand trends. As I see it, however, the availability of coal will cause a tendency to favor it over imported oil and gas. Thus, the point is that even if the energy crisis is not as serious as is generally thought, the demand for coal may well fulfill the predictions.

The Western Energy Supply and Transmission Associates, known as the WEST Group, which is a 22-member association of southwestern and California utilities, has done some prognosticating on a regional level. They see the need for coal, for electricity generation only in our fast-growing region, as rising 3.8 times between the 1970 level and 1980. By 1990, they forecast a need for 98,500 tons per year, or 6.4 times the 1970 level. Apparently the Golden West is going to need proportionally much more energy--and coal--than the nation as a whole.

Now, more specifically, where does New Mexico fit into the market picture? Figure 2 shows the general distribution of coal resources, both strippable and deep, in light shading, and the country's major population centers as circles proportioned to population. At first glance several things seem obvious: (1) the heavily-populated east has plenty of coal of its own, (2) the population centers of the west have coal resources somewhat closer than ours to draw upon, (3) any demand in the extreme northwest can be met most easily by the great reserves in Wyoming, Montana, and North Dakota. There is more to this than meets the eye, however. For one thing, eastern coal is at a disadvantage because of high sulfur content and increasing pressure there against strip mining. It is true that the fast-growing southwest has plenty of Arizona and Utah coal, but Arizona's Black Mesa coals are beginning to be heavily committed already, and Utah's coal is nearly all too deep to be strippable and therefore at some economic disadvantage. Montana coal is under very heavy tax and environmental pressure.

The real clincher is evident on a natural gas pipeline map (fig. 3). Synthetic gas made from coal in northwestern New Mexico can go into the present system with the greatest of ease, particularly to serve west coast markets. This is because the coal lies, for the most part, right in the nation's second largest gas field.

It is worth noting that our gas production is beginning to slip and synthetic gas is going to take up the slack and carry on.

What does New Mexico have to offer in this market situation? Figure 4 shows all of the known areas of strippable coal, in dark shading, and the areas known to be underlain by coal, but at a depth too great for strip mining. These "deep coal" areas are shown in light shading. Except for minor, mostly insignificant, reserves scattered here and there, the coal lies in the San Juan Basin within the Albuquerque-Gallup-Farmington triangle, and in the Raton Basin south and west of Raton. Before I start to describe these reserves in terms of tonnage and mineability, I should say a few things about what size reserve is really economic and what constitutes economically mineable coal.

For a major power plant, something on the order of 75 million tons of coal is a threshold reserve size. This must be in reasonably continuous seams under less than 150 feet or so of overburden, and the coal must be thick enough so that the ratio of overburden thickness to coal thickness averages considerably less than 10.

Under foreseeable economics here in New Mexico, strip-mined coal is the only kind we can develop for generating electricity or making gas.

So with the 75-million ton figure and the strippability requirement in mind, let's look at the map. The Tijeras field, designated A on the map, and the Sierra Blanca, Una del Gato, Cerrillos, Carthage, Jornada, Datil Mountain, and Engle fields, all the way down to H, have been estimated to contain some 1,750 million tons altogether. Of this, only 841 million are thought to lie above 1000 feet in depth (a rule-of-thumb limit for deep mining). Nowhere is a 75-million ton strippable reserve known.

The Raton Basin, designated I on the map, contains an inferred 4,700 million tons--say 4.7 billion tons of coal. That would seem to be a lot of coal, but only 2.5 billion tons are thought to be less than 1000 feet deep, and only about 715 million are economically accessible. This coal is a special case in the energy picture because it is suitable for steel-making. That fact makes it feasible to mine underground rather than by stripping. In fact, the Raton Basin coals are too valuable to be used for electricity generation or the manufacture of synthetic gas. They are the only such coals in any important quantity in the state. Kaiser Steel Company's York Mine is the only active mine in the Raton Basin. It is a very efficient modern underground operation, and in 1971 produced just over 1 million tons of metallurgical coal. The coal is shipped by Santa Fe Railway unit train to Kaiser's Fontana, California steel mill.

We are now left with the San Juan Basin (fig. 5). The geologic formations that comprise it may be thought of as a stack of shallow, very irregular bowls whose rims are turned up sharply in some areas, but slope only very gently in others. The northern part of the Basin is across the line in Colorado, not shown on the map. Two of the bowls are coal-bearing formations: the lower bowl, represented by the outer band is the outcrop of the Menefee Formation, and the upper, inner one is the Fruitland Formation.

That outer band is shown in dark shading in areas known to be underlain by strippable Menefee coal, and is shown as light shading where a favorable part of the formation is shallow enough to contain strippable coal but has not been explored. The Menefee has not been extensively explored, but it is known to contain several large areas of thick coal at depth, and some extensive barren areas. Some of the strippable areas are of economic size. These will be described briefly below; more extensive descriptions can be found in Shomaker and others, 1971.

The principal undeveloped area lies north and northeast of Grants, and is owned in large part by a subsidiary of Santa Fe Industries. The area is presently under exploration. A reserve estimate made by the State Bureau of Mines in 1971 of 60 to 75 million tons is almost certainly far too low. West of it, near Standing Rock on the Navajo Reservation, drill holes revealed more strippable coal. This area was estimated to contain at least 64 million tons, and probably far more. The coal in these areas is mostly of high-volatile bituminous C rank and contains 0.5 to 1.1 percent sulfur.

Small strippable reserves are also known just south of Cuba, near Lake Valley south of Bisti Trading Post, and near Newcomb, north of Gallup. None of these appear to be economic; only the last-mentioned appears to contain more than 75 million tons.

The only important production from the Menefee (and the related Crevasse Canyon Formation) is from two strippable areas near Gallup. Northwest of Gallup, partly on the Navajo Reservation is a block estimated to contain 358 million tons or more of strippable coal. A much smaller reserve is known just southeast of Gallup. The coals of these areas are also of high-volatile C bituminous rank, with sulfur content around 0.5 percent.

The Menefee Formation has also been estimated to contain on the order of 34.3 billion tons of deep coal; current work being done by the State Bureau of Mines indicates that this figure is low.

It is the Fruitland Formation that contains our really major coal reserves. On fig. 5, the inner band represents the Fruitland. Strippable areas are in dark shading. Within the outer edge of the band, the entire area is underlain by both deep Fruitland and deep Menefee coal. Along the west side as far as the Navajo Reservation boundary (indicated by a heavy broken line), strippable reserves have been well-explored, and are under lease and committed to various development plans. These plans will be discussed further on.

From the Colorado line southward to the Navajo boundary, there is a total of some 1.1 billion tons beneath less than 150 feet of overburden, and another

1.4 billion from 150 feet down to 250. Most of this is on the Navajo Reservation.

From the Navajo Reservation eastward, there is another 1.3 billion or more tons above 150 feet and 1.2 billion more between 150 and 250. Most of this is under lease or prospecting permit from the Federal Government, and has been fairly extensively explored. Beyond a depth of 250 feet, the Fruitland contains a staggering amount of coal. An estimate by Fassett and Hinds (1971) of the U.S. Geological Survey indicates a total of some 154.2 billion tons.

It's apparent that only a tiny fraction, in fact about 1.5 percent, of our state's total coal reserve is currently strippable. I have described a total of about 2.9 billion tons which can be considered strippable to a depth of 150 feet, and a grand total of some 188.5 billion tons that is not strippable.

The Fruitland Formation coal is of high-volatile C bituminous or subbituminous A rank-good steam coal, but not suitable for metallurgical use.

Just to get things in perspective, let's have a glance at the comparative position of coal among New Mexico's energy resources. We have some 6 billion tons of coal considered strippable by either present standards or those expected to prevail in a few years. We have about 137,000 tons of U_3O_8 (mineable at 8 dollars per ton of ore), and we have an estimated one and one-quarter billion barrels of oil. Natural gas is estimated at 14.3 trillion cubic feet (fig. 6). These are known reserves, more or less economically workable; the numbers on the chart indicate the number of British thermal units available and the bars are proportioned in terms of British thermal units. Strippable coal makes up almost 60%. A key point here is that the Btu value assigned for uranium assumes use in a present-day light water reactor--if saved until breeder reactor technology reaches economic feasibility, this uranium reserve would represent well over 100 times as much energy, and strippable coal, oil, and gas reserves would pale into insignificance by comparison.

But we are dealing now with today's problems and technology, and those of just a few years hence. By current yardsticks, New Mexico's 6 billion tons of strippable coal represents 34% more energy than the total production of crude oil in the whole world during 1971.

Figure 7, a map of the San Juan Basin and surrounding areas, shows existing and planned coal developments. Triangles are strip mines, boxes are power plants, and circles are gasification plants. Dark shading represents existing developments or those under construction, unshaded symbols represent developments in the late planning stages, and light shading indicates developments that I am speculating on. All of the latter are mines rather than plants of some sort; this is because of uncertainty about the water needs of future gasification plants in view of the meager amounts of water available.

The two dark squares just west of Farmington are the Four Corners power plant south of the river and the San Juan generating station north of the river. The Four Corners plant is owned by a consortium including Arizona Public Service Co., Southern California Edison Co., El Paso Electric Co., Tucson Gas and Electric, the Salt River Project, and New Mexico Public Service Co.

This plant is capable of generating 2,085 megawatts, and is now using almost seven million tons of coal per year. Coal is supplied by the Navajo Mine of Utah International. This was the largest coal mine in the United States in 1971 and 1972. The combined payroll of mine and power plant is about 4.5 million dollars, much of it to members of the Navajo Tribe.

The San Juan station, which belongs to Public Service of New Mexico and Tucson Gas and Electric, will have an ultimate capacity of 1,035 megawatts. Coal will be furnished from a mine at the plant owned by Western Coal Co. and operated by Utah International.

The McKinley Mine, of Pittsburg and Midway Coal Mining Co. is located northwest of Gallup. It is partly on the Navajo Reservation and partly off. Its production--421,000 tons in 1971--is shipped by rail to the Arizona Public Service Co. Cholla Plant at Joseph City. The McKinley Mine is planning a major expansion.

The two gasification complexes in the planning stages are close together on the Navajo Reservation. One is being planned by El Paso Natural Gas Co. near Bisti; if all goes well it will ultimately produce 750 million cubic feet of pipeline-quality gas per day from some 73,000 tons of coal. The coal will be mined at the site. It is estimated that the complex will eventually employ 2,000 to 3,000 people with a combined payroll of over 35 million dollars per year. In addition, well over 5 million dollars will go to the Navajo Tribe in the form of royalties and other payments.

The other gasification complex will have an ultimate capacity of 1000 million cubic feet per day. It will be owned by a group including Utah International, Pacific Lighting System, and Texas Eastern Gas, and will require over 100,000 tons of coal per day. Employment in both mines and plants is expected to total some 3500 people, about 50 million dollars per year. Royalties should be over six million dollars yearly.

In the next decade coal production on the Reservation alone should reach over 70 million tons, a gross value of perhaps 200 million dollars; this will represent several thousand good jobs, and some 18 million dollars in royalty payments. I would point out that the land involved in the strip mines is not highly productive at present; it is not likely to be worth very many dollars per acre as it stands now. On the other hand, at a royalty rate of 25 cents per ton, each acre from which a 10-foot-thick seam can be recovered will represent well over 3,000 dollars in royalty payment.

The light triangles on fig. 7, all on Federal acreage outside the Reservation, represent my guesses as to where new strip mines will be located. Coal from these mines would either be shipped out of the Basin by rail, or possibly by slurry pipeline, or be utilized in air-cooled electrical generating plants. There is no foreseeable source of water on a scale suitable for conventional gasification or electrical generation. At least one proposed railroad--one which would serve the coal areas of the Reservation from a connection at Gallup, has been announced. Rail connection to the eastern part of the Basin (where the light-shaded triangles are) has been a subject of speculation for several years.

The developments and potential developments I have discussed so far represent a contribution of at least 1000 trillion Btu per year to the energy budget by 1985 or so. This is an awesome figure--and it amounts to about 1 percent of the nation's projected energy consumption for that year. Let me enumerate some of the changes we can expect to see in New Mexico as a result of all this:

The most obvious transformation will be the enormous increase in activity in northwestern New Mexico. There will be heavy construction activity for a number of years and several thousand new permanent jobs. There will be paved roads crossing the San Juan Basin from several directions, and modern towns where virtually nothing existed before.

The change in the appearance of strip-mined land will seem profound at first. Much of the mineable area looks about like the area shown in fig. 8 in terms of productivity. If we make a conservative assumption of 10 feet as the average coal thickness, then an extreme total of 340,000 acres may be mineable under the economics of a few years hence. This overall total amounts to 4 tenths of one percent of the state's land area. If we eventually manage to reach an annual production of 100 million tons, we will be opening 5,600 acres or less per year, and for a little while it will look considerably different, more or less like fig. 9. The area stripped per year would be less than 7 thousandths of one percent of the state's area, equivalent to 230 miles or so of interstate highway right-of-way with no sprawling interchanges at all. The big difference between interstate highways and strip mines is that the former are permanent scars, while the latter are temporary. Within a few years the land will be back in use for grazing, and it may be better for that purpose than before. The new contour can be such as to provide better drainage, and there can be an opportunity for well-chosen vegetation to get a good grip, undisturbed by animals and erosion. This reclamation will cost the consumer perhaps 2000 dollars per acre, but I'm sure it can be done satisfactorily.

By the time the reclaimed acre has been returned to grazing, it will have yielded no less than 44,000 dollars worth of coal. There aren't many acres in Albuquerque that are worth that. The whole 5600 acres mined that year will have yielded at least 248 million dollars worth of coal. That turns out to be somewhat more than the total statewide cash receipts from all livestock and livestock products in 1968, just for comparison.

To put the comparison another way, the total acreage temporarily out of use after mining at the 100-million-ton-per-year rate would be roughly the same as the area totally and almost irrevocably lost by the filling of Navajo Reservoir.

"Acid mine drainage" is a familiar phrase nowadays, and it's a genuine problem in the eastern part of the U.S. In our part of the country, however, it is not likely to be. Except for infrequent rains, our strip mines are dry. If, as I expect, most of the energy derived from coal is shipped as pipeline gas or raw coal, there will be few new electrical transmission lines to argue over.

There are two other major points in this matter. One is that coal production for energy needs will be temporary--it can taper off and eventually stop whenever breeder reactor technology can take over the load. The other point is that at that time we'll still have a great deal of coal left. New Mexico won't have used much, if any, of its deep coal, and I'm betting we'll have much of our strippable coal left. The box score in the year 2020 may be: remaining deep coal--188.5 billion tons; remaining strippable coal--2 billion tons; permanently damaged acreage--next to zero.

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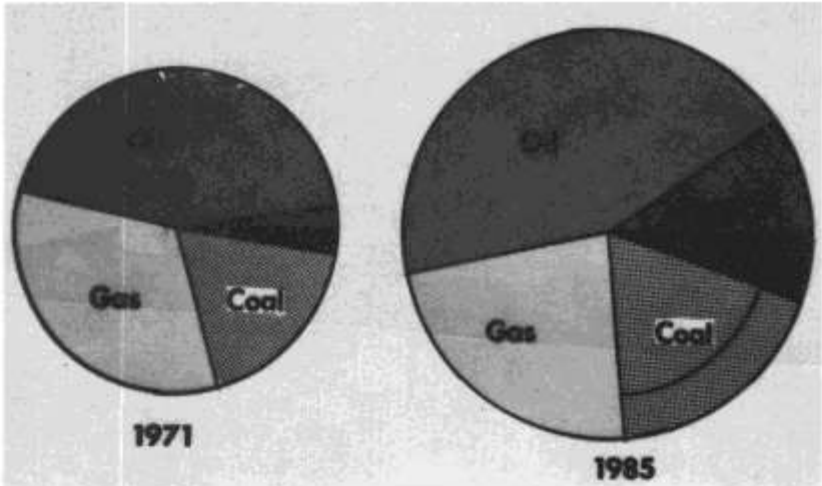

Figure 1. Comparison of energy consumption in 1971 and U.S. Department of the Interior estimated consumption for 1985.

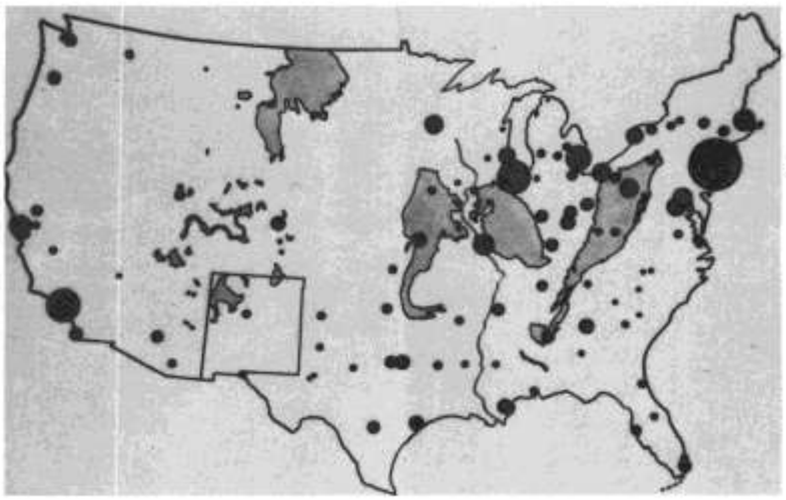

Figure 2. Distribution of coal-bearing areas (light shading) and major population centers in the United States.

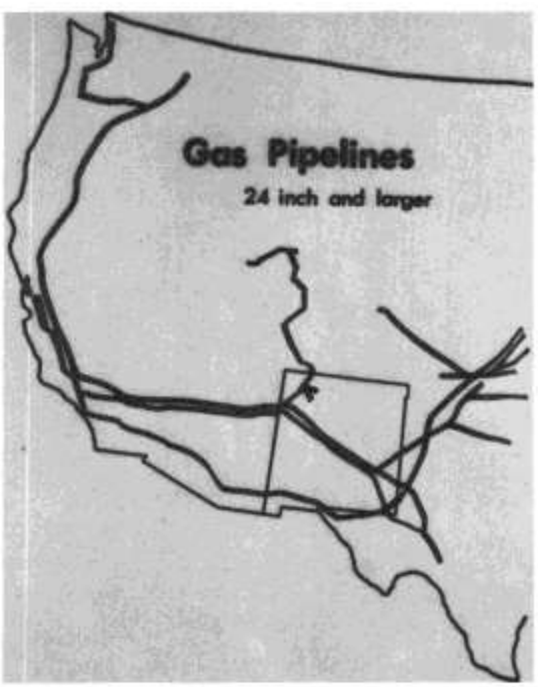

Figure 3. Routes of major natural gas pipelines in the western United States.

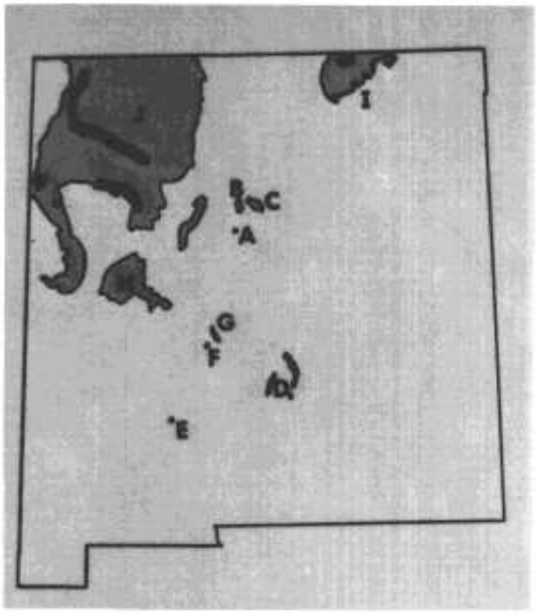

Figure 4. Coal-bearing areas of New Mexxco: A, Tijeras; B, Una del Gato; C, Cerrillos; D, Sierra Blanca; E, Engle; F, Jornada; G, Carthage; H, Datil Mountain; I, Raton Basin; J, San Juan Basin. Dark shading indicates areas that contain important strippable coal.

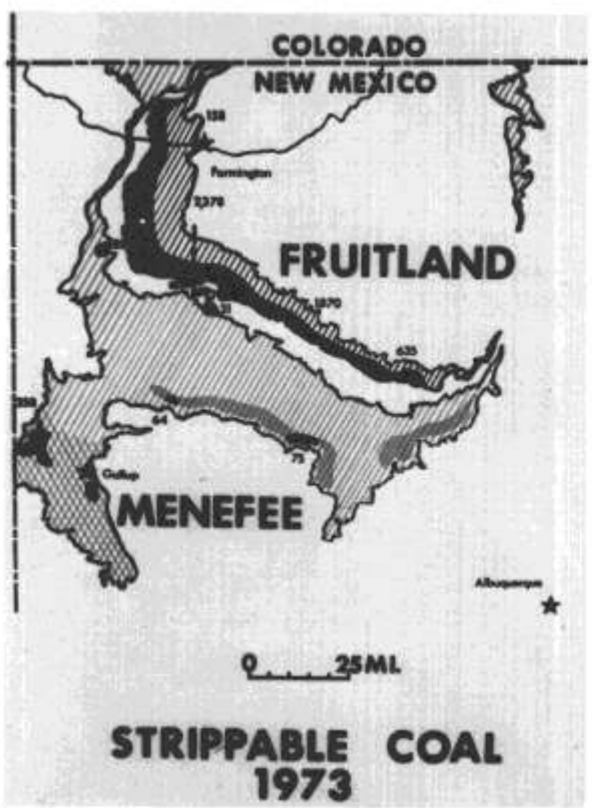

Figure 5. Distribution of strippable coal (dark shading), and areas of potential strippable coal (light shading) of the Fruitland and Menefee Formations, San Juan Basin.

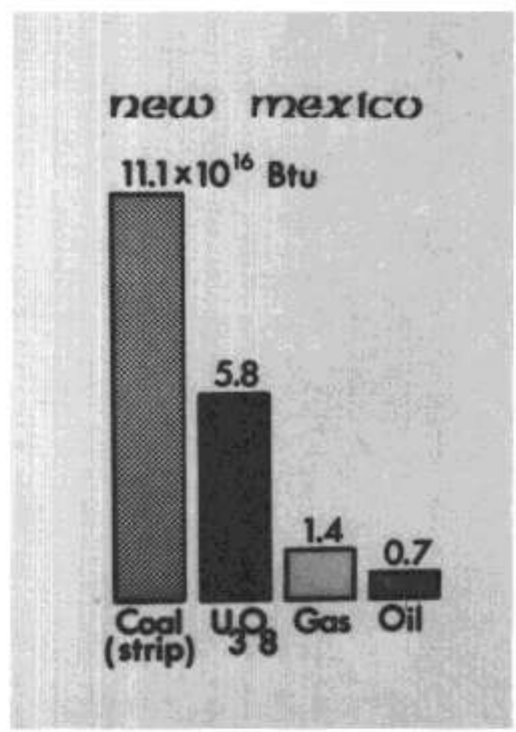

Figure 6. Comparison of currently-estimated energy resources of New Mexico.

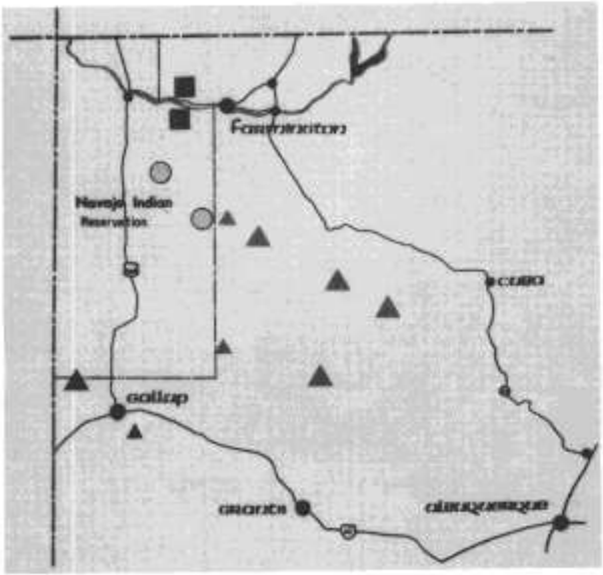

Figure 7. Existing, planned, and conjectural coal developments in the San Juan Basin. Squares, existing power plants; circles, planned gasification plants; dark triangles, existing mines; light triangles, conjectural mine locations.

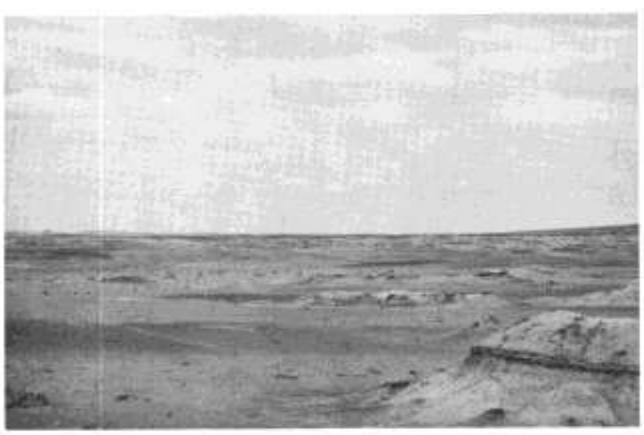

Figure 8. View of typical strippable terrain; Fruitland Formation near Bisti.

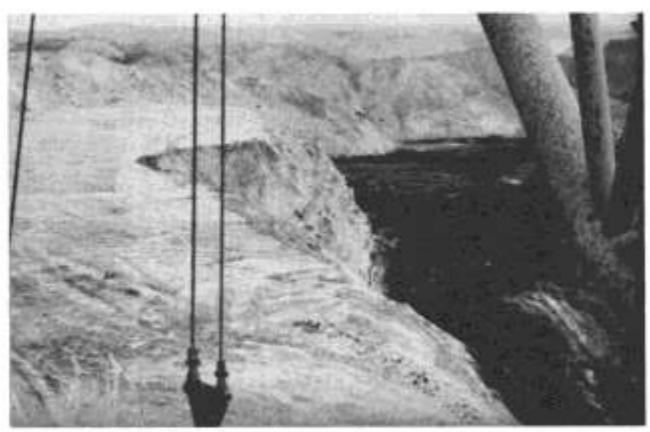

Figure 9. View of pit during mining.

THE UTILIZATION OF SOLAR ENERGY TO HELP MEET OUR NATION'S ENERGY NEEDS

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SUMMARY

There is a national need for abundant clean supplies of energy. Our present fossil fuels are being depleted at an ever-increasing rate. Nuclear energy and coal can supply our needs but each has environmental and safety problems to overcome. This paper discusses the potential of solar energy as a major source of energy to meet our nation's energy needs. Solar energy is a clean, nondepleting resource that is available and has the potential to meet our expected needs. The optional solar energy systems presently under evaluation are briefly discussed. These options include systems for meeting our needs for generation of electricity, for heating and cooling of buildings and for production of clean fuel for transportation and industrial uses. The key technology requirements, estimated system costs, and potential of meeting our national energy needs are presented for each of the solar energy options. And, finally, the present national solar energy plans and programs and their possible impact on our energy needs are briefly discussed.

INTRODUCTION

There is a national need for abundant domestic supplies of clean energy. At the present time this need is often referred to as the "Energy Crisis." As a nation our energy needs are increasing rapidly and are expected to double by the year 2000. In addition to our increasing energy needs, some of our energy resources are being rapidly depleted (refs. 1, 2, 3). As if these problems are not enough, we also have environmental problems and balance-of-payments problems due to our energy needs.

The nation's energy needs, domestic energy resources, and possible future energy resources are briefly discussed in this paper. Three potential solutions, coal, nuclear and solar are compared as to benefits and problems. The paper primarily discusses the options available in using solar energy as a natural energy resource. These options are discussed under the generation of electricity, heating and cooling of buildings, and the production of clean fuel.

Discussed under the generation of electricity from solar energy are such systems as photovoltaics in space and on Earth, thermal energy collected from sunlight to operate conventional powerplants, solar-derived energy in the winds to obtain power from wind turbines, and a heat-engine that operates from the temperature difference available in the ocean.

The heating/cooling section discusses the principle of operation utilizing flat-plate collectors, thermal storage and heating and cooling equipment. Several examples of solar heated residences are described and the key technologies required to make the systems practical and economical.

Solar energy also offers ways of producing clean fuel: solid, gas and oil from crops. Several possible methods of producing fuel are discussed and the key technologies identified.

This paper then discusses current funding levels and programs for the development of solar energy. Also identified are projected milestones and possible impact of solar energy on our nation's future energy needs.

U.S. ENERGY: DEMAND AND PROBLEMS

Demand

The U.S. presently uses about 70X10 BTU/yr of energy. These energy sources are primarily oil, natural gas and coal. A small amount of our energy is supplied by hydroelectric systems and an even smaller amount by nuclear reactors. Figure 1 shows the U.S. energy demand projected through the year 2020. This projection was made by the Associated Universities for the Office of Science and Technology (ref. 1). It can be seen from figure 1 that our needs are forecasted to increase rapidly, with four times the total energy predicted to be required by the year 2020. The increases are predicted to be met by a very large increase in the use of nuclear energy and increases in the use of oil and coal. Natural gas consumption is not projected to increase because of the depletion of gas reserves.

Energy Problems

Depletion

The forecast increase in energy use in the U.S. will result in a rapid depletion of some fuels as shown in figure 2. The Associated Universities, the Brookhaven study (ref. 1) and the AEC forecasts show that if present trends in energy consumption continue, oil, gas and uranium 235 (used in present power reactors) will be exhausted in 40 to 50 years. There are, however, abundant supplies of coal and uranium 238 (used in the fast breeder reactors now being developed by the AEC).

Pollution

Another impact of increased energy consumption is increased pollution. Figure 3 shows the possible output of several key pollutants over the next 50 years. As can be seen in figure 3, there is a temporary reduction of pollutants like NO_x and SO_2 by 1980 because of present government restrictions on emissions from automobiles and power-plants. However, the projected increase in energy consumption will override the present controls and cause the rate of pollution to double by 2020 unless new controls or new technology are introduced. Not shown in the figure are environmental impacts of strip mining operations and the generation of large quantities of radioactive wastes. An important fraction of these radioactive wastes must be stored for many thousands of years before they could be safely released. This latter is a crucial problem to which the AEC is giving very serious consideration.

Balance-of-payments

One of the major impacts of the depleting oil and gas reserves is dependence on foreign purchase of those convenient-to-use fuels. The value of oil and gas imports from 1968 to 1971 is shown to vary in figure 4 from 1.5 to 2.2 billion dollars. By 1985 the National Petroleum Council predicts a cash outflow for oil and gas of 20 billion dollars (ref. 4). This is to be compared to the net outward flow of cash of 10 to 30 billion in the years 1970 and 1971. Obviously, our dependence on fuel imports will have a major adverse impact on the net balance of payments in addition to making us dependent for more than half of our fuel on the policies of foreign countries.

DOMESTIC SOLUTIONS TO NATION'S ENERGY NEEDS

There are three major potential solutions to the shortage of oil and gas that can be considered seriously because they are technically feasible. These solutions are summarized in Table I. They are the gasification and liquefaction of coal, the use of nuclear energy to produce electricity, and the use of solar energy. The reserves of coal and nuclear energy (assuming the commercial success of the fast breeder) are measured in terms of centuries but even so they are limited. Solar energy is unlimited. Another fossil fuel is shale oil. It is estimated that the U.S. has an order of magnitude more energy in shale oil than in coal (ref. 5), but at the present time it is not economical to utilize this source of energy. For this paper, solar is compared with only nuclear and coal, both of which are expected to provide much of our energy in the near future.

The use of coal involves solution of the SO_2, NO , and particulate pollution problem. In addition the added burden on the environment of unprecedented strip mining operations will create further problems already considered serious in several locations in the U.S.

The use of nuclear energy to solve the energy problem introduces safety questions and management of the large amounts of radioactive waste products that are generated by the fission of uranium.

There are no major environmental problems introduced by utilization of solar energy. Solar energy continuously falls on the Earth whether or not we use it. Solar energy therefore does not add any new thermal burden on the Earth's atmosphere as does the combustion of fuel and fission of uranium.

The technology that is needed to use coal involves the successful development of large-scale economical and efficient processes to convert coal to oil and gas. In addition, work needs to be done to economically extract coal in a socially acceptable way.

The technology required for the use of nuclear energy to solve the energy problem requires the successful development of an economical and safe breeder reactor. Also required is an acceptable and safe means for handling the vast amount of radioactive waste products that will be generated and that require storage or disposal with positive assurance of no release for 300 centuries.

The solution to the technical and environmental problems associated with the use of coal and nuclear fuel is expected to substantially increase the cost of energy. Estimates are that energy costs may triple in the next ten years because of the dependence on foreign sources, the cost of replacing oil and gas sources with nuclear and coal, and the cost of eliminating pollution and environmental problems.

It appears timely now to consider the use of solar energy. The chief problem in the past has been achieving cost-competitive systems. There is no question that technically solar energy is feasible. What is needed now is technology that will reduce the cost of solar energy systems. Innovative approaches, good simple efficient designs, proper selection of concepts, optimized systems approach and sound management of technology development programs are required to make solar energy an economical solution to the energy shortage problem. It is the only energy source that is unlimited, everywhere available, and offers a clean solution to the energy shortage.

SOLAR ENERGY CAN PROVIDE ALL OUR ENERGY NEEDS

Solar energy is diffuse and variable but abundant. In space at the Earth's distance from the Sun, the solar radiation available is approximately 130 watts/ft . Considering day-night and seasonal variation of solar flux and attenuation due to atmospheric conditions (clouds, dust and smog), the average energy falling on the U.S. on a year-round basis is 17 watts/ft^2 or 1410 BTU/ft^2 per average day (ref. 6). Figure 5 shows that the daily solar flux in the 9.5. varies from 1000 to 2000 BTU/ft . As shown in figure 5, the solar energy falling on the continental U.S. is 300 times the total projected 1985 energy needs of the U.S. At an average efficiency conversion of 5%, it would take less than 7% of the U.S. land area to supply all our 1985 forecasted energy needs.

Figure 7 shows percentage of land area required versus efficiency of conversion of solar energy for both total U.S. energy consumption and energy required to produce electrical power. From figure 7 it can be seen that solar cells at 10% efficiency could meet all our 1985 electrical power needs by covering less than 1% of our total land area. Solar energy is diffuse but its abundance makes it possible to be a major energy resource for the U.S. and for the world.

The U.S. uses energy to generate electricity, heat and cool buildings, and to provide fuel for transportation systems and industrial processes. At the present time, approximately 22% of our total energy consumption is used for generating electricity, 25% for providing thermal energy for buildings, 23% for transportation and 30% for industrial processes. As shown in figure 8, solar energy can provide all forms of our energy needs.

ELECTRICITY FROM SOLAR ENERGY

Several methods of generating electricity from solar energy have been identified. Briefly these methods are:

1. Direct conversion of solar energy to electricity using solar cells.

2. Collection of solar energy by collectors to heat fluids that can be used to operate heat engines. These heat engines are then used to drive generators to produce electricity.

3. Using the solar-heated upper layers of the ocean water and the cold lower depths of the ocean to operate a low T heat engine. This heat is then used to drive a generator to produce electricity.

4. Using the solar-derived wind power directly to operate a wind turbine. The wind turbine then drives a generator to generate electricity.

5. Using solar energy to grow crops that can be converted to fuel. The fuel is then used to operate heat engines that are used to generate electricity.

A brief description of each of these methods is discussed in the following sections along with their potential, technology needs and estimated costs.

Electricity from solar cells in space

The SERT II solar array is shown in the upper photo of figure 10. This array demonstrates that reliable electric power can be provided in space with solar cells.

The lower photo in figure 10 is a proposed concept for using solar cells in synchronous orbit to make power for use on the ground. This is the Satellite Solar Power System (SSPS) concept proposed by Glaser (ref. 6). The solar cells convert the solar energy to dc electrical power; this electrical power is converted to microwaves and beamed to the Earth. On the Earth, a receiving station converts the microwaves back to electrical power through a combined antenna and rectifier, called a rectenna.

The SSPS concept shown is proposed to generate 5000 MWe on the ground. The$_2$ solar array panels total nearly 21 mi with a total system weight of about 25 million pounds.

Because of the availability of nearly limitless solar energy in synchronous orbit, the deployment of SSPS's could provide all the Earth's energy needs. For example, 80 SSPS's could supply all our projected 1985 electrical needs of 400,000 MWe.

The technologies required to make the SSPS a viable system are: low-cost high-efficiency solar cells; lightweight structures that can be assembled in space; a low-cost synchronous-orbit transportation system, and a reliable, safe microwave system.

At the present time the costs of such a system are prohibitive. For example, present space solar arrays cost $200,000/kW or more. Such a high cost would result in a power cost of 4800 mills/kW-hr for electricity compared to conventional electricity costs of about 7 mills/kW-hr. The goal for the SSPS concept is to reduce the costs so the total system is of the order of $1000/kW.

Electricity from solar cells on Earth

The possibility of placing large solar arrays on the ground in prime areas of the *U.S.* has also been looked at by Cherry (ref. 8) and by Spakowski and Shure (ref. 9), (figure 11). Several advantages over the space system are immediately obvious, such as elimination of the need for a microwave system and for a space transportation system. However, on the ground the average solar radiation is much less, being less than 25 watts/ft even in our prime southwest desert areas compared to 130 watts/ft in orbit. Also, because of the day-night cycles and inclement weather, energy storage is required for the ground-based system.

Even with the above limitations, the ground system offers the potential of supplying all our 1985 electrical needs by using an area 100 by 100 miles of our southwest deserts covered with presently available solar cells of 7% efficiency. In addition to the solar cells, however, energy storage must be provided for the day/night cycle.

The technologies required for the ground-based system are low-cost solar arrays and low-cost energy storage.

It is now possible to purchase arrays for ground usage at about $100,000/kW (significantly lower than space arrays). This cost must be lowered to $1000/kW or less if solar cells are ever to compete with conventional means of generating electricity.

Electricity from solar thermal energy

This concept uses solar energy in the form of thermal energy and has recently been suggested for re-evaluation by the Meinels (ref. 10) and by the University of Minnesota and Honeywell, Inc. (ref. 11). Very simply, solar energy is collected and focused on pipes carrying a heat transport fluid. The fluid is heated to a high enough temperature for operation of a conventional steam power Rankine system (fig. 12).

The major system components are the focusing collector, absorber, heat transport loops, energy storage and the power plant. The key technologies are both in the component and the systems area. Focusing-type collectors are needed to obtain the required temperature range of 600° F to 1000° F for efficient power plant operation. The collectors must also be able to withstand periodic cleaning and problems associated with wind, desert, and rain storms. Stable absorber coatings of *ale* of 10 or greater are required. The heat transport loops collect energy from square miles of desert and must be efficient. Pumped loop and heat pipe systems using H_2O, air, and liquid metals are being investigated. Energy storage may be limited to supplying requirements for daily periods of darkness, for longer periods of inclement weather, or for averaging summer peak radiation with the lower winter radiation.

Because of the higher efficiencies possible with this system, it is estimated 60 x 60 miles of our southwest desert could supply all our 1985 electrical needs.

Preliminary cost estimates have been made by advocates of this system. Their estimates range from $1000/kW to $3000/kW resulting in a 15-50 mills/kW-hr cost for the electricity.

This system appears to have potential, but what is needed is innovative component and system approaches to develop low-cost competitive systems.

Electric power from ocean temperature difference

An interesting system for generating electricity that has been demonstrated by Claude (ref. 12) is the ocean T system that uses the warm and cold ocean water to operate a heat engine (figure 13). It is proposed by the Andersons (ref. 13) that such a system would float in the Gulf Stream off the southern coast of Florida and generate electricity economically. The upper ocean layers are warmed to about 80° F by the sun and are used to boil a fluid to drive a turbine. The turbine operates a generator for making electricity. The fluid is condensed by a cold water supply of 40° F at depths of about 2000 feet. The cold water is the result of melting of the polar ice caps and this cold water is flowing toward the Equator.

Systems using the ocean T have been demonstrated: Claude demonstrated a 22 kW system in Cuba in 1929 and the French built two 3500-kW systems in the 1950's. The major advantages of such a system are that no collectors or storage are required. The ocean both collects and stores the solar energy for day/night cycles and inclement weather.

The ocean T system has the potential to make a major contribution to our energy needs. For example, it has been estimated that less than a 0.3° F drop in Gulf Stream would supply all our 1985 electrical needs (400,000 MWe). It is also interesting that the ocean T system reduces the thermal pollution of oceans instead of increasing it as most other systems do.

The ocean T does have some key technology needs that must be solved before this system can contribute to our needs. The technologies identified are:

1. The long large-diameter cold-water duct--.The duct will be about 30 feet in diameter and 2000 feet in length. A major problem is how to support and anchor such a duct with the lateral forces exerted on it by the ocean currents flowing in opposite directions at different depths.

2. The large low-cost heat exchangers--.Because of the low T available, large heat exchanger surfaces are required to extract large amounts of power. New methods for fabricating large, low-leakage heat exchangers at low costs must be determined.

3. Seawater compatibility--.The ocean T system must be compatible with the ocean. It must withstand corrosion, hurricanes, and the possibility of debris, fish, etc., from clogging up the boiler passages. The methods for operating and maintaining a sea-plant and delivering its energy to shore must also be determined.

Preliminary cost estimates by advocates of the ocean T system range from $300 to $500/kW. Such capital costs indicate that the ocean T system may provide very competitively priced electricity. However, these estimates depend on solving the key technology problems.

Electric power from the wind

Solar-derived wind power can and has been used to generate electricity. A large 1.25 MWe wind-generator was built in Vermont (ref. 14) in the early 1940's and delivered electricity directly into the local power grid. Wind-generators are currently being used to generate small amounts of power around the world. A 200 kW wind-generator was constructed in Denmark (ref. 15) in 1957, (fig. 14).

There is no question about the technical feasibility of generating electricity from wind-generators as evidenced by the many demonstrations. The only question is can electricity be generated continuously and competitively by wind power and is there enough wind power available to make a significant impact on our energy needs? Besides electricity, the wind-generators could be used to produce fuel (H_2) by electrolysis to be used for transportation or other purposes.

Estimates by advocates of wind power in this country, such as Heronemus (ref. 16), claim there is enough wind power to supply all our electrical needs and that winds in the Great Plains alone could supply 50% of our 1985 electrical needs (400,000 MWe).

The question that comes up most often when discussing wind power is that of energy storage. What happens when the wind stops? Energy storage would certainly make it possible to use wind-generators for individual or small-scale applications such as homes or small communities. However, wind-generators could be added to any system that has storage such as pumped-storage or a conventional hydroelectric plant. In addition, wind-generators could supply power to any grid and the storage could be considered to be the fuel that runs the conventional generating plant. What needs to be done is to determine applications for large-scale use of wind-generators. This includes wind analysis and economic analysis. Also, storage should be worked on but is not essential for all applications. Analysis of wind data may show that networking of large generators without storage may make sense.

Costs of previous demonstrations and estimates by present-day advocates range from \$200 to \$650 per installed kWe with a cost of electricity from 7-15 mills/kW-hr. Electricity from wind appears attractive and should be looked at seriously.

SOLAR ENERGY FOR HEATING AND COOLING BUILDINGS

Approximately 25% of our present energy consumption is used for heating and cooling buildings. This energy demand is met by the use of gas and oil. Supplying this thermal energy for buildings by solar energy would save our dwindling supplies of gas and oil for other uses.

As shown in figure 15, solar energy can be utilized for heating and cooling of buildings by putting flat-plate collectors on the roof. These collectors are fairly simple in construction. A black surface is used to absorb the sunlight, this surface is covered with one or several panes of glass which reduce re-radiation. The collector is insulated on the sides and back to prevent conduction and convection losses.

Water, air or some other fluid is passed through the collector and can reach temperatures from 140° F to greater than 200° F. The thermal energy from the fluid is then stored in a heat storage container to provide energy for the day/night cycle. The thermal storage can be sensible heat of water or rocks or the latent heat-of-fusion of special salts.

Coupled to the heat storage system are a heating loop and a cooling loop. The heating loop takes heat from the thermal storage system to heat the building. The cooling loop takes heat from the thermal storage to operate an absorption or mechanical air conditioning system. Also connected to the heat storage loop is an auxiliary heater. The purpose of this heater is to supply thermal energy to the system during periods of inclement weather using conventional fuel.

Twenty buildings are presently heated with solar energy in the United States. The upper photograph in figure 16 is of a home in Dover, Massachussets. Solar energy provided 90% of the heat load during the month of February. The bottom picture shows an office building in Albuquerque, New Mexico. Solar energy provides 75% of the heating load for this building.

None of the solar-heated homes has solar-supplied air conditioning. The addition of air conditioning could make the solar energy systems for buildings much more competitive. Systems could then be utilized nearly 12 months of the year. Solar supplied air conditioning will also help reduce our peak-load requirements on our electrical systems.

The Federal Council on Science and Technology (FCST) solar energy report estimates that by 2020 40 to 50% of the thermal energy for buildings in the U.S. could be supplied by solar energy. In areas and buildings where solar energy is used, it is estimated that solar energy can supply up to 75% of the buildings' thermal energy needs.

The technology needs include efficient low-cost flat-plate collectors. To operate air conditioning systems, temperatures equal to or greater than 200° F are needed. Collectors must be developed that can be manufactured for about $2/ft compared to present costs of about $4/ ft . Also needed is low-cost efficient thermal storage. Present methods use water or rocks and the latent heat of fusion of some salts. As mentioned above, a critical need is to develop low T air conditioning systems. Absorption and mechanical systems are being considered.

Economic studies by Lof and Tybout (ref. 17) have indicated that solar heating is less expensive than electrical heating anywhere in the U.S., but is not competitive with gas or oil in most places. If solar air conditioning systems can be developed, however, the picture should change. For example, it is estimated that it costs $312/yr for fuel to heat and cool the average house. These fuel costs could pay for a $3000 solar heating/cooling system mortgaged over 15 years. With the increase in fuel costs, the solar systems will become even more economical.

CLEAN RENEWABLE FUEL FROM SOLAR ENERGY

At the present time gas and oil supply nearly 75% of all the nation's energy sources. The U.S. is rapidly running out of domestic supplies of gas and oil. Figure 17 shows several processes for producing fuel from solar energy:

<u>Electrolysis:</u> Hydrogen can be produced from electrolysis powered from solar-generated electricity.

<u>Direct Burn:</u> Land and water plants can be grown, dried and processed to provide fuel for use in present power plants in place of coal dust as proposed in the Energy Plantation Concept by Szego (ref. 18).

<u>Conversion Systems:</u> There are several systems for converting organics to gas or oil. These systems include pyrolysis, chemical, and biochemical conversion.

Pyrolysis is a destructive distillation process that heats organics in the absence of air. Pyrolysis has been investigated as a way to convert refuse to oil by Sonner (ref. 19). A present demonstration plant produces two barrels of oil (12,000 BTU/lb) from each ton of dried organics at a brgakeven cost of about 75 cents/ 10 BTU.

In the chemical process organics are heated under pressure in the presence of water and a cover gas of CO. A small pilot plant demonstration of this system indicates that two barrels of oil per ton of dried organics can be produced (15,000 BTU/lb) at g breakeven cost of about 87 cents/10 BTU.

Several biochemical or fermentation processes have been in the U.S. over the past 20 years as sanitary plants. These systems produce methane which is used in the process for fuel; however, the plants have not been optimized to produce fuel.

Photolysis

A process currently being funded by the NSF for laboratory research is the photolysis of water. This is a proposed method for getting H_2 and 0_2 from water and sunlight using blue-green algae and micro-organisms. This process is fundamentally possible but must be developed to determine technical feasibility.

As shown in figure 18, approximately 15% or 470,000 mi of U.S. land is presently used to produce food, and another 3% or 95,000 mi is kept in reserve as surplus land. We presently pay farmers nearly $2.6 billion not to grow crops on this surplus land. If this surplus land could be used to grow crops for fuel at the present efficiency rates of 1%, enough fuel could be produced to meet 10% of our predicted 1985 total energy needs. If this efficiency could be increased to 5%, then 7% of our land area could supply all our 1985 energy needs.

To make fuel from crops economically feasible, crops with the highest BTU's per acre per year must be identified or developed. Also, low-cost processing methods such as harvesting, preparation, and transportation must be identified. And finally, low-cost conversion systems for converting crops to gas and/or oil must be developed.

Assuming an average of 1500 BTU/ft^2 per day, it can be shown that one acre of farm land growing crops at 1% conversion efficiency produce 230x10 BTU/yr. At $1/10 BTU one acre of land then yields $230 worth of energy. Conversion efficiencies must be pushed higher and harvesting and processing costs must be kept low if clean fuel from solar energy is going to be economical.

Several preliminary costs estimates for producing fuel from organics indicate that such processes are close to being economically competitive today. Present-day costs fog natural gas and oil range from $.50/10 BTU respectively.

NATIONAL SOLAR ENERGY PROGRAM

As shown in Table II, the National Science Foundation Solar Energy Program was begun in 1971 with a total of 1.2 million dollars. This effort has grown over the last 4 years to an expected value of 12.2 million dollars for 1974. The effort is divided between the three major areas of electric power generation, heating and cooling of buildings and clean fuel production. The National Aeronautics and Space Administration's program invested about $1 million in 1973 and has about 15 scientists working in this area.

During the year 1972 a joint NASA/NSF solar energy panel was formed to assess the potential of solar energy as a national resource. Experts in all areas of solar energy were pulled together to come up with recommended development plans for the selected solar energy systems. The panel report was published in late 1972.

The objective of the present NASA and NSF solar energy programs is to develop practical, economical and socially acceptable systems utilizing solar energy for the generation of electricity, heating and cooling of buildings, and the production of clean fuels.

Figure 19 shows the possible milestones that could result from the solar energy program. The upper arrows indicate the systems developed under government funds while those at the bottom show potential industry takeover. As indicated in the NASA/NSF Solar Energy Report, it is estimated that solar energy, if developed vigorously, could supply up to 50% of the total U.S. energy required in 2020.

The total U.S. energy research and technology funding as shown in Figure 20 has increased from about $300 million in 1970 to just over $500 million in 1973. This funding has been divided mainly between nuclear and coal, with nuclear receiving the most, followed by coal, and with a small amount for solar. It is interesting to note the U.S. spends about $100 billion a year for energy and that $500 million for research and technology represents only 0.5% of our total energy bill. With as little as a 0.5% increase in our energy costs, we could double our nation's research efforts on energy. This would allow adequate investigation and development of alternate sources with potential, such as solar.

CONCLUDING REMARKS

1. Solar energy is a nondepleting energy source that is abundant, clean and safe.

2. Solar energy can be used to supply all our energy needs such as generation of electricity, heating and cooling of buildings, and production of clean fuel.

3. Development of technology and systems utilizing solar energy will make us less dependent on foreign nations. It will also help our balance of payments by reducing fuel imports and providing an exportable technology that can help other countries.

4. Solar energy appears to offer much potential as a major energy source to help meet our nation's energy needs. It is an area that has been inadequately funded and should receive increased support.

See pages 40-50 for tables I & II and figures 1-21

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TABLE I. - DOMESTIC SOLUTIONS TO NATION'S ENERGY NEEDS.

SOLUTIONS	RESERVES	MAJOR ENVIRONMENTAL PROBLEMS	TECHNOLOGY NEED
COAL	~500 YR	POLLUTION STRIPMINING	COAL GASIFICATION LOW COST EXTRACTION
NUCLEAR	~10 000 YR	SAFETY QUESTIONS NUCLEAR WASTE	FAST BREEDER WASTE HANDLING
SOLAR	UNLIMITED	NONE	LOW COST SYSTEMS

TABLE II. - NSF SOLAR ENERGY PROGRAM

	FY 71	FY 72	FY 73	FY 74
ELECTRIC POWER	1.2 M	1.1 M	1.5 M	6.0 M
HEATING AND COOLING	0	0.1 M	1.0 M	3.3 M
RENEWABLE FUEL SOURCES	0	0.4 M	1.5 M	2.9 M
TOTAL	1.2 M	1.6 M	4 M	12.2 M

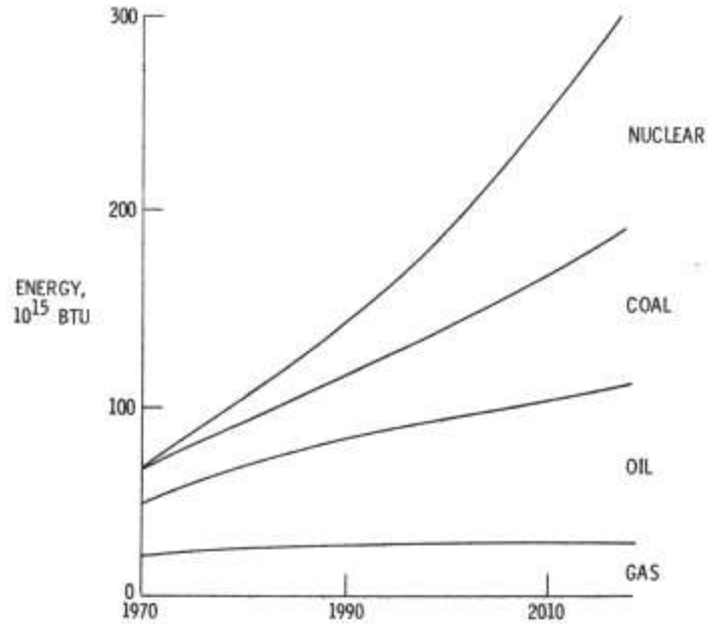


Figure 1. - U. S. energy demand.

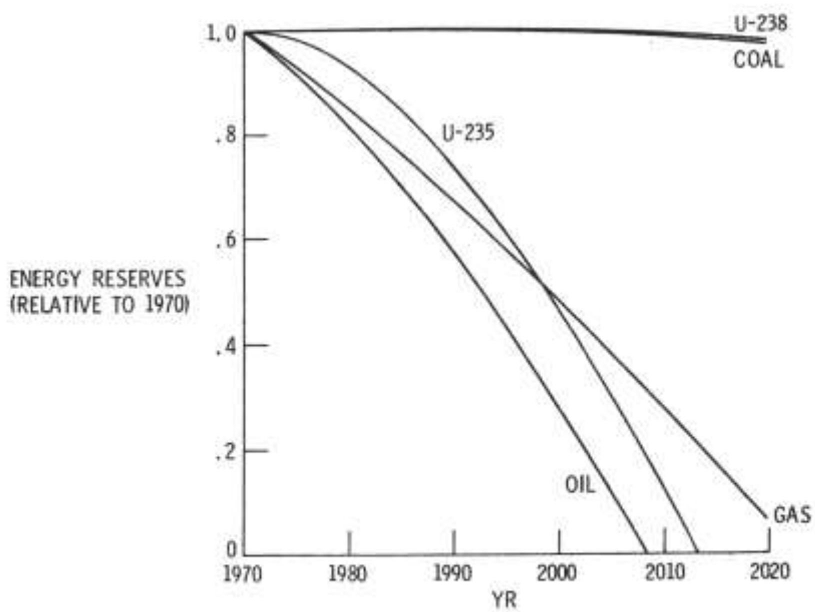


Figure 2. - Depletion of domestic energy reserves.

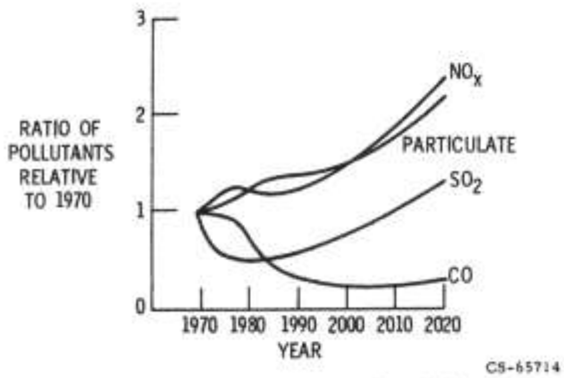


Figure 3. - Relative annual production of pollutants.

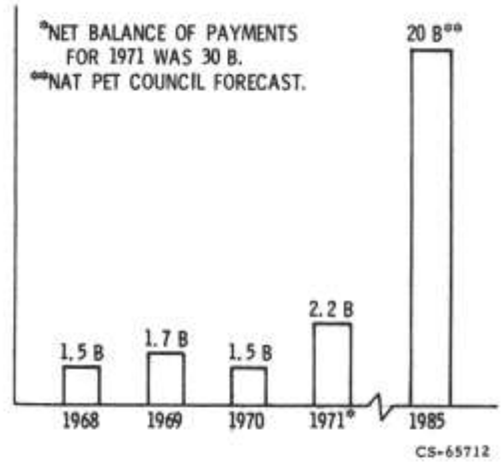


Figure 4. - U. S. net cash outflow for fuel imports.

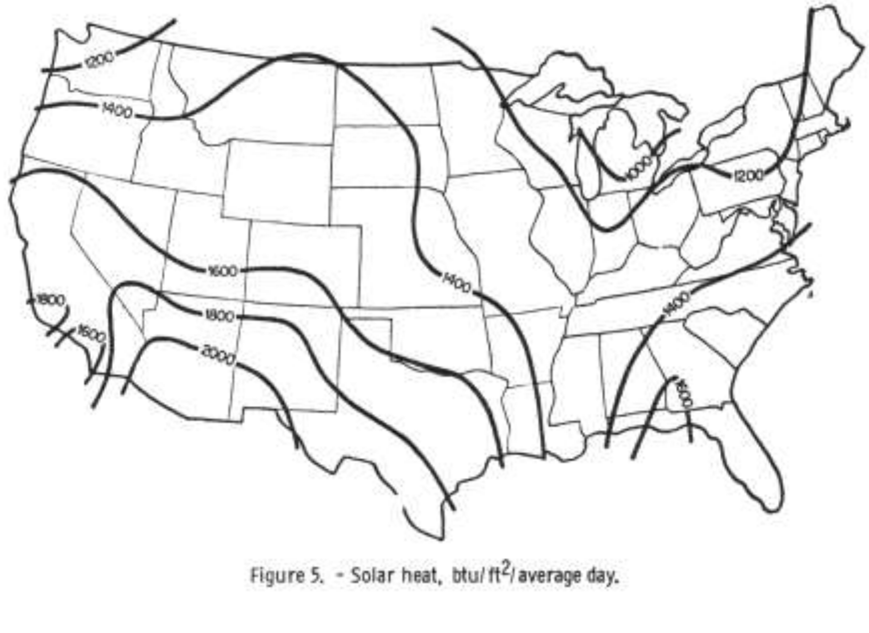


Figure 5. - Solar heat, btu/ft²/average day.

Figure 6. - Solar energy is diffuse but abundant.

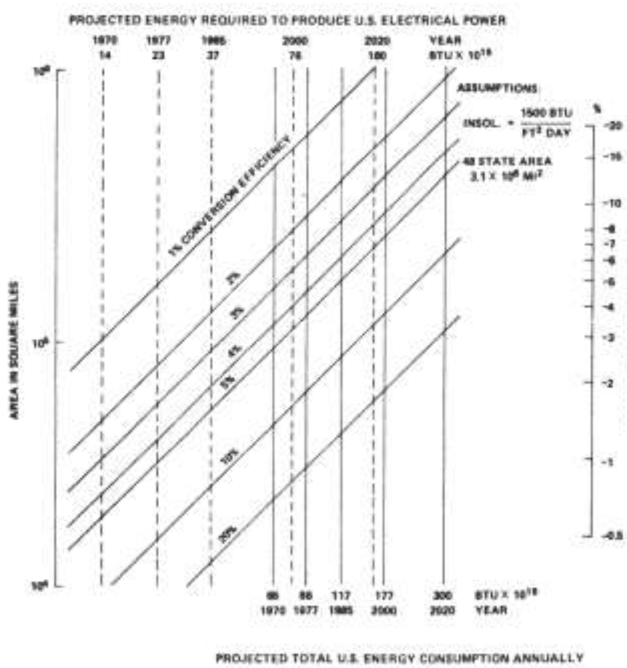


Figure 7. - Percent U. S. land area required to meet U. S. energy needs as a function of conversion efficiency. (1) From the NSF/NASA solar energy report (ref. 6).

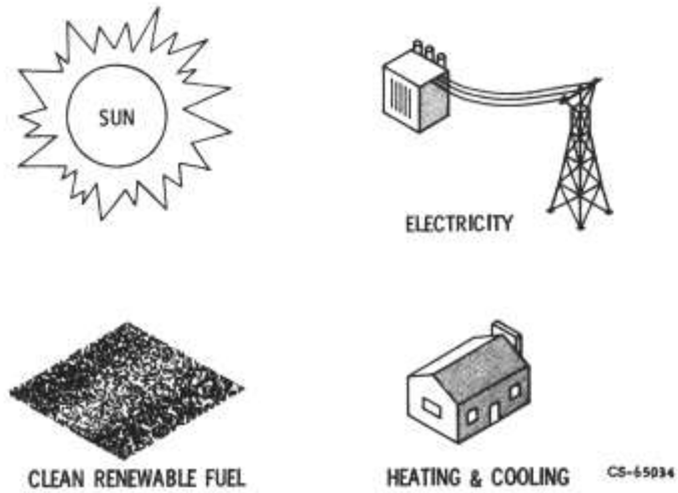


Figure 8. - Solar energy can provide all energy needs.

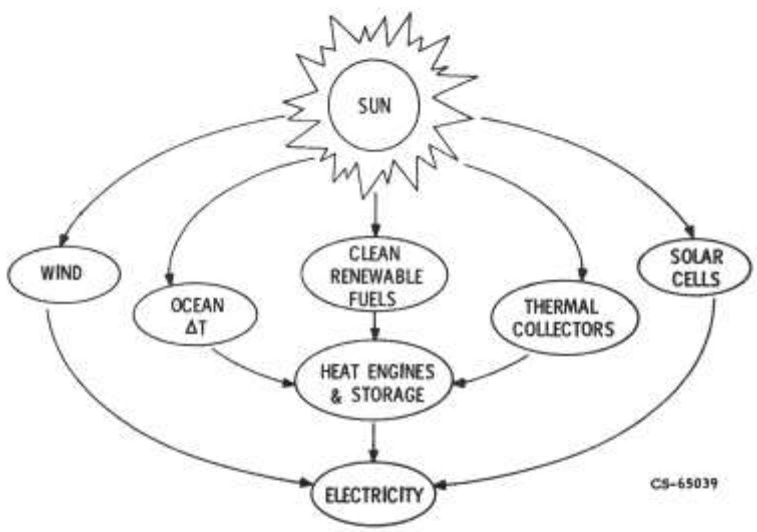


Figure 9. - Electricity from the sun.

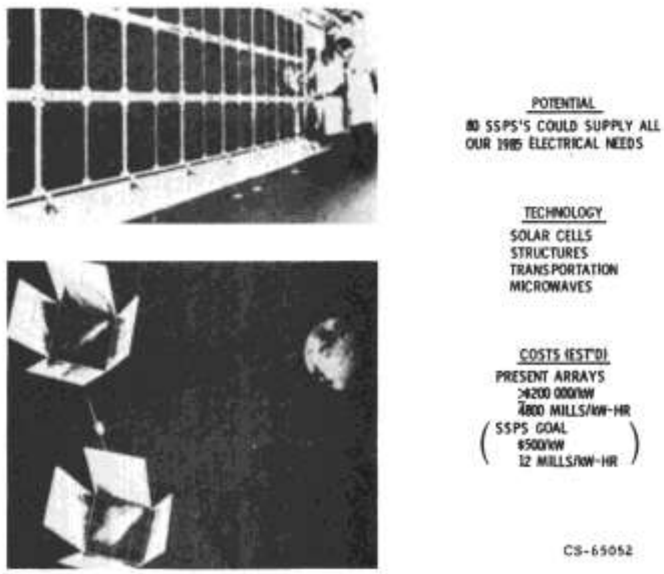


Figure 10. - Electricity from solar cells in space.

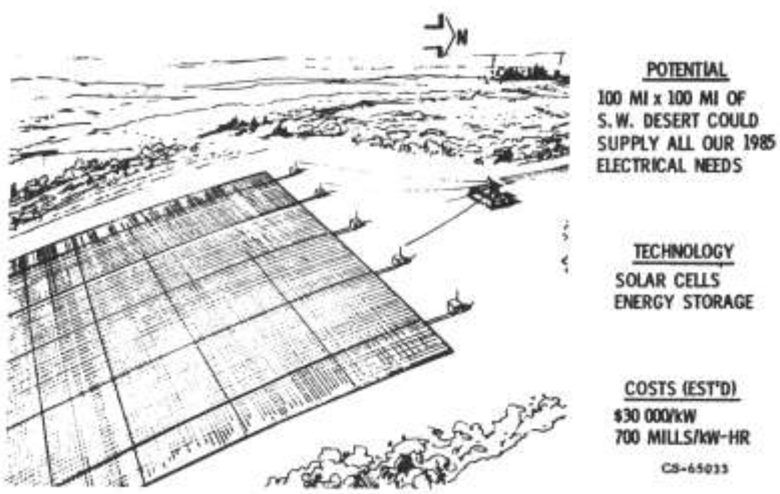


Figure 11. - Electricity from solar cells on the earth.

Figure 12. - Electric power from solar thermal energy.

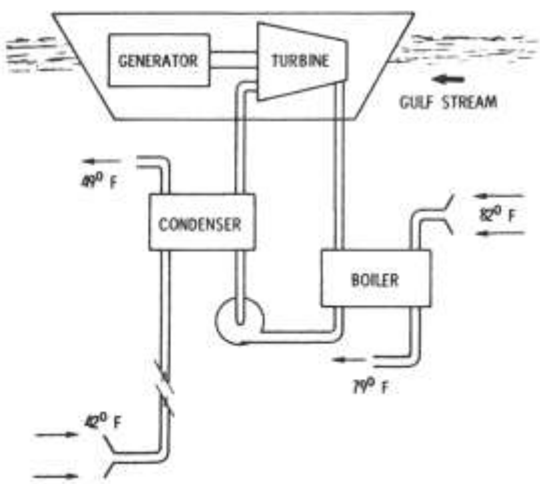


Figure 13. - Electric power from ocean ΔT.

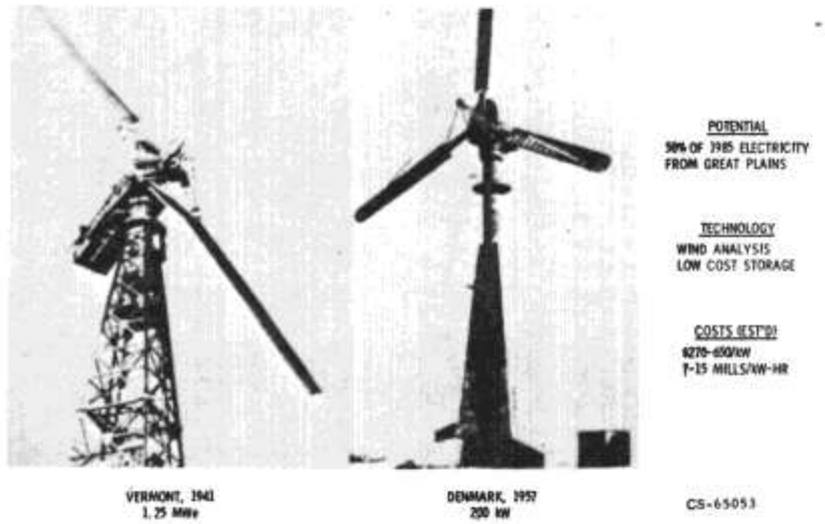


Figure 14. - Electric power from wind.

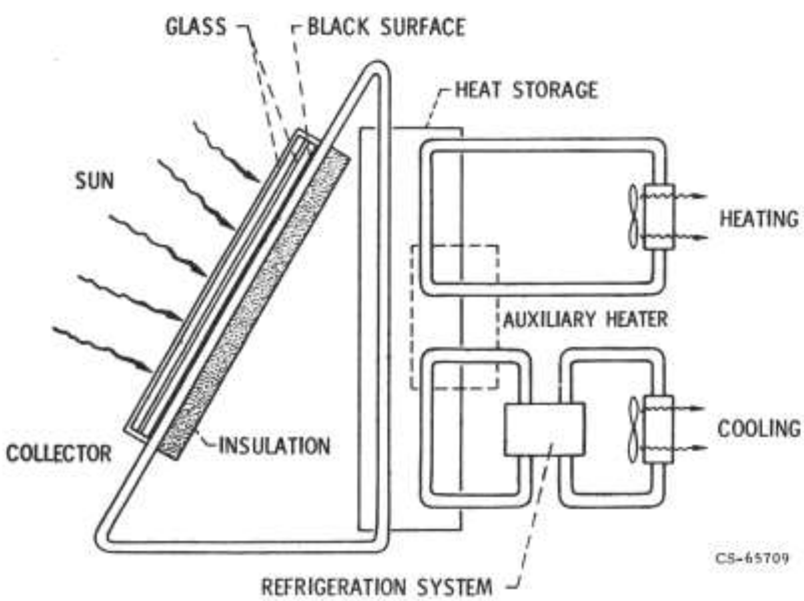


Figure 15. - Solar energy for heating and cooling buildings.

Figure 16. - Solar energy for heating and cooling buildings.

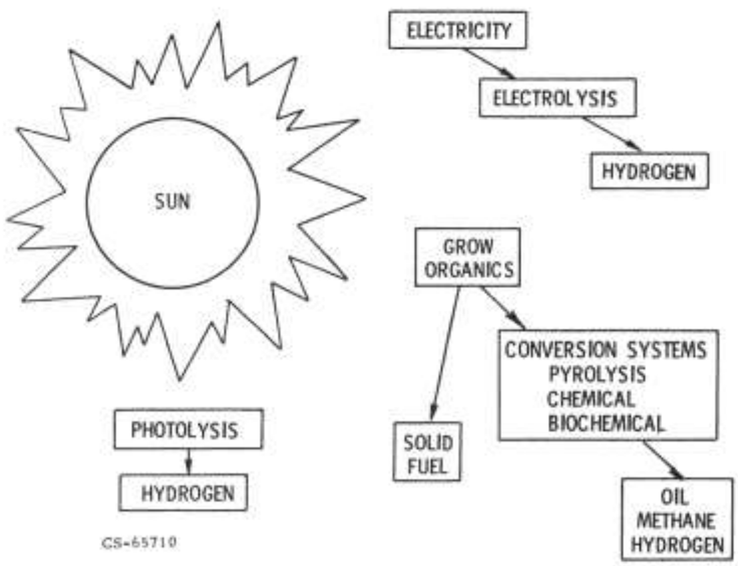


Figure 17. - Clean renewable fuel from solar energy.

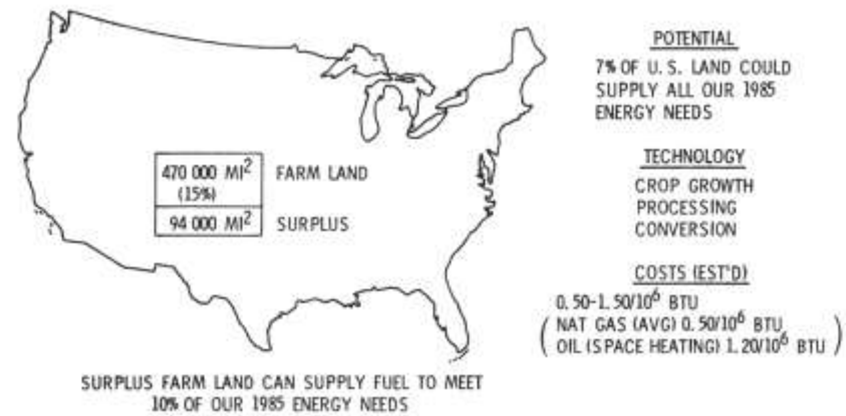


Figure 18. - Clean renewable fuel from solar energy.

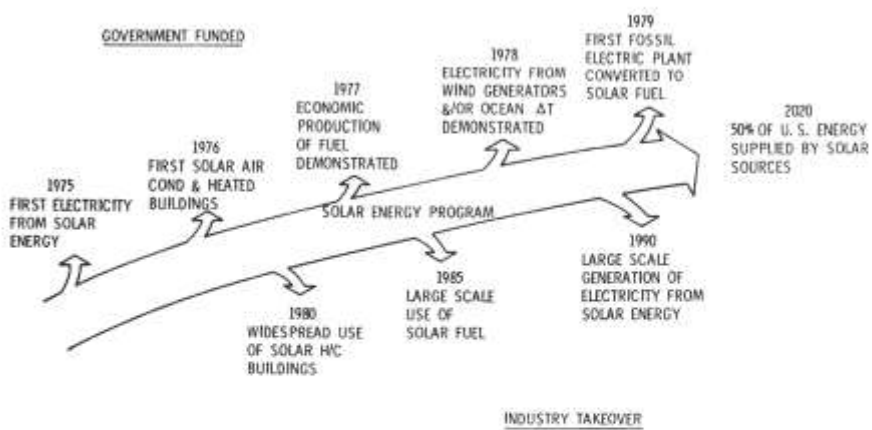


Figure 19. - Solar energy program milestones.

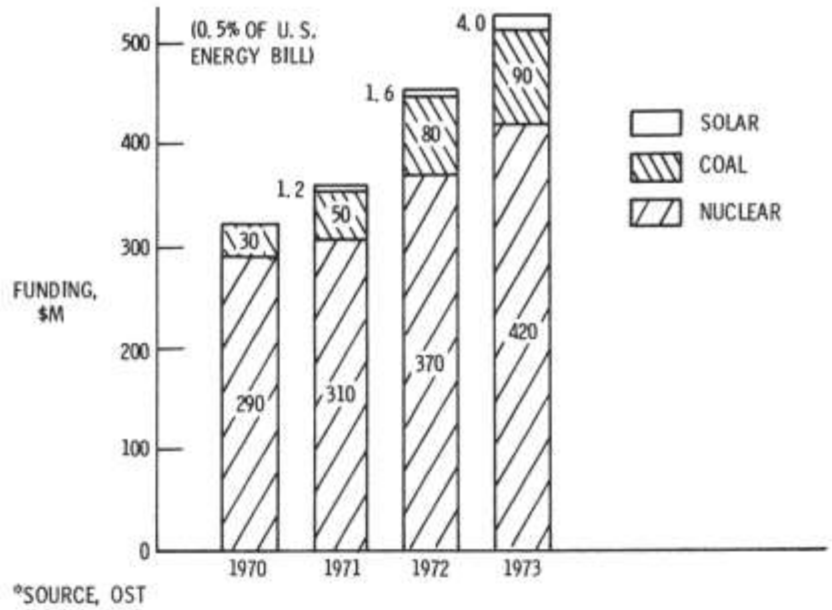


Figure 20. - U.S. energy research and technology funding[a].

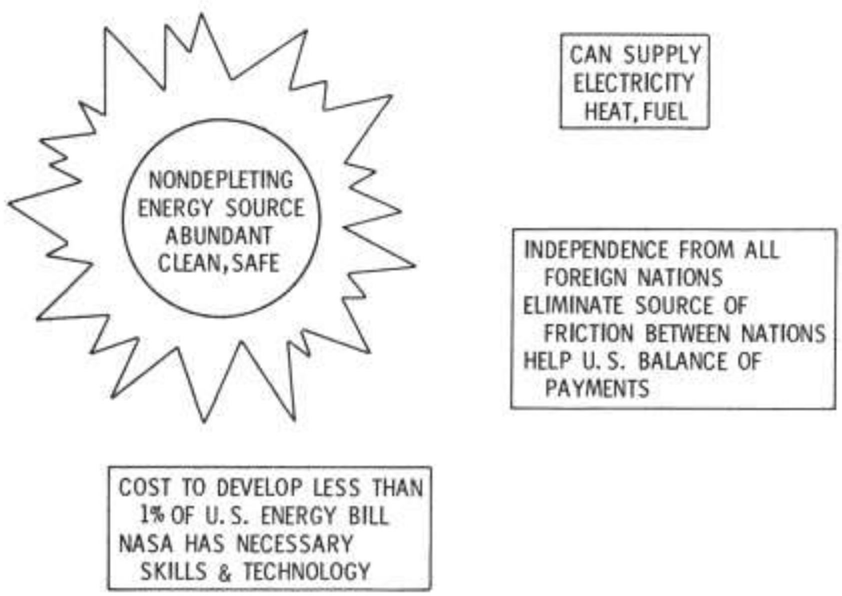


Figure 21. - Solar energy program summary.

NASA-Lewis-Com'l

NUCLEAR ENERGY

Dr. Bruce H. Van Domelen
Western Interstate Nuclear Board

There are many ways in which nuclear energy can contribute to the solution of the energy problems which lie ahead, both in New Mexico and in the nation as a whole. Some of these are in use today, while others are being studied with an eye toward the future. Today, we will discuss in some depth the most significant use of nuclear energy; namely, the generation of electricity from the present generation of nuclear fission reactors. We will emphasize the nuclear fuel cycle, the points of that fuel cycle of greatest interest to New Mexico, and comparison of nuclear and fossil fuel power plants. We will also discuss, although more briefly, the possibility and the status of nuclear energy from the breeder reactor and the fusion reactor, as well as the use of nuclear explosives to produce natural gas and oil from oil shale.

FISSION POWER AND THE NUCLEAR FUEL CYCLE

The most important use today of nuclear energy in the United States is for the production of electrical energy through the use of the fission process in nuclear reactors and this is the area we will now cover.

The first, and only, slide shows you a schematic of the nuclear fuel cycle. As you see, uranium ore is mined, then passed through mills where it is concentrated into a product called "yellowcake" which is some 90% uranium oxide (U_3O_8).

The yellowcake is then sent to plants where it is further purified and converted into a gaseous form, uranium hexafluoride.

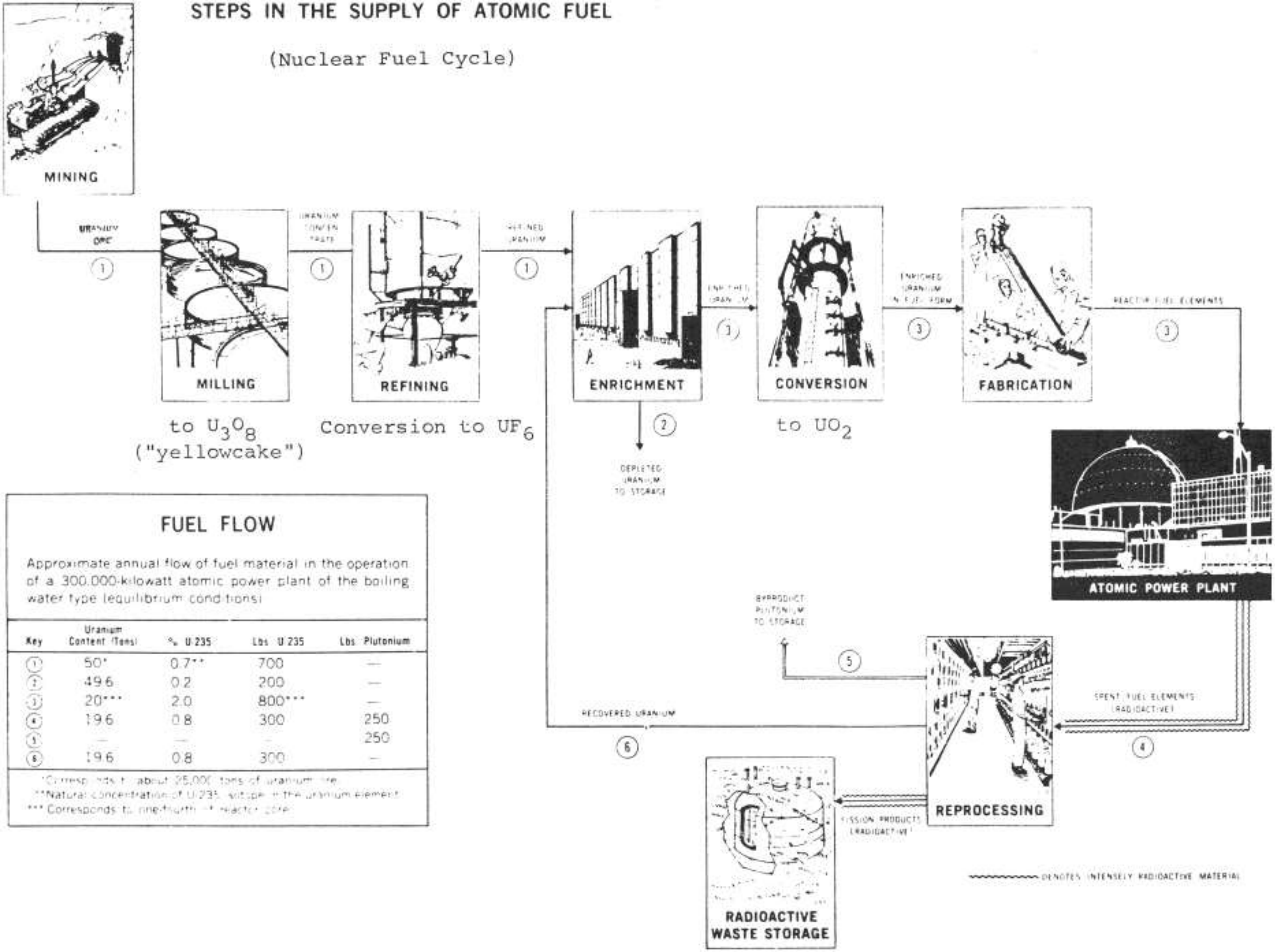
The uranium hexafluoride is then shipped to one of the three Atomic Energy Commission plants in Oak Ridge, Tennessee; Paducah, Kentucky, or Portsmouth, Ohio, where it undergoes a process known as enrichment. In normal uranium the fissionable isotope, U 235, is present to an extent of only 3/4 of 1%. However, for use in modern light-water reactors or gas-cool reactors, the fuel must be enriched to contain 2-4% of the isotope U 235 in the light-water reactors and over 90% for use in the gas-cooled reactor. This enrichment is accomplished in plants known as diffusion plants.

After the uranium is enriched, it is then shipped to fuel fabricating plants where it is reduced to uranium-oxide; in this case UO_2, and made into fuel elements. These fuel elements consist of bundles of zirconium tubes. Typically, these tubes are approximately 1/2 inch in diameter and 10 to 12 feet long. They are filled with pellets of UO_2 about an inch long. After assembly, these fuel rods are shipped to a nuclear reactor site where they are placed in the reactor and used to generate electricity.

Once a year the reactor is shut down and approximately 1/4 of the partially-depleted fuel rods are unloaded. These are highly radioactive; but after a suitable cooling period at the reactor site, they are shipped in large casts to a reprocessing plant. There, a by-product, plutonium is separated from the uranium as are the fission products which are the main source of the radioactivity. The remaining uranium is then re-enriched, either with highly-pure U 235 or with the by-product plutonium, and goes back through the cycle again--through the fuel fabrication, into the reactor, etc. The highly radio-reactive fission products,

STEPS IN THE SUPPLY OF ATOMIC FUEL

(Nuclear Fuel Cycle)



FUEL FLOW

Approximate annual flow of fuel material in the operation of a 300,000-kilowatt atomic power plant of the boiling water type (equilibrium conditions)

Key	Uranium Content (Tons)	% U 235	Lbs U 235	Lbs Plutonium
(1)	50*	0.7**	700	—
(2)	49.6	0.2	200	—
(3)	20***	2.0	800***	—
(4)	19.6	0.8	300	250
(5)	—	—	—	250
(6)	19.6	0.8	300	—

*Corresponds to about 25,000 tons of uranium ore.
**Natural concentration of U 235 isotope in the uranium element.
*** Corresponds to one-fourth of reactor core.

the waste materials, are stored at the reprocessing plant for up to ten years and then will be disposed of in a Federal repository. We will discuss this in more detail shortly.

It is of interest to note at this time, New Mexico is involved in both the beginning and the end of the fuel cycle; the beginning through the mines and the mills, which are located in New Mexico producing yellowcake, the end through the feasibility studies which are now being done by the Atomic Energy Commission at Carlsbad, to see if it is a suitable site for a waste-management pilot plant.

POINTS OF INTEREST TO NEW MEXICO

We shall now discuss those points of greatest importance to New Mexico; namely, the mining and milling, the waste management, the enrichment process, and the possibility of nuclear power in New Mexico.

Mining and Milling

The area of mining and milling is currently of great importance to New Mexico. It is also an interesting subject which will be discussed with you tomorrow by Mr. David Fitch. Today, I shall merely highlight this area for you.

New Mexico has consistenly remained the nation's greatest producer of uranium, producing thus far well over half this nation's supply of uranium. Although this year, Wyoming outranked New Mexico in exploration, New Mexico again ranked first, both in the production of ore and in the production of yellowcake. In the area of exploration, Wyoming accounted for 43% of the total footage drilled while New Mexico accounted for 23%. In the production of ore, New Mexico produced 41% versus Wyoming's 33%; and in the production of yellowcake New Mexico accounted for 43% versus Wyoming's 25%. As you can see, these two states alone account for about two-thirds of the total mining and milling in the United States.

Waste Disposal

Next in importance and possibly of greatest interest is the consideration of salt beds east of Carlsbad for a waste-management pilot plant. Basically, the problem is this, there are nuclear power plants currently producing depleted fuel from which, after reprocessing, waste fissionable materials remain. The amount of this waste will increase as more nuclear power plants come on line.

If one agrees that nuclear power is necessary to help solve the energy crisis, then one must find a means to isolate these wastes from the biosphere for thousands of years. Most people agree that there should be a single depository for these wastes rather than many scattered across the country. To develop such a depository, the AEC in 1961 began investigating the possibility of burying wastes in a bedded salt deposit near Lyons, Kansas. About 2 years ago, the Lyons project was terminated for both technical and political reasons. This left the nation with a problem--what to do with the first wastes which would be scheduled for burial in the early 1980's?

The AEC assessed this problem and last spring proposed a policy which would take care of the immediate wastes on a temporary basis (storage) while providing adequate time, possibly as long as 50 years, to evaluate and select a permanent means of caring for the wastes (disposal). The Atlantic Richfield Company at Hanford, Washington is studying possible storage concepts. I'll describe two of these for you.

The first is called Retrievable Surface Storage. The waste will arrive in canisters about a foot in diameter and ten feet long. These will be stored in concrete vats of water located at or just below ground level. The circulated water will remove the generated heat which initially is about 5 kilowatts per canister. A few canisters will arrive in 1983. This rate will rise to about 1000 per year by 1990 and 3000 per year by the year 2000. If a permanent disposal method has been established, the canisters will be removed and placed in the disposal site.

Another storage technology that I shall call the Gun Barrel technique has only recently been proposed. Steel cylinders about 4 feet in diameter and roughly 15 feet in length would have a centerhole large enough to accept a canister. These gun barrels would be capped and sealed and then stored on racks in an open, dry, isolated location such as the Nevada Test Site. This concept is attractive from several points of view: power failures, earthquakes, maintenance, etc., become trivial concerns. In fact, even extreme accidents such as a 747 crashing into a mass of steel gun barrels doesn't really upset anyone.

These and other storage alternatives are now being considered. By the late 70's one will be selected, a site chosen, and construction commenced. Meanwhile, the permanent disposal techniques will still be under evaluation. This responsibility falls upon Battelle Northwest at Hanford. They are comparing a number of alternatives and will report initially on their studies this fall. One can expect that this report will delete some alternatives from further consideration. One can also expect that other alternatives will be recommended for further, more detailed evaluation. In addition, one or two alternatives, such as domed salt, will be recommended for preliminary experimental investigation; and the bedded salt disposal will be recommended for immediate experimental evaluation. Carlsbad is one of several bedded salt sites, including some in Kansas, being evaluated as potential disposal sites. If one of these meets the necessary criteria, an experimental or pilot plant will be proposed. In-this concept, a cavern is carved into the salt bed, holes to receive the canisters are drilled into the floor of the-cavern, the canisters are inserted, and the cavern is backfilled with salt. During the experimental phase, the holes will be lined with steel cases so that the canisters can be retrieved if experimental results show that this technique is not feasible.

At the present time, the Oak Ridge National Laboratory has the technical responsibility for bedded salt disposal and is carrying out some exploratory drilling and seismic studies of the Carlsbad site. If all results are favorable, construction of the experimental pilot plant would begin about 1975. At the earliest, it would be about 1983 before any canisters are stored. I would guess that at least another five to ten years would be required before this technique could be judged safe for permanent disposal. In other words, if everything proves out, it would be about 1990 before any permanent disposal could be authorized for the Carlsbad location.

The waste management problem is not only a national problem, but also a regional and state problem since it affects the energy supply of every state in the nation, either directly or indirectly. I believe if a state, like ours, has a site which may safely solve this problem, then we have an obligation to at least evaluate the possibility. Conversely, we must also have the right to participate in the evaluation and decision process; so that we, the citizens of New Mexico, are assured that a complete and satisfactory evaluation has been made. The AEC recognizes that this participation is not only desirable but necessary; and they have made every effort to encourage the participation of the western region and, in particular, the State of New Mexico.

On a regional basis, the Western Interstate Nuclear Board (WINB) is keeping informed of AEC actions and advising the AEC to pursue studies and alternatives which WINB believes are in the interest of the western states. Yesterday, at its annual meeting, the WINB passed a resolution-which will be sent to the western governors, the

Western Congressional Delegation, and the AEC. If we skip all of the whereas's, it essentially recommends: (1) the approval of the AEC.policy of fully-retrievable interim storage, with continuing research and development to pick the best method of alternate disposal; (2) support of a pilot plant project in bedded salt after careful evaluation and study of alternative sites to select the best potential site; (3) continued study and R&D on alternate methods of disposal oriented towards providing viable alternatives to bedded salt disposal, and (4) encouragement to the AEC, with an offer of WINB's assistance, in attempting to develop meaningful forms of public participation and education in the second and third items above.

The WINB also officially supports Governor King's Technical Excellence Committee (G-TEC) which Governor King has asked to work with the AEC in order to see that "The Committee ensures that all facets of the problem have been studied and resolved by the best talent that can be brought to bear upon such problems as: environmental impacts, safety, the matter of transportation, etc. Second, the Committee establishes procedures, whereby, all persons who feel the need to express opinions and offer suggestions are given an opportunity to do so, and that the channels of communication are known and readily available to the public. Third, that the procedures include a method by which the public can be kept informed on an interim basis as to the problems being examined and the proposed solutions to whatever degree the Committee deems necessary. The term "public" should be interpreted in its broadest terms.

"As a general conclusion I think the Committee can operate under the principle that the State of New Mexico is one of the most logical locations for the national repository; that the repository be located in the state only when we can be reasonably assured as to the safety of the operation and that the methods have been devised to minimize the impact upon the environment in both the short- and long-range problems." The G-TEC consists of Gerald Thomas, Stirling Colgate, Ferrel Heady, Morgan Sparks, Robert Rowden, Louie Rosen, and Sam Donnelly. The G-TEC will have a subcommittee to carry out the technical evaluations. The tentative chairman of this subcommittee is Dr. Gale Billings of New Mexico Tech. Gale was involved in the technical evaluation of the Lyons, Kansas site and, in my opinion, is an excellent choice for this responsibility.

In summary, the Carlsbad site is one of several being evaluated for possible location of an experimental pilot plant. If selected, the pilot plant construction would begin in the late 70's. Retrievable canisters would first be stored about 1983; and if the evaluations are acceptable to all parties concerned and better than any evaluated alternatives, permanent disposal might begin by 1990.

Enrichment Plants

Another point related to fission reactors and of some, but lesser, importance to New Mexico is the location of an enrichment plant in the western states. AEC predictions indicate that another enrichment plant is desirable by about 1982 and that the logical location for such a plant is in the western region. Because of the time frame required for financing, construction, etc., decisions must be made within the next one to two years as to the feasibility of private industry building these plants and where they will be located. The plants themselves are clean, non-polluting, and safe. The problem, of course, comes with providing the 2500 megawatts of power needed to run the plants. Whether this is best done by an electrical generating plant in conjunction with the enrichment plant or whether it is best done by transmitting the power from somewhere else is hard to say. Again, it depends on many tradeoffs. A number of companies are now cooperating with the AEC in studies on the costs, feasibility, etc., of plants of this type; and I personally expect that some time within the next two to three years construction of such a plant will start. These plants are diffusion plants as opposed to the gas-centrifuge plants being considered in Europe.

The gas-centrifuge approach in Europe is at the pilot plant stage. The main advantage of this technology is that much less power is required, about a factor of 10. The capital costs and maintenance costs, however, are somewhat higher than for gaseous diffusion. The main technical problem appears to be in the expected life of the rotors which are required to operate at speeds of 100,000 rpm or more. Because of the time scales involved and the experience already available for diffusion plants, it's highly unlikely that gas centrifuges will be considered for the next enrichment plant in the United States. However, it is likely that a western state will be considered for the location of the next enrichment plant; Alaska and Wyoming have already been formally approached by companies interested in establishing enrichment plants in these states.

Nuclear Power for New Mexico

The last point, which I am sure is of interest to all of you, is whether a nuclear power station will or should be built in the State of New Mexico. This is a question which has no simple answer because it is up to the people of the state to determine where their priorities are. The question of a nuclear reactor versus a fossil fuel plant is one which needs to be decided on an individual basis.

This leads us into the next topic of the discussion, the comparison of the nuclear and fossil fuel plants. Based upon this discussion, you yourselves should consider whether you desire fossil or nuclear power for New Mexico.

ADVANTAGES AND DISADVANTAGES OF NUCLEAR POWER

There are three clear-cut advantages which a nuclear power station has over a fossil fuel station. First, there is no pollution, or at least there is little emitted from the plant itself. There is some small amount of radiation, about 1/20 of the natural background; but this is hardly measurable beyond the plant boundaries.

Second, the fuel cost is less than 1/2 that for a fossil fuel plant; and the availability of nuclear fuel appears to be much greater than that for fossil plants. I am sure you are aware of the potential natural gas shortage, the shortage of fuel oils, and the difficulty of getting low sulfur fuel or being allowed to mine coal in those areas where it must be strip mined, and the problems of removing sulfur dioxide from flue gases.

The third clear-cut advantage of the nuclear power station is that it is physically smaller than a fossil fuel station of the same capacity, and therefore can be designed to be more environmentally compatible with its surroundings.

There are also three clear-cut disadvantages of a nuclear power station. First, the capital costs are about 20% higher than that for a comparable fossil fuel plant. This gives rise to a tradeoff between nuclear and fossil fuel plants. When the particular site chosen places predominant consideration on capital costs, fossil fuel plants are preferred; and conversely, when the location places preference on fuel costs, the nuclear plant is preferred.

Second, at least at the present time, the nuclear industry is having difficulty in meeting schedules, and nuclear power stations are running two or three years behind scheduled completion dates. Fossil stations are also running behind schedule, but can be brought on line about 3 years sooner than the nuclear plants. Although there has been considerable environmental concern expressed about nuclear power stations, so far interventions have not been the major factor in the delay of the stations, at least with most of them.

Third, because of the lower efficiency of the thermal cycle in a nuclear reactor, a greater supply of cooling water, almost 50% more, is required than for a fossil station. This is an important consideration for many of the western states. However, one case where this is not true is the high-temperature, gas-cooled reactor. Here, efficiencies equivalent to that of fossil-fired stations can be obtained. A plant of this type is going on line sometime late this year in the State of Colorado, the Fort St. Vrain Plant. Operating experience from this will contribute significantly to the knowledge of these plants. Four others have been sold, but the starting dates are quite a ways off in the future. This type of station will be particularly attractive for the West since it will require no more cooling water than a comparable fossil station.

Thus, the advantages of nuclear are negligible pollution, low fuel costs, and stations compatible with their surroundings. The disadvantages are: higher capital costs, longer construction schedules, and the need for more cooling water.

PUBLIC ACCEPTANCE

There is however another problem, public acceptance. Although this applies to both fossil and nuclear plants, it seems to have focused more strongly on the nuclear plants. Since these issues relate to the acceptance of nuclear stations, they should be mentioned, as well as some of the similar issues related to the fossil stations.

Radiation

The first issue was the public's fear of low-level radiation from nuclear plants. This no longer seems to be an issue because the public has become educated in this area and existing technology has allowed the radiation levels to be decreased a hundredfold. The average radiation dose to an individual from all nuclear power plants is about half a millirem per year. By comparison, that from natural background is about 140 and that from medical diagnosis is about 90. The comparable fossil issue is, of course, air pollution.

Thermal Pollution

Then, for awhile, the issue was thermal pollution or the fear that the temperatures of rivers and lakes would be raised so high that there would be damage to the ecology. This issue has been pretty well resolved through the use of cooling towers and the use of man-made lakes and canals where the cooling water is recirculated. It's interesting to note that, at the time this was an issue, the thermal pollution from fossil stations was about 30 times that from nuclear stations; yet this never became a public issue.

Safety

At the present time the main issue is safety--are nuclear plants safe enough? This is an extremely difficult question to deal with because we are faced with a situation where the probabilities of a really serious accident, which would pose a threat to the public, appear to be very small; but the consequences of such an accident, remote though it is, could be very large. The question is--how safe is safe enough? So far, an answer has not been determined.

Waste Disposal

People are also concerned over the problem of long-term storage of the highly-radioactive wastes resulting from the fission process. As we discussed, these must be isolated from the biosphere for thousands of years, and the method for doing this has not yet been chosen. There are a number of alternatives which are being studied besides storage in bedded salt: burial in polar ice fields, deep underground storage (10,000'), storage in shale or granite, sending the wastes into space, and chemical separation of the more dangerous isotopes followed by nuclear transmutation to relatively safe isotopes.

The policy of the AEC has been designed to provide time to select the best method for final disposal. In order to do this, interim storage facilities are being considered which will accommodate the wastes produced in the commercial reactor until the final disposal method is fully evaluated and tested. These wastes in the interim storage facility will be fully retrievable and carefully monitored.

Transportation

Finally, another issue is the transportation of radioactive materials during the various steps in the nuclear fuel cycle. This is not presently a strong issue because the shipping casts are well-developed and capable of withstanding almost any conceivable accident. Even in the event of a materials release, the danger would be small and confined to the local area since the materials are not highly toxic. However, this issue becomes of more importance with the advent of the fast breeder reactor, discussed later, since this involves the handling and shipping of large amounts of plutonium. This isotope, ingested in the body, is a deadly poison because of the alpha radiation it emits. In addition, only a few pounds are needed to make an atomic bomb. Because there will be large amounts of plutonium formed in the fast breeder reactors, the problems associated with it are large and are the subject of intensive study in the AEC, the nuclear industry, and state government. The WINB has established a committee to address this problem on a regional basis for the western states.

FUTURE FISSION

CONCEPTS Nuplexes

Let us now discuss a couple of projects which are being considered in conjunction with fission reactors. The first of these is the nuplex. This is an industrial site which is designed around a nuclear reactor. One of its chief purposes is to use the 2/3 of the heat which is not converted to electricity and rejected from the reactor. Now, it's difficult to do this because it usually is a very low-grade heat. It comes in the form of water which is only 15 to 20 degrees above that in the river, lake, or ocean which is being used to cool the reactor. However, studies have been done on the use of this water for agricultural purposes, and there appears to be promise for the future. Studies in Oregon, sponsored by the Eugene Electric Water Board, have shown that, for many crops, the planting season can be advanced several weeks and the growing season can be extended a couple of weeks by the use of warm water for irrigation; and in addition, the growing rates of the plants are higher. This heated water can also be used to raise fish, clams, and lobsters at a faster rate. In other words, the heated water, if controlled and if used properly, may turn out to be a benefit rather than a a hazard to the ecology as is now assumed.

Power Parks

Another concept which has been considered is power parks. This is a number of reactors located in the same area and having their own fuel-fabricating facilities, reprocessing plants, and low-level waste disposal sites. By the days of the breeder economy, these power parks could be essentially self-contained if they also have their own high-level radioactive waste disposal mechanisms on site. The desirability of this is that it would alleviate potential safety problems caused by the shipment of high-level radioactive wastes around the country.

FUTURE NUCLEAR ENERGY SOURCES

The Breeder Reactor

What about other future forms of nuclear energy? The major thrust at the moment by the utilities, the Atomic Energy Commission, and the nuclear industry is toward the development of the liquid-metal fast-breeder reactor of LMFBR. A prototype which will produce some 500 megawatts of electricity will be constructed in the South on land owned by the Tennessee Valley Authority and should be ready for operation in the early 80's.

There are two major advantages of this type of reactor. One is that because of the use of liquid metal sodium, which provides high-operating temperatures, the efficiency will approach that of modern fossil-fueled power stations, about 40%. Second, and perhaps most important, is that the LMFBR will produce, through a nuclear process called breeding, more fissionable material than it burns up in producing power. This can be accomplished because, in the process of fission when the uranium atom splits, it produces 2-1/2 neutrons. One neutron is needed to continue the chain reaction, that is, the fission of another nucleus of uranium. This leaves 1-1/2 neutrons which can be used for other purposes. By proper design of the reactor, these other neutrons can be absorbed in the plentiful isotopes of uranium 238 or thorium 232 which then become the fissionable isotopes of plutonium 239 or uranium 233. These can then be used as a fuel for nuclear reactors. This is a great example of "lifting yourself up by your own boot straps."

The Fusion Reactor

Another development, and one of the greatest hopes for the future at this time is the use of fusion reactors. These have a tremendous potential advantage; for their fuel is heavy water (deterium) and there is enough of this in the oceans to meet power needs, literally forever. However, despite this potential, one must recall statements first made by the nuclear industry over 20 years ago. At that time the use of fission reactors was going to solve the problems of the world, unlimited energy, very cheap, no problems--everything looked rosy. Today, that promise may still be true, particularly if the fast-breeder reactor develops according to schedule; but nonetheless the industry is still faced with very real problems. There have been many of those engineering details, with which we are familiar, which have raised their heads from time to time. There have been great problems with public acceptance. Costs are much higher than were expected, and time scales are much longer. All in all, even though the promise is still there and will probably be fulfilled, the road has been difficult.

If one looks at fusion energy from the same point of view, we are not today where fission energy was in 1942. In other words, there has been no Chicago pile. Although the mathematics and the physics, and indeed the existence of the hydrogen bomb itself indicate that fusion power is theoretically attainable, no one has been able to produce this in practice. So far no one has produced a fusion reaction in the laboratory in which more energy is emitted than is required to cause the reaction to take place. Even assuming it proves feasible and the principle can be demonstrated, there will be many difficult years of engineering before a power-producing reactor can be put on the market. There are technical problems which have not as yet been seriously tackled. There may be others that are unknown. Materials will be required which will have to operate at very high temperatures and under an intense neutron bombardment. These are problems that will require considerable time to solve.

In the March issue of "Physics Today," Richard F. Post, Leader of the

Controlled Fusion Research Division of Lawrence Livermore Laboratory, stated that, without a fusion program comparable to the NASA space effort of the 60's, the earliest that fission reactors could be expected is the year 2000.

I don't mean to sound pessimistic; for fusion power is the most promising energy source. The point is that it is premature to count upon fusion to solve our energy problems until the beginning of the next century. In the meantime other energy sources must be developed and brought on line.

Natural Gas Stimulation

Another use of nuclear energy is the Plowshare experiments to stimulate natural gas flow from impervious formations by use of nuclear explosives. This has been demonstrated to be technically feasible; but again, society must ask itself--are we willing to pay the price? Are the citizens of New Mexico, Colorado, and Wyoming willing to have hundreds, perhaps thousands of nuclear detonations fired in their states in order to provide natural gas for the nation? As far as one can tell today, there are few, if any, safety problems. Presumably, administrative systems can be set up to handle damage claims for seismic effects. However, many citizens in Colorado and in other western states are still concerned about the long-range future. They remember the problems with the uranium tailings in Grand Junction, the fire at the Rocky Flats Plant, etc. So, even though these technologies are feasible and may be economically justifiable, there will be serious problems with social acceptance.

Another question which the WINB has attempted to approach in its technology assessment of the Plowshare program, done with financial support from the National Science Foundation, is whether there is actually a net gain in energy from the use of nuclear devices to stimulate natural gas. There is little question but that there is an increase in the amount of natural gas which can be produced. On the other hand, if the plutonium or uranium used in the nuclear explosives were instead used in reactors to generate electric power, there would be considerable energy produced there, too. Which is the greatest, the energy from the explosives or the energy from the natural gas produced? Unfortunately, due to national security restrictions, we cannot answer this question because the answer depends upon the efficiency of the nuclear device which is classified.

However, you can gain some insight by assuming certain efficiencies. If you assume it to be 100% efficient; in other words, all the fissionable material in the device is converted to explosive energy, calculations indicate there would be an increase in total energy of some 26 times. The amount of this increase of course becomes less as the efficiency of the nuclear device becomes less. The crossover point, the point at which the energy available from the amount of fissionable material in the device is equal to the amount of energy available in the natural gas produced, occurs at something like 20% efficiency.

ENERGY POLICIES

Remember, earlier in the discussion we asked if New Mexico would have nuclear power. As you can see the question is easy, the answer is difficult. Even in just the nuclear area, there are complex tradeoffs between nuclear vs. fossil, and even nuclear vs. nuclear. When one adds to this all the other possible energy sources, the problem of finding the right answers becomes staggering. However, these answers must be found, and the means of doing this is the establishment of energy policies. These policies must consider the technical, economical, social, environmental, and political factors that are involved. You'll gain considerable weight into the difficulty of this problem tomorrow when Frank DiLuzio discusses the process of evolving an energy policy for New Mexico.

OIL AND GAS ENERGY AND ITS IMPACT ON NEW MEXICO

William J. LeMay
Consulting Geologist

Historically, New Mexico has been a net exporter of energy. Among all 50 states, New Mexico ranks 6th in production of crude oil, 4th in production of natural gas, and 3rd in production of natural gas liquids. With such high national rankings and with a population of slightly over 1 million people, it is obvious why our state is a net exporter of oil and gas energy.

This enviable position benefits our state in many ways--mainly in our state treasury. New Mexico's oil and gas industry is the greatest single source of revenue for the state. Oil and gas receipts rank 3rd behind gross receipts taxes and state income taxes, in the State's General Fund revenues, the majority of which is spent for educational purposes. Approximately 95% of our State's Permanent Fund can be traced to revenue derived from oil and gas, and total petroleum industry taxes and other oil and gas revenues amounted to over $100 million in 1971. The petroleum industry employed over 15,000 people in 1971. It is obvious that oil and gas plays a critical part in New Mexico's economy.

Will our valuable petroleum reserves dry up tomorrow? Hardly. Without new oil and gas discoveries, however, our reserves and producing capacity will be insignificant within 10 years. It is a fact that New Mexico, as well as most oil and gas producing states in this nation, are producing more crude oil and natural gas than they are finding. This, combined with projected increases in demand, constitutes what is commonly referred to as the "Energy Crisis". It is also true that the 1960's saw a progressive decline in the number of wells drilled in the nation as a whole as well as in New Mexico. You cannot find oil and gas without spending the money to drill for it. Consequently, it is natural that our net reserves have decreased over the past 10 years. In my opinion, the following factors have accounted for this decline in New Mexico's petroleum reserves:

1. The more obvious oil and gas fields were discovered early. Most of the lucrative Devonian structures in southeast New Mexico were defined by the seismograph and drilled in the 1950's. By the early 1960's well density in the northwest and southeast producing areas of the state was sufficient to classify these areas as mature petroleum provinces, producing a psychological impediment to extensive exploration.

2. Unrealistic governmental policy has reduced incentives for direct investment in oil and gas. Product price has not kept pace with inflation and tax incentives have been reduced by Congress.

3. The petroleum industry has not found commercial oil and gas in virgin basins. Discoveries are still confined to the state's two old producing areas, the northwest and the southeast.

One may place greater or lesser emphasis on any one of the three points but all have contributed to the decline in drilling and the reduction of reserves.

Signs of optimism have emerged on the horizon during 1972 which will effect the New Mexico oil and gas picture. Prices paid to producers for natural gas have increased and by all projections, should increase further in the future. The American public is cognizant of our energy shortages and this should produce a friendlier climate in Washington toward legislation effecting oil and gas interests. This optimism has been translated into increased drilling, reversing the downward cycle of the past decade. Very tangible results have emerged being an increase in the state's natural gas reserves at higher well-head prices. Two exploration "plays" in southeast New Mexico serve as examples for renewed optimism.

<u>Queen Gas Play:</u> In southeast Chaves County, New Mexico, approximately 35 miles southeast of Roswell, in an area of approximately 450 square miles, I have estimated a recoverable gas reserve in the Queen Formation of approximately 130 billion cubic feet. This reserve occurs in stratigraphic traps at depths ranging from 1600 to 3300 feet Only recently has this gas become commercial because of increased product price. The gas is poor in quality (low BTU) having a heating value of approximately one-half that of average gas. Dry holes have been and will be drilled in developing this reserve because of erratic changes in the Queen sand reservoir. Numerous independents are currently active in this play and I would anticipate continued future acceleration of drilling activity. The Queen gas play is a classic example of natural gas energy which could not be economically exploited until the price structure made it profitable to do so.

<u>Lower Pennsylvanian Sand Play:</u> Without a doubt, the hottest play in New Mexico is the search for Lower Pennsylvanian age gas sands in Eddy, Lea and Chaves Counties. It is no coincidence that over 300 billion cubic feet of gas reserves have been discovered in Lower Pennsylvanian sandstones in 1972, a year which saw the well-head price of newly discovered natural gas roughly double. Prior to January 1, 1972 these sands had produced less than one-half trillion cubic feet of gas with remaining reserves of approximately 200 billion cubic feet. I have estimated that within the past year, remaining reserves from these sands have more than doubled and the play is just starting. Tempted by high prices and a very favorable success ratio, operators are risking up to a million dollars per well to explore for gas in these discontinuous and erratic reservoirs. The sands were deposited in ancient stream channels, flood plains and deltas, and have been subjected to extensive modification since deposition and burial. Thus, their predictability is poor, even within distances as short as half a mile. Because the Lower Pennsylvanian interval (Atoka and Morrow in age) usually contains 3 or more 10-foot thick sands, the chances of finding commercial gas in at least one of these sands is about 1 in 4--an exceptionally low risk factor for this business.

I would predict that approximately 4 trillion cubic feet of additional gas reserve will be discovered in the next 10 years from Lower Pennsylvanian sands. This is approximately 1/3 of New Mexico's current total reserve of natural gas. It is about 1-1/2% of the nation's total gas reserve and is enough gas to supply all of our nation's gas needs for 64 consecutive days. It represents over 1.5 billion dollars in product, much of which would be deposited in the state's treasury in the form of taxes and royalty. The state is already benefiting by the increased price companies must pay to successfully purchase state leases at the competitive state land sales held each month. There are additional benefits to local economies such as in Carlsbad where merchants and service contractors are experiencing increased business generated by the recent development of the South Carlsbad gas field.

The above are examples of tangible reasons for optimism in our search for new supplies of natural gas. I believe similar examples of oil will be forthcoming if the well-head price of oil is allowed to rise in the marketplace. Marginal reserves will be exploited and new plays will develop if the incentives to drill are present.

(continued)

My optimism is reserved for only 10 more years in New Mexico unless commercial oil and/or gas is discovered in virgin areas. Many areas of our state have petroleum potential but exploration to date has been only superficial. Drilling density of one well per 30 to 100 square miles is common in our state's virgin sedimentary basins. We need oil and gas discoveries in these virgin areas to sustain or increase the state's present petroleum prosperity beyond the next 10 years. State policy can and should incorporate incentives toward this end.

New Mexico's oil and gas reserves are critical to our state's economy and important to our country's energy needs. We cannot afford another decade like the previous one. We must accelerate the search for hydrocarbons and that means drilling more wells. Even with a major effort there is no guarantee that our oil and gas will last indefinitely. In fact, fossil fuels are a finite quantity and eventually our energy needs must be satisfied by other means. When will that be? 20, 50, 100 years? No one knows. Exotic alternatives to fossil fuels are still extremely expensive if the technology is available at all and the American consumer demands energy which is reasonably priced. The day of cheap energy is over but energy at an excessive price is an unattractive alternative. A national energy policy which reflects risk incentive and a free market product price, will go a long way in narrowing the energy gap between supply and demand for at least the next 20 years. The people of our country and particularly New Mexico taxpayers will be the beneficiaries of such a policy.

HYDROELECTRIC POWER GENERATION IN NEW MEXICO

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Bureau of Reclamation
Rio Grande Project

There are only a few hydroelectric powerplants in the state of New Mexico. The majority of these powerplants are used only for station power or are on standby. The powerplant at Elephant Butte is the only one producing power commercially in New Mexico. Of the total installed nameplate capacity in the state, the powerplant at Elephant Butte represents less than 3 percent of the total.

The dam and powerplant at Elephant Butte were built and is operated by the Bureau of Reclamation.

This project, like most hydro-installations, is multipurpose in nature and meets the needs of supplemental water for municipal and irrigation use, additional electrical energy, additional protection from floods along the Rio Grande River below the dam, and recreational resources.

A total of 20,135,930 KWH of smog-free electrical energy was produced in 1972. Listed on Figure 1 are the energy products for the powerplant for the years from 1942 to 1972. The highest output was in the calendar year 1942 when 136,176,556 KWH was produced and the lowest was in calendar year 1964 when 9,437,840 KWH was produced.

The output of electrical energy from the powerplant is governed by the water level (acre-foot storage) in the reservoir. Figure 2 shows the output of the powerplant and kilowatt hours per acre-foot of water as a function of reservoir water level. The plant has a rated capacity of 24.3 KW at a reservoir elevation 4,347.00. The present reservoir elevation is approximately 4,327, which will generate approximately 100 KWH of electrical energy without pollution of the environment or consumption of nonrenewable resources for each acre-foot of water released through the turbine.

The effects of Elephant Butte Reservoir on the climate is small and confined to the area immediately surrounding the reservoir. Only those areas within a few hundred yards of the reservoir experience a change in climate conditions because of the reservoir's presence. The large body of water will bring a more permanent presence of moisture in the air immediately adjacent to this area and will cause generally cooler days and warmer nights with slightly higher relative humidities.

The project has accelerated land development in the area. Many permanent residences and summer homes have been built along the west shore of the reservoir.

The increased public use of the area increases the potential of erosion and vegetation damage. Also increased public use of the area increases the risk of fire.

The reservoir will alter the temperature of the water in the river below the dam. The temperature of the water is lowered. Visitation to the dam and surrounding recreational area will result in an increased noise level. Operation of the dam and powerplant are not a major noise source.

A comparison of the adverse effects on the environment that are associated with a hydroelectric powerplant, a nuclear powerplant, and a fossil-fueled steam-electric powerplant is shown on Table 1.

Table 1 - Comparison of Adverse Effects on Six Environmental Perimeters of Hydro, Nuclear, and Fossil-Fuel Powerplants

Adverse Effects on Environment	Hydro Power Plant	Nuclear Power Plant	Fossil Fuel Steam-Electric Powerplant
Land Use	yes	yes	yes
Major River Regul.	yes	no	no
Thermal Pollution	no	yes	yes
Air Pollution	no	yes	yes
Radioactive Waste	no	yes	no
Consumes Natural Resources	no	yes	yes

The Rio Grande and its tributaries have produced a great volume of water in the past which contributed to bank erosion and flooding in areas below the dam site.

The dam, which was completed in 1916, is a 301-foot high, straight gravity type structure. The crest length is 1,162 feet and a total of 629,500 cubic yards of material was used in the construction of it. The original capacity of the reservoir was 2,638,860 acre-feet of water, but the capacity has decreased to 2,248,531 acre-feet in 1970. From the decrease in the capacity of the reservoir it can be seen that high sediment flows have been trapped in the reservoir. The quality of water in the river below the dam has been improved by the impounding of water-borne sediments.

The powerplant is operated on a schedule governed by water releases for irrigation. A total of 157,000 acres of land is under irrigation below the dam. The demand for irrigation water on the project is about 3 acre-feet per acre annually under normal conditions.

The reservoir is located approximately mid-way between the cities of El Paso, Texas and Albuquerque, New Mexico. Citizens from these two cities along with those from the two states come to enjoy fishing, water sports, camping and picnicing at Elephant Butte Reservoir. A total of approximately 1 million people visited the reservoir and surrounding areas during 1972.

The Elephant Butte powerplant and dam has both beneficial and adverse impacts on the environment.

The Elephant Butte Reservoir inundated 41 miles of the Rio Grande River when filled; at the existing water level only about 15 miles of river. The area inundated by the reservoir will not be available for rodents and other small animals. Nesting places for waterfowl will be increased.

The evaporation losses from the impoundment have been increased over what it was previously. On the average, approximately 67,400 acre-feet of water are lost to evaporation each year.

Studies have been conducted to list the water resources in the state. To conduct these studies the state was divided into nine major areas, largely determined by surface topography (see Figure 3). The nine drainage basins are as follows:

(1) Arkansas River
(2) Southern High Plains
(3) Pecos River
(4) Central Closed Basins
(5) Rio Grande
(6) Western Closed Basins
(7) San Juan River
(8) Lower Colorado River
(9) Southwest Closed Basins

The water resources for each of these areas follows:

1. Arkansas River Basin: The basin

has six streams draining the area, only one, the Canadian River, runs year round and that is only in the upper reaches. The Canadian River and its tributaries drain most of the basin. The major portion of all the run off in this basin is regulated by a number of reservoirs. Three of these reservoirs have a usable capacity of 30,000 acre-feet or more.

2. Southern High Plains: The Plains area has no permanent streams. A few streams run following thunderstorms in the area, but most precipitation infiltrates the soil and evaporates.

3. Pecos River Basin: The Pecos River and its tributaries drain the basin. The flow of the river is erratic, being influenced by flood flows resulting from heavy rains. The surface water in the basin has been experiencing shortages in recent years.

4. Central Closed Basins: There is no place in the Central Closed Basins where there is a large supply of surface water. The basin has no year round streams that reach the valley floor, but there are some small streams on the west side that run year around in the higher reaches.

5. Rio Grande Basin: The Rio Grande Basin in which Elephant Butte Dam and powerplant is located has an estimated 1,834,900 acre-feet of water available for use in the basin. Figure 4 shows the acre-feet flow into Elephant Butte Reservoir for years 1915 to 1972. Practically all the river's perennial tributaries are upstream of the town of Los Alamos, either in New Mexico or Colorado. Runoff is derived mainly from snow melt, although additional runoff is furnished by summer and fall rainstorms. In the Middle and Lower Rio Grande Valleys, all the runoff occurs after heavy rainstorms.

6. Western Closed Basins: The Western Closed Basins have no permanent streams and none of the intermittent streams are named. During periods of heavy rains, water is impounded in several natural lakes or flows into the basins below where it disappears into the ground or evaporates.

7. San Juan River Basin: The San Juan River Basin provided the theoretical location for another hydro-powerplant until completion of Navajo Dam. This dam is part of the Colorado River Storage Project and no provision for a hydro-powerplant was considered. The average annual water supply of the San Juan River in New Mexico has been estimated as 2,250,000 acre-feet; of this some 2,000,000 acre-feet flows into the state from Colorado and 250,000 acre-feet is delivered into New Mexico.

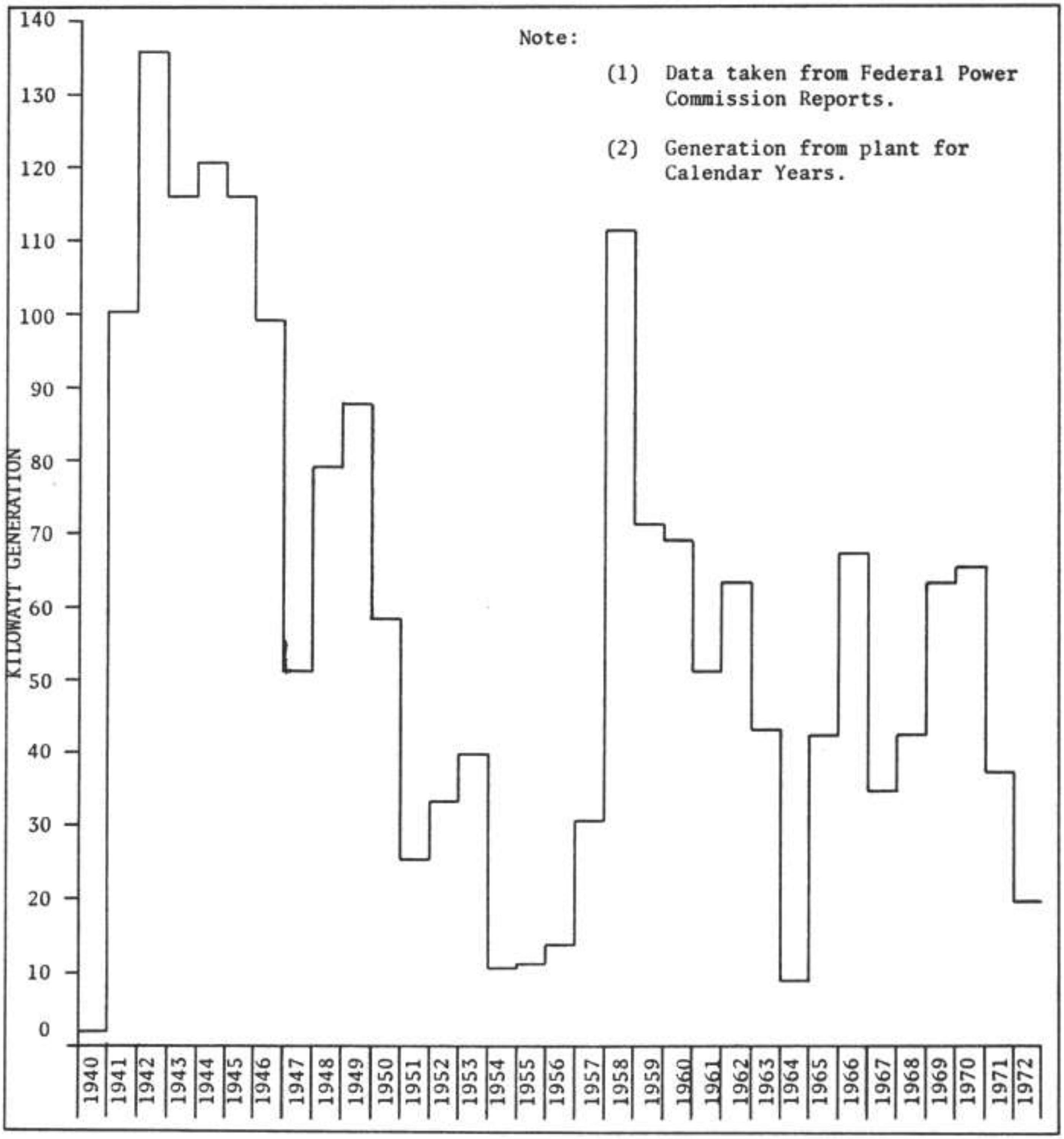
8. Lower Colorado River Basin: The Lower Colorado River Basin has several rivers that run year around in the upper reaches but are dry in the lower areas.

9. Southwestern Closed Basins: The Southwestern Closed Basins have only one stream; the Mimbres River that runs year around. This is only in the upper reaches.

Hydroelectric power development is not feasible in the future, and the existing facilities cannot be considered a source of firm power. Studies of possible hydroelectric site locations within the state have been made and no potential for plants of any appreciable size has been found.

The Albuquerque Journal Action Line in the March 17, 1973 edition had a question concerning the unharnessed water flowing in the Rio Grande River near Taos and why a hydro plant wasn't built to generate power for the southwest. The answer given was as follows and I quote: "An extensive survey of the gorge at Taos was made and found in the early 1960's that, although at times there appears to be a lot of water going down the gorge, there is not enough of a constant flow to justify a hydroelectric dam. The flow fluctuates. A hydro plant would rest idle a half or three-fourths of the year. The Bureau of Reclamation installed a hydro plant below Elephant Butte and it is in operation only about three months of the year."

I don't agree with the last part of the statement concerning Elephant Butte as power could be generated year around at Elephant Butte powerplant and the water flow in the Rio Grande River could be controlled by the outlet gates at Caballo Dam.



KILOWATT GENERATION FROM ELEPHANT BUTTE POWERPLANT

Figure 1.

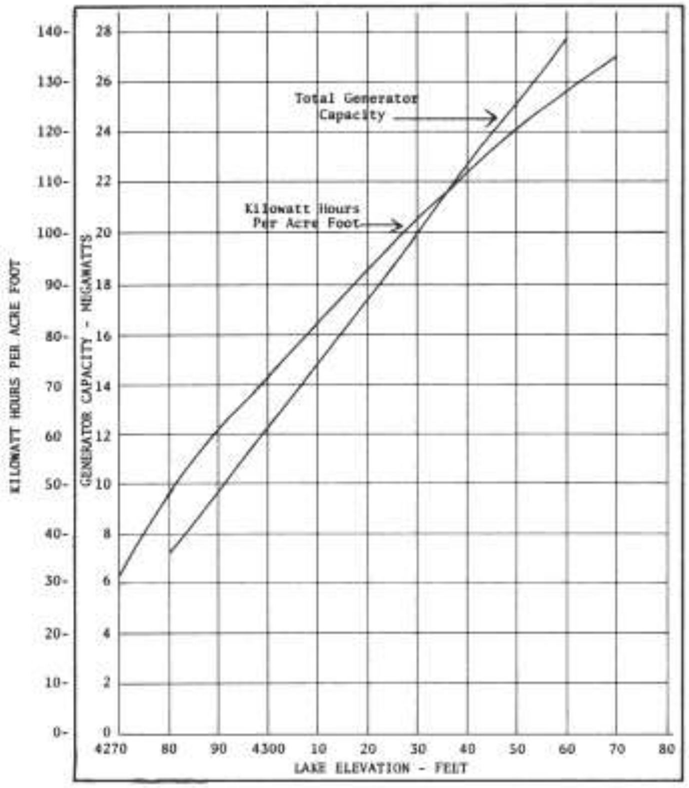


Figure No. 2.
ELEPHANT BUTTE POWERPLANT
CAPABILITY CURVES

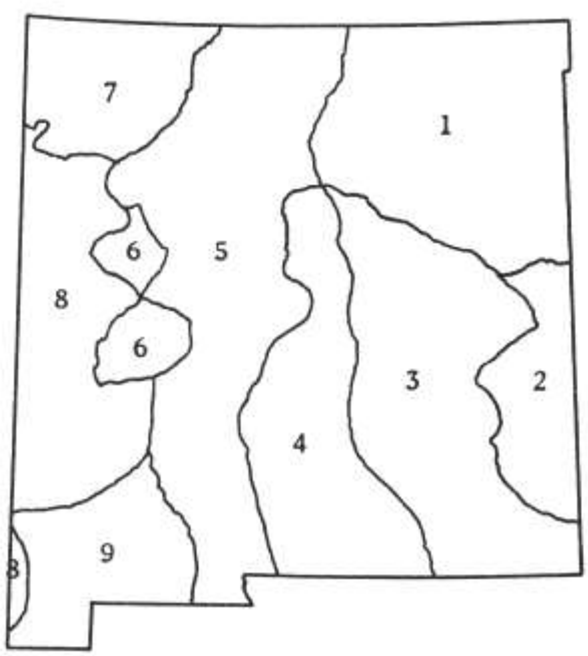
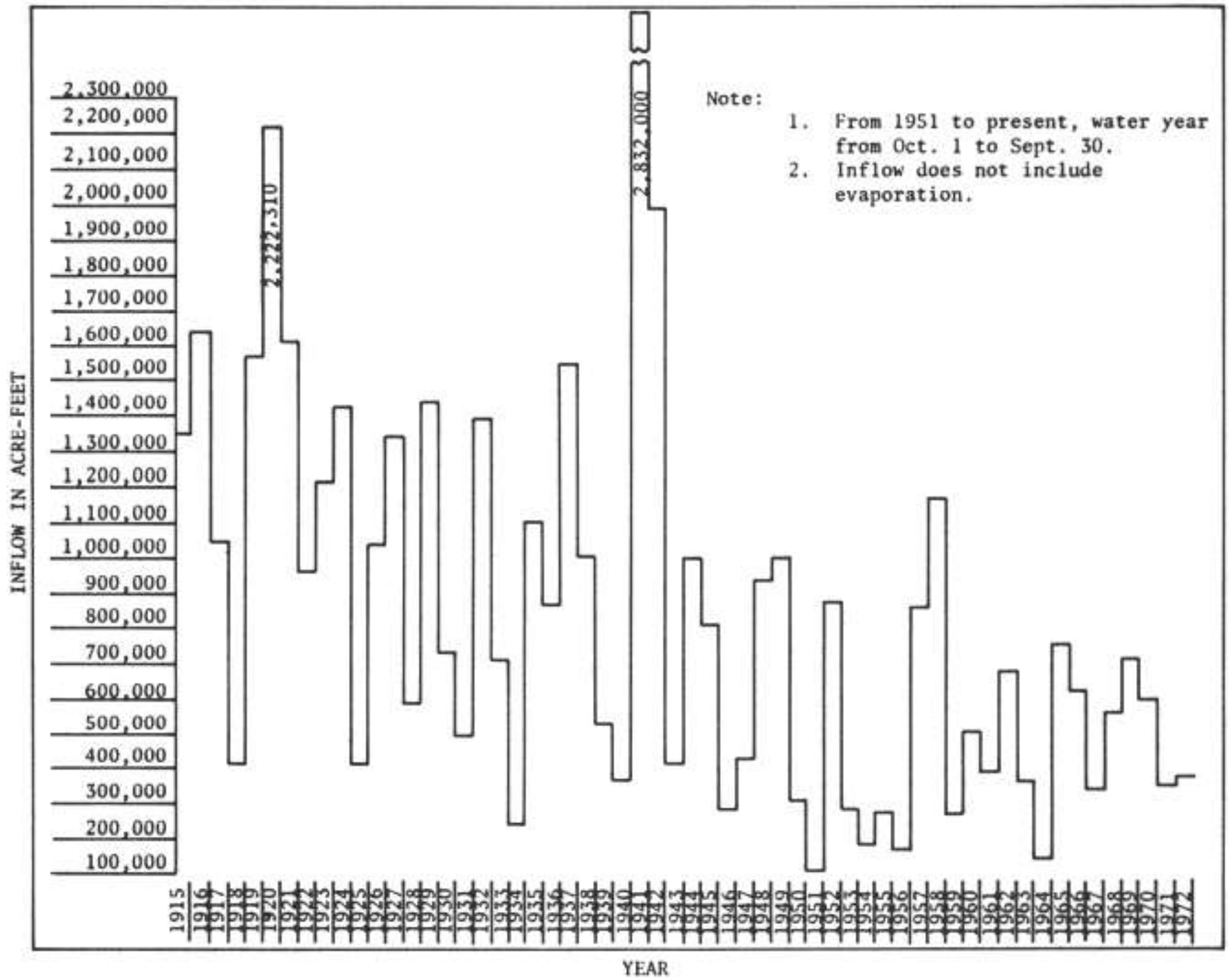


Figure 3.
DRAINAGE BASINS OF NEW MEXICO



ACRE-FEET INFLOW INTO ELEPHANT BUTTE RESERVOIR

Figure No. 4.

COAL GASIFICATION--A NEW ALTERNATIVE IN CLEAN ENERGY PRODUCTION

Joseph Byrne and Dan Cook
Pacific Coal Gasification Co.
Western Gasification Co.

In the past four to five years, it has become apparent that natural gas supplies are becoming short in the United States. Normally, large energy users would have switched to other forms of fossil fuel, such as coal, for which the proven reserves are very large. However, the current strong public concern with air pollution has worked against the increased use of coal. In fact, many industries now using coal are under extremely heavy pressure to develop and improve technology for the removal of sulfur from their coal or their stack gases.

This combination of events, a natural gas shortage plus the emphasis on removal of sulfur from fuels, has accelerated the search for new sources of Substitute Natural Gas (SNG) as well as new supplies of Liquefied Natural Gas (LNG). In the long term, it is apparent that the vast coal energy reserves in the United States must be utilized. Coal gasification can convert these large coal energy reserves into a high-BTU, clean-burning, sulfur-free fuel gas as noted by President Nixon in his recent "Energy Message".

With this background, Western Gasification Company (WESCO), a joint venture of Pacific Coal Gasification Company and Transwestern Coal Gasification Company, initiated a feasibility study in late 1971 for a coal gasification project to be located in northwestern New Mexico.

Key elements of coal gasification are the mining of coal and its chemical conversion to gas of pipeline quality. Output of the proposed project would be 250 million cubic feet of substitute natural gas to offset dwindling gas reserves in the southwest.

WESCO, after thoroughly evaluating all aspects of the proposed project, firmly believes it to be technically and economically feasible, environmentally sound and economically benefical to the Navajo Tribe and the people of New Mexico.

The facility will require a capital investment of more than $400 million including over $40 million solely for environmental protection.

Subject to necessary approvals, construction would begin in 1974, with the plant becoming operational in 1977.

Operation of the SNG plant and related mining activities will provide substantial benefits to the Navajo Tribe and to all the people of New Mexico. The project will create over 900 steady new jobs with an annual payroll exceeding $13 million. It will generate annual tax revenues for the state, amounting to about $34 million during the first five years of operation. It will also provide continuing lease and royalty payments for the Navajos.

NUCLEAR STIMULATION OF RESERVOIRS AND SUPPLIES OF NATURAL GAS

Fred Holzer
University of California
Plowshare Division
Lawrence Livermore Laboratories

The United States is presently faced with a developing crisis in its energy resources and specifically in its supply of natural gas. The use of nuclear explosives in the stimulation of low-permeability gas is one of the methods which can make more gas available. Two nuclear explosive gas-stimulation experiments (projects Gasbuggy and Rulison) have produced a substantial quantity of gas. Data from these experiments have been used in the design of the next experiment, Rio Blanco, in which three 30-kiloton explosives are planned to be detonated simultaneously in the same hole.

As an example of the possibilities and opportunities presented by this technology, we have estimated that nuclearly stimulating 10 to 15 wells per year in Colorado's Piceance Basin could make that state independent of any external supply of natural gas for domestic and industrial consumption. Additionally, substantial cost savings over other gas supplies alternatives would accrue to the consumers and to local governments. We estimate that the residual radioactivity in the gas would result in an individual radiation dose of about 1 millirem per year or about 1/2 percent of the natural background in Colorado.

ENERGY RESOURCES OF THE VERMEJO RANCH, COLFAX COUNTY, NEW MEXICO

William R. Speer
Consulting Geologist

The 480,000-acre Vermejo Ranch of northeastern New Mexico represents the largest contiguous private land holding in the state. The recent consideration given to the purchase of this ranch by both the state and federal governments has focused much interest on its resource possibilities. Its location in the heart of the New Mexico portion of the Raton sedimentary Basin makes it a prime candidate for valuable energy resources. During the past two years several important deep oil and gas well tests have been drilled in previously unexplored portions of the ranch. These Dakota formation tests have afforded important data on the subsurface Tertiary-Cretaceous geological section and its hydrocarbon possibilities, which, until very recently, has not been released as public information. Significant gas shows were encountered in the Raton, Trinidad, and Dakota Formations, which resulted in several completion attempts. The geology and pertinent oil and gas data from these wells is discussed.

In addition to hydrocarbon possibilities the Vermejo Ranch contains very important and valuable reserves of coal which are being developed by the Kaiser Steel Corporation. The York Canyon mine near the heart of the ranch currently is being mined by underground methods--both continuous and long-wall-and by surface stripping methods. Estimated reserves of the high volatile A bituminous coal with its low sulfur content and high coking quality make it one of the more important sources of metallurgical coal in the Western United States.

A SOLAR COMMUNITY

R. P. Stromberg
Exploratory Projects Division 5712
Sandia Laboratories, Albuquerque, New Mexico 87115

ABSTRACT

In response to increasing public and official recognition of the pressing needs for new, nonpolluting sources of energy, a series of systems studies concerning potential uses of solar energy has been conducted at Sandia Laboratories. These studies have included performance and cost evaluations in the following areas: (1) solar-powered central station power plants, (2) solar energy collection systems, (3) energy storage systems, (4) heat-to-electric conversion systems, (5) methods for transportation of energy, and (6) means for using thermal energy for air conditioning systems.

One outcome of these studies is a new concept described in this paper which envisions a "Solar Community" that would significantly reduce its needs for fossil fuel energy, by using the sun as the source of practically all of its energy needs. By including air conditioning and generation of electricity, this system goes beyond the economically and technically feasible solar-powered space and hot water heating systems currently being developed.

When Sandia Laboratories personnel examined the energy problem for ways in which we could contribute, we chose solar energy as a possibility because of our very favorable geographic location and a staff able to deal with quite extensive systems design and development projects. As we examined the problems of concentrating the energy from the sun and the expense of that energy, we looked for ways to make maximum use of the energy available. By heating a fluid with solar collectors, then using the energy in the fluid for different uses as it cools, we were able to design a system we call the "Solar Community," where almost all the energy needs of the community could be met, except for extended periods of cloudy or unusually cold days. Several current solar energy development programs consist of either electrical generation or a combination of heating and cooling of living space. The Solar Community concept is more ambitious, treating the combined needs of a community.

The feasibility program will challenge the system's engineering skills of the laboratory, but if successful, will offer a more complete solution to the energy problem as applied to residential *uses.*

The Solar Community can best be explained with an illustration. Although the picture shows a central collection area and individual homes, high and mid-rise apartment construction, as well as many forms of industrial buildings, are compatible with the concept. Energy would be collected by the many partial cylinder type collectors shown on the shopping center roof. Fluids heated in the collectors are stored underground in insulated tanks to supply the energy needed for generating electricity. Energy remaining after generating the electricity is stored in another set of insulated tanks, but now at a lower temperature than that used for electricity. This energy is used to heat water, operate air conditioning equipment in the summer, or heat the houses in the winter. A careful study of the needs of typical houses shows this system is not only technically feasible, but close to being economically competitive with fossil fuels. Examples of different collector configurations are shown in the next two illustrations.

In the block diagram, the system can be described more completely. Sizing studies will not be completed for some time, but studies indicate a community larger than 20 living units and smaller than 1,000 living units.

Systems studies have produced some interesting requirements for subsystems. The illustration shows that maximum collector-turbo generator efficiency occurs at turbine inlet temperatures well below those used in modern steam plants. Maximum cost effectiveness occurs at even lower temperatures, as collector area requirements are a most powerful cost influence.

The next illustration, with air conditioning subsystem requirements, indicates a desire to lower the generator temperature as much as is feasible: The coefficient of performance can be lower than several of the data points shown and still permit satisfactory overall systems operation.

Another cost study was interesting. The cost of steel to contain water under pressure definitely increases with temperature, since the pressures are greater and the amount of steel needed is also greater. Small tanks are more expensive than larger ones, until a size for 20 or more living units is reached, with costs leveling off beyond that point.

Future fuel costs are difficult to obtain. No one seems willing to put values on future prices. In order to evaluate the effect of future increases in prices on the competitive position of solar energy, a set of estimates were made as shown. As you can see, wholesale prices are going to see an abrupt rise; but household prices, already much higher than wholesale, will not show the same percentage change. These prices are being used in our systems analyses.

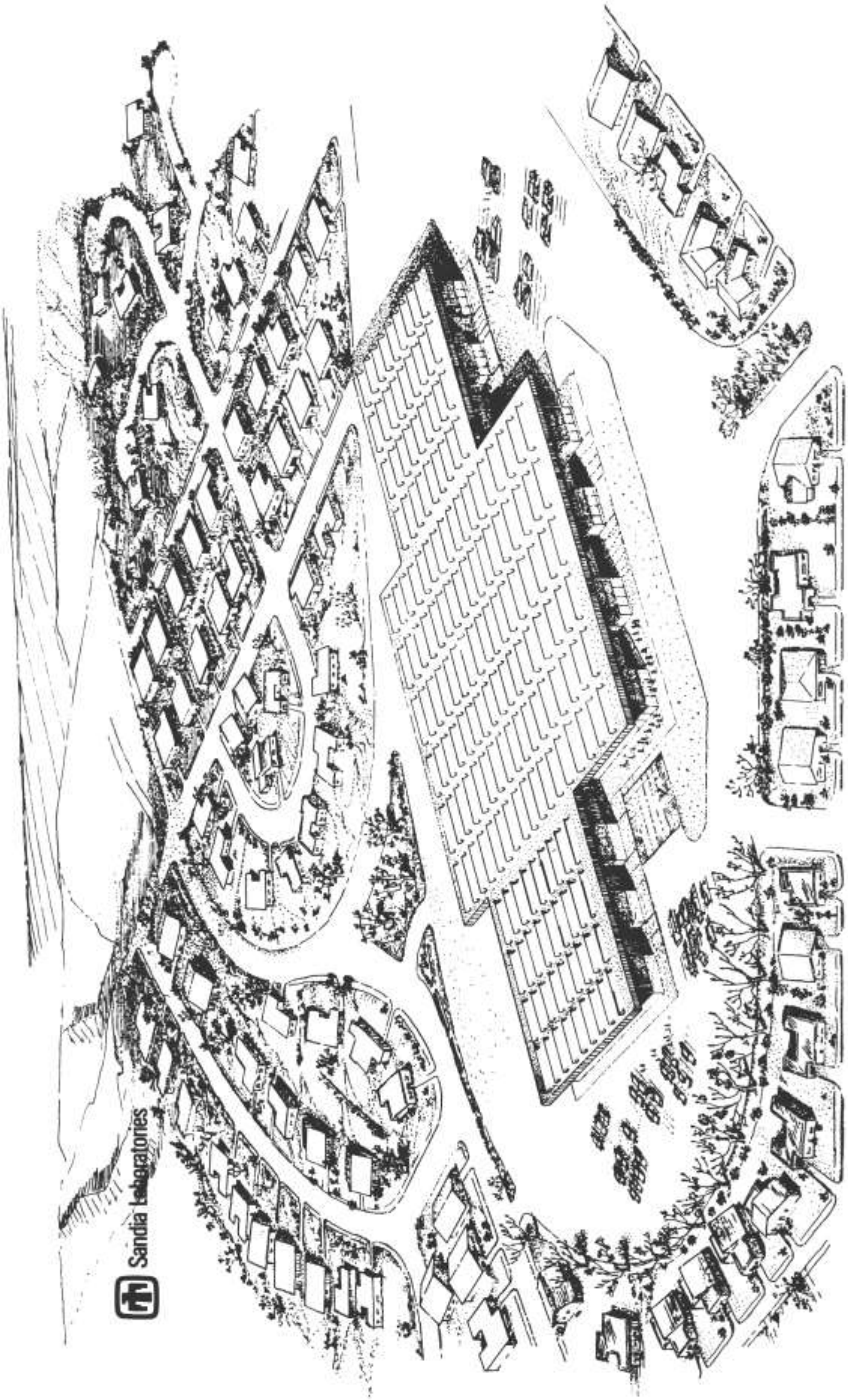
In mid-January, the system design was based upon collection of energy at individual home sites, transport to a central electrical generating plant, and then back to living units for air conditioning, hot water and space heating. The collection temperature was 700°F. The system saved 65% on energy, but cost was 240% of a conventional community.

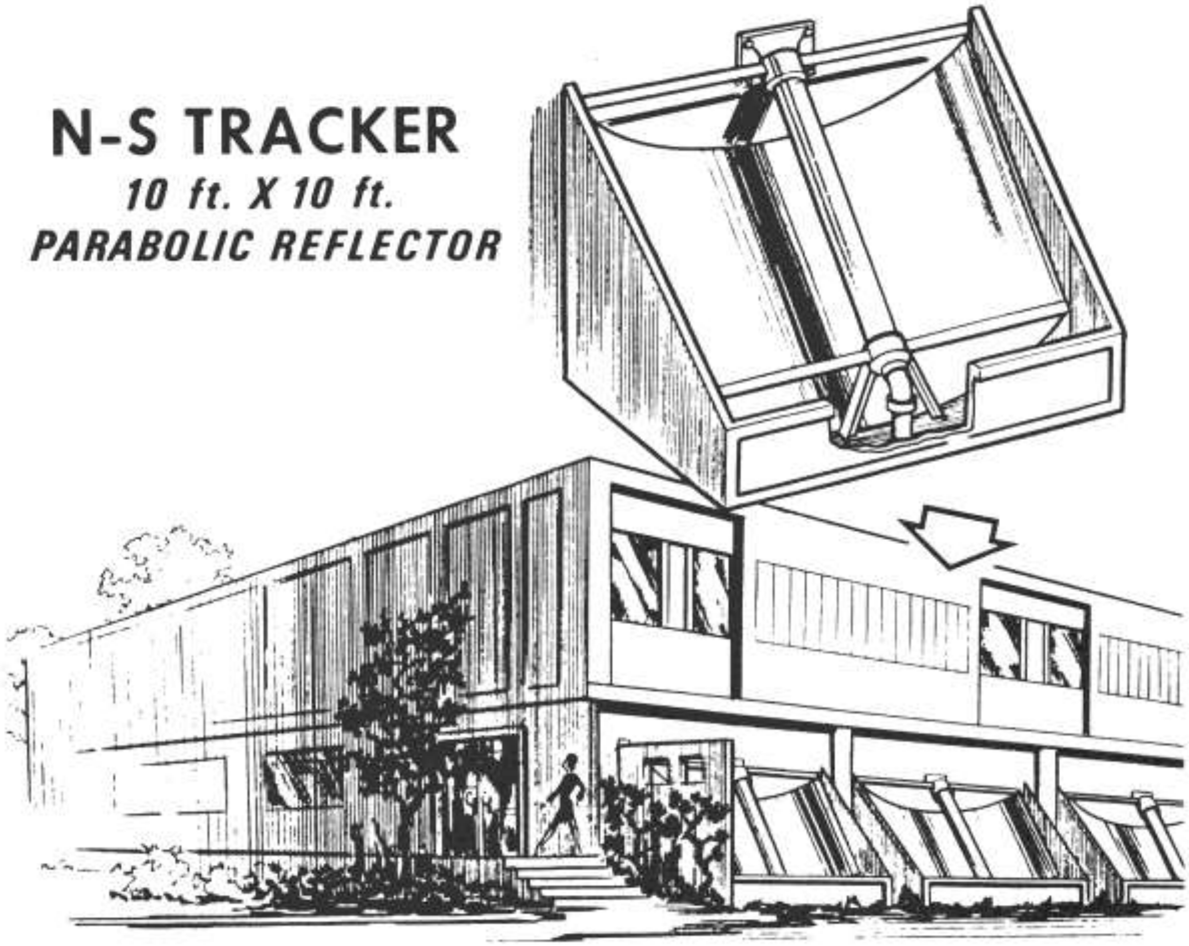
Separate studies of subsystem effectiveness suggested a temperature of 450°F and elimination of two-way transfer of energy. With these changes, costs were reduced in several ways. Energy storage was now possible in water, much less expensive than fused salts. Transmission of energy was less than half as costly. As shown in the illustration, the new estimates for 1985 or later indicate savings of 62% on energy, with costs now approximately 120% of those in a conventional community.

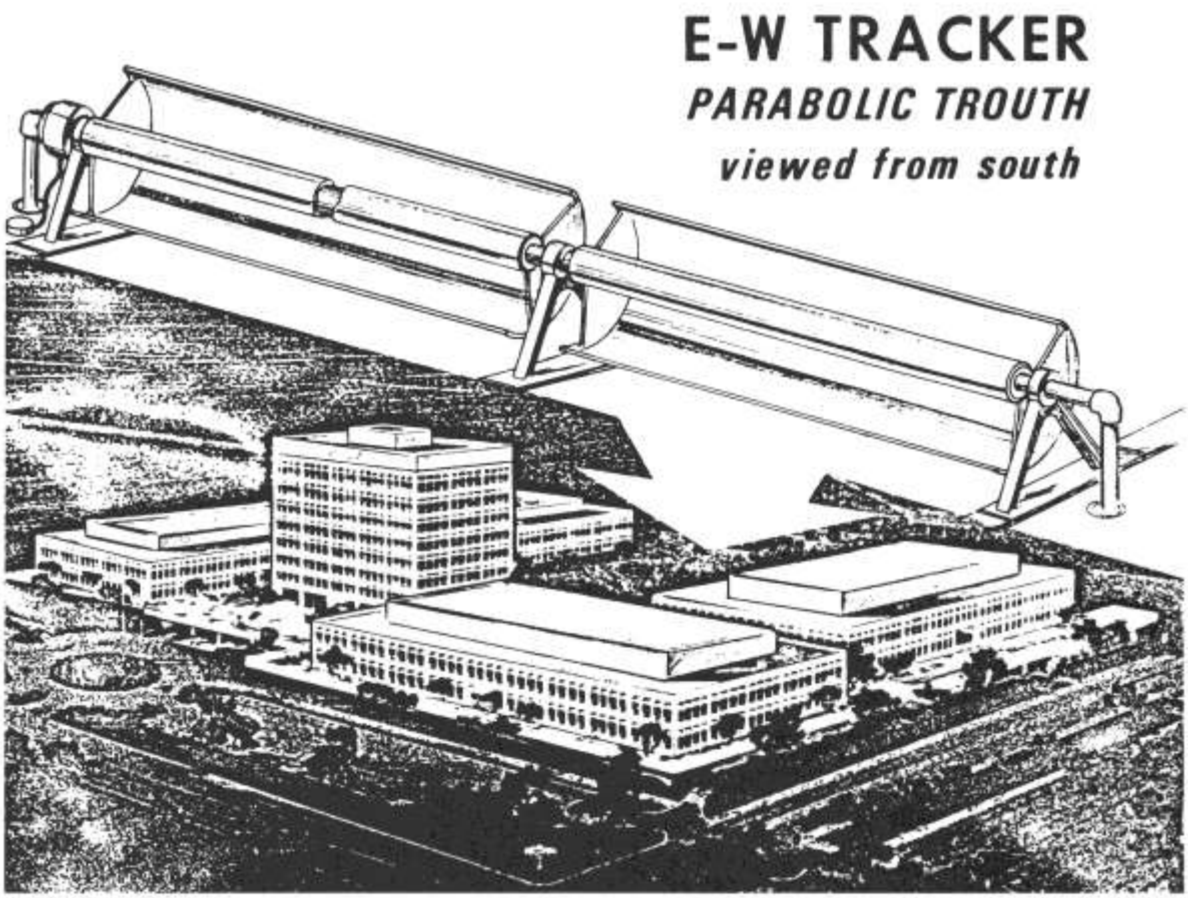
Albuquerque is an ideal location for a laboratory doing solar energy research and development, as can be shown by the following illustrations of Solar Insolation in June and December in the United States, as well as effects of altitude. A set of typical records from the Albuquerque Sunport illustrate the rate at which energy is received. If government sponsored experiments take place in areas of the country where chances of success are relatively high, applications to other sections of the country can proceed as increased performance makes the system competitive over large geographic areas.

On the basis of these findings, we think the Solar Community concept can offer significant improvement in the residential consumption of energy, if development proceeds to the point where private builders and utilities can commence construction and operation at a profit. We are seeking additional funding to continue the work to this point.

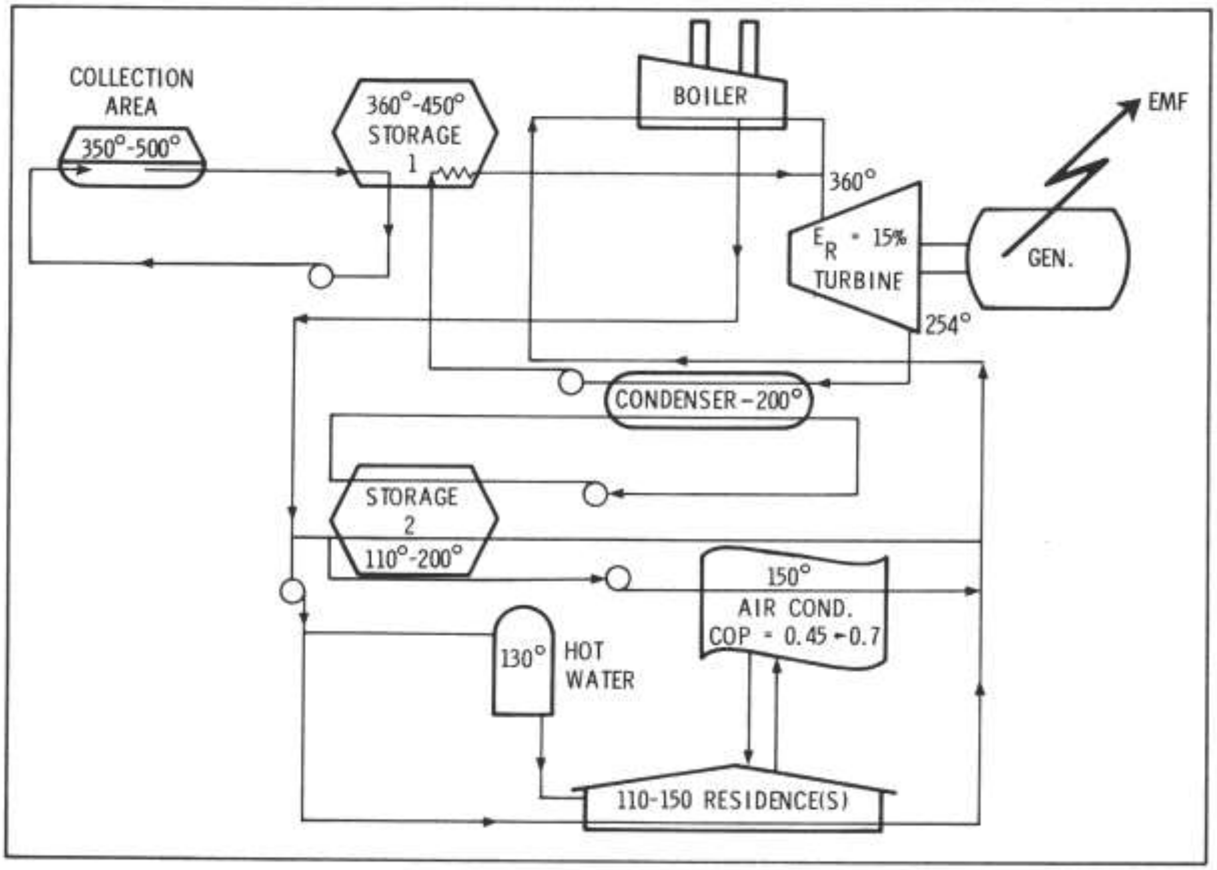
Figures follow on pages 75-81


Sandia Laboratories

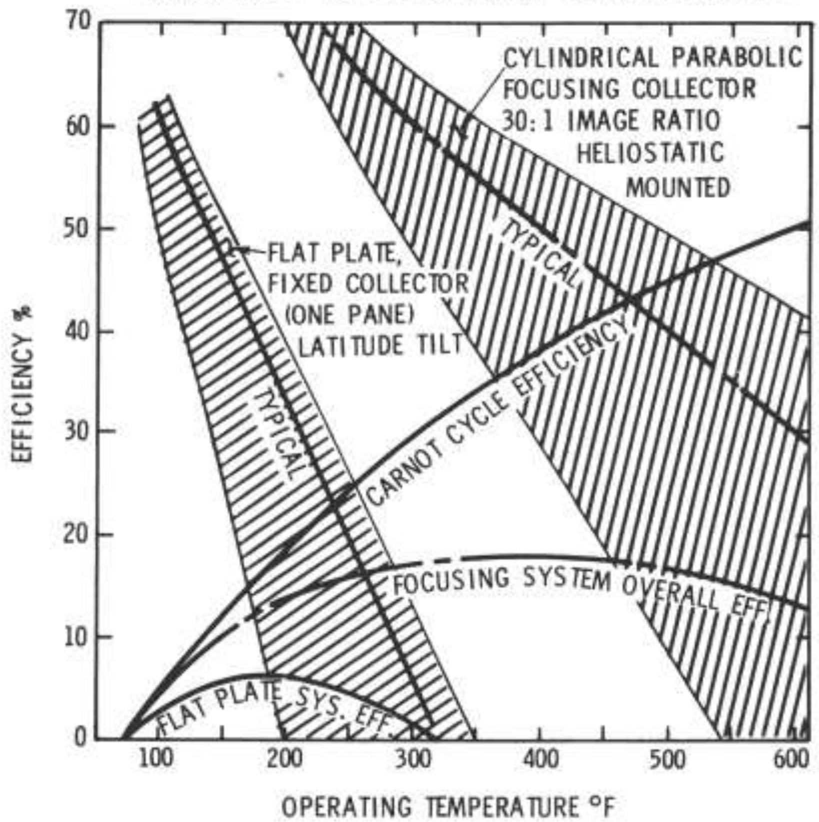

N-S TRACKER
10 ft. X 10 ft.
PARABOLIC REFLECTOR


E-W TRACKER
PARABOLIC TROUTH
viewed from south

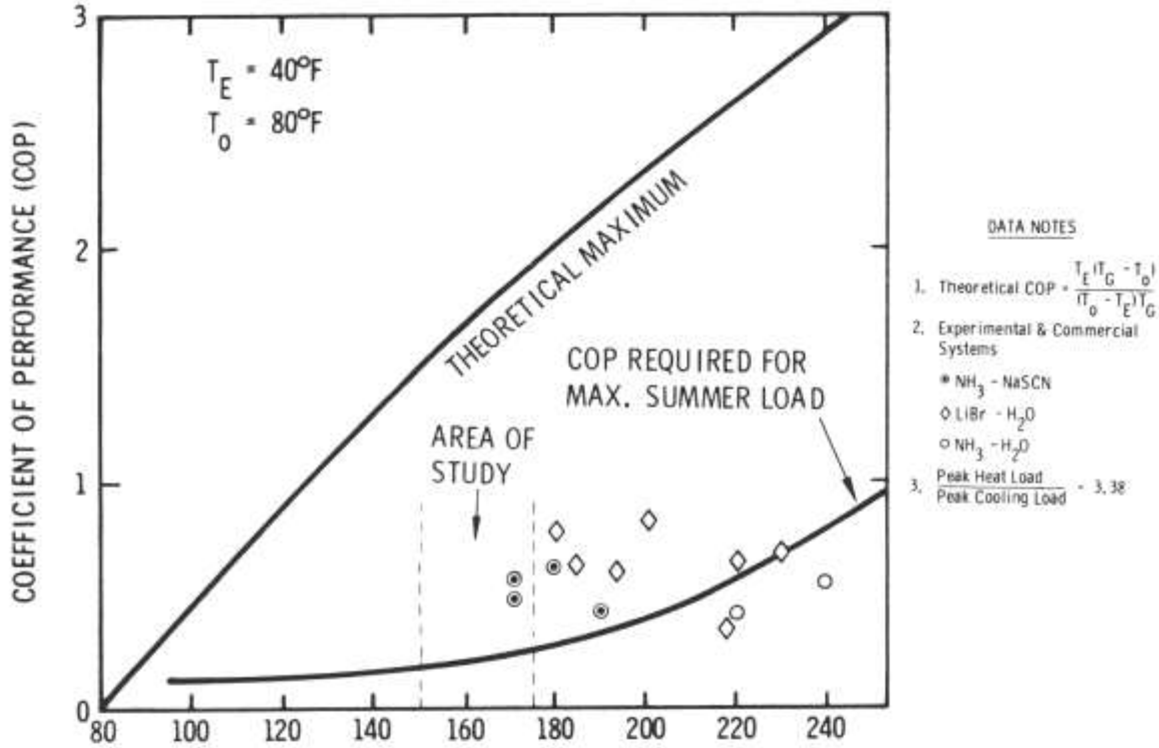
TYPICAL CASCADED SYSTEM



EFFICIENCY vs OPERATING TEMPERATURE

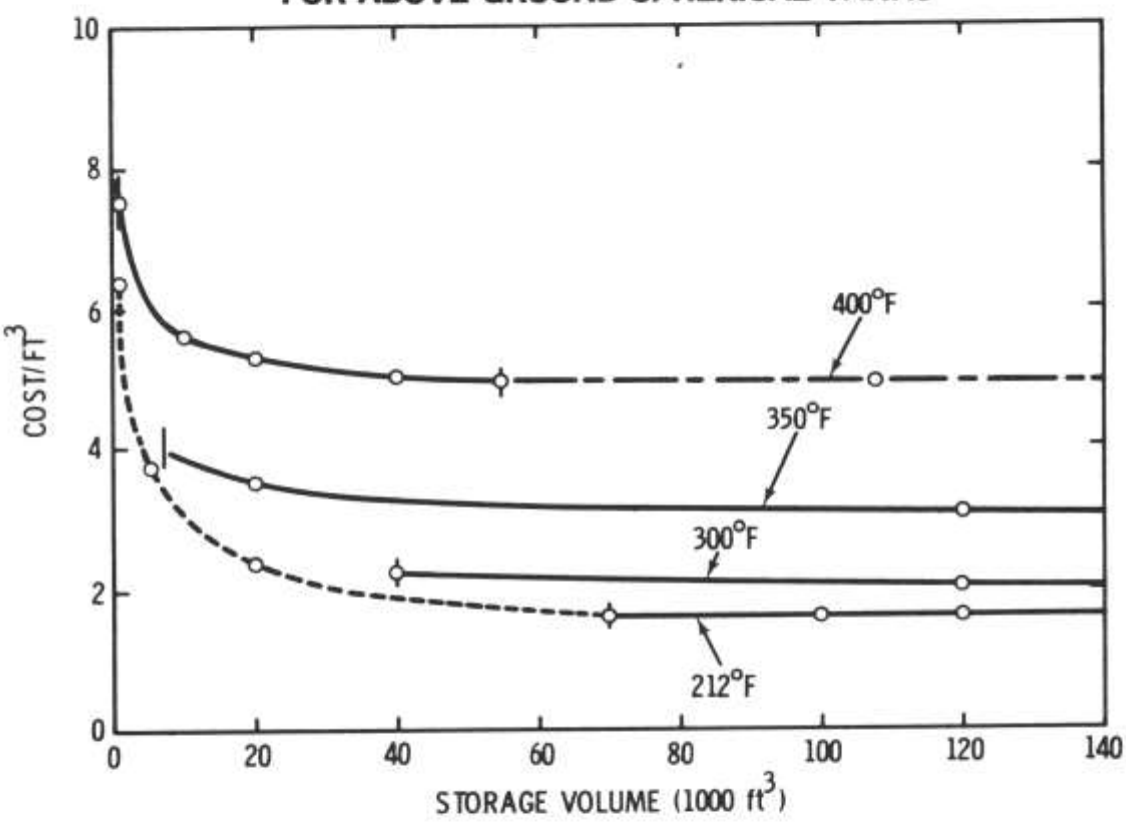


TRACKING FLAT PLATE COLLECTOR SIZED FOR MAX. WINTER LOAD.



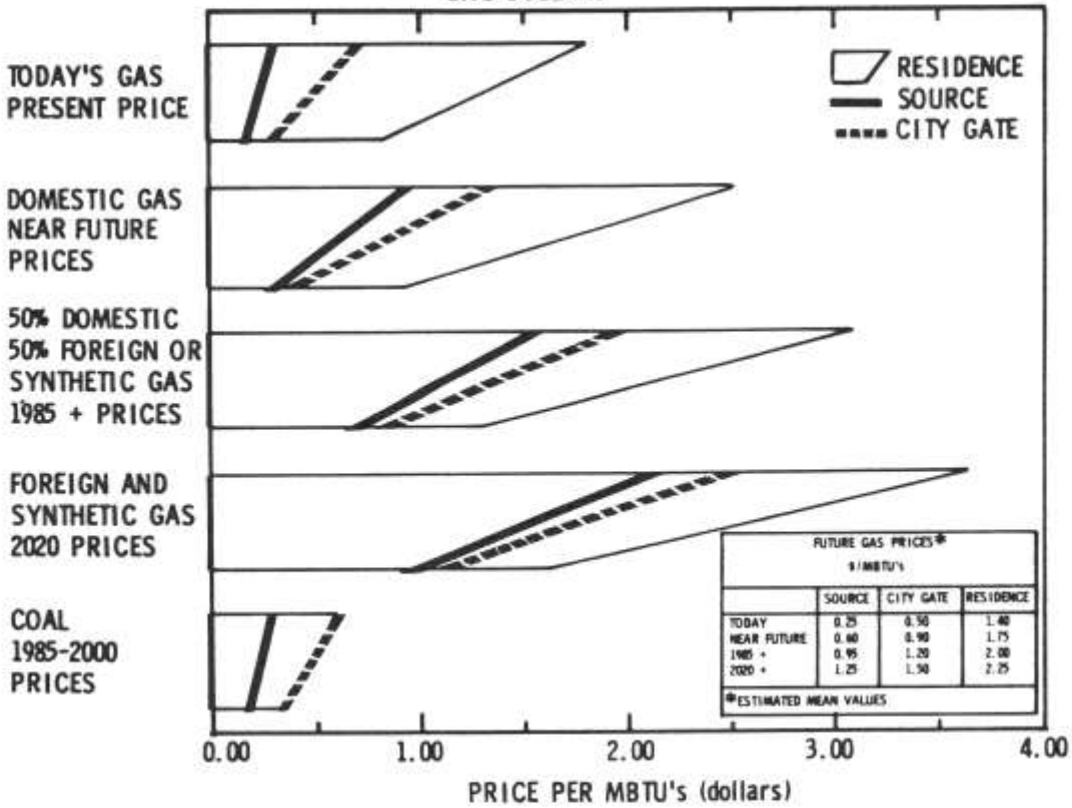
GENERATOR TEMPERATURE °F = T_G
ABSORPTION CYCLE AIR CONDITIONER

H2O SENSIBLE HEAT STORAGE COSTS FOR ABOVE GROUND SPHERICAL TANKS



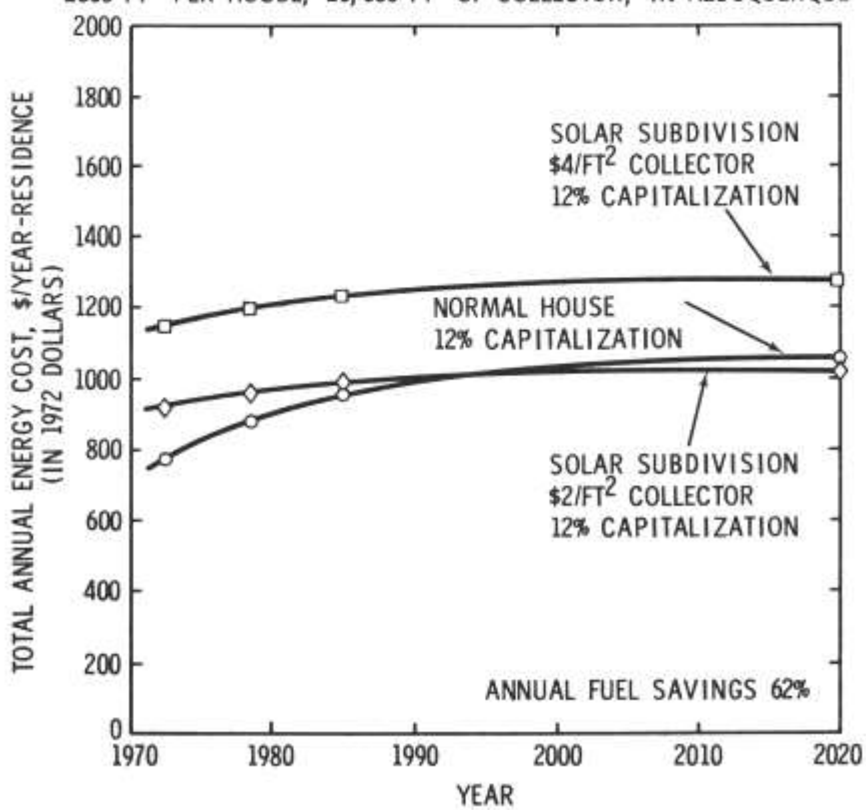
A SUMMARY OF SOURCE, CITY GATE, AND RESIDENTIAL COSTS OF NATURAL AND/OR SYNTHETIC GAS

1972 DOLLARS

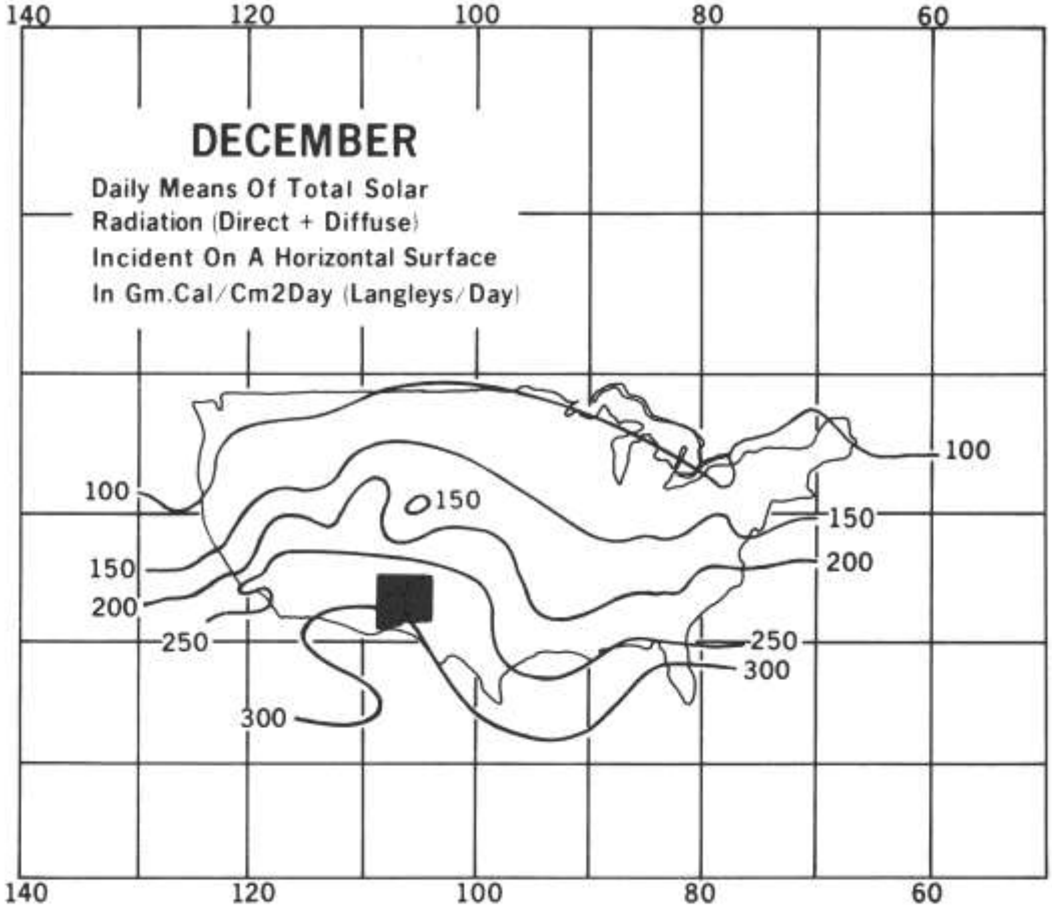


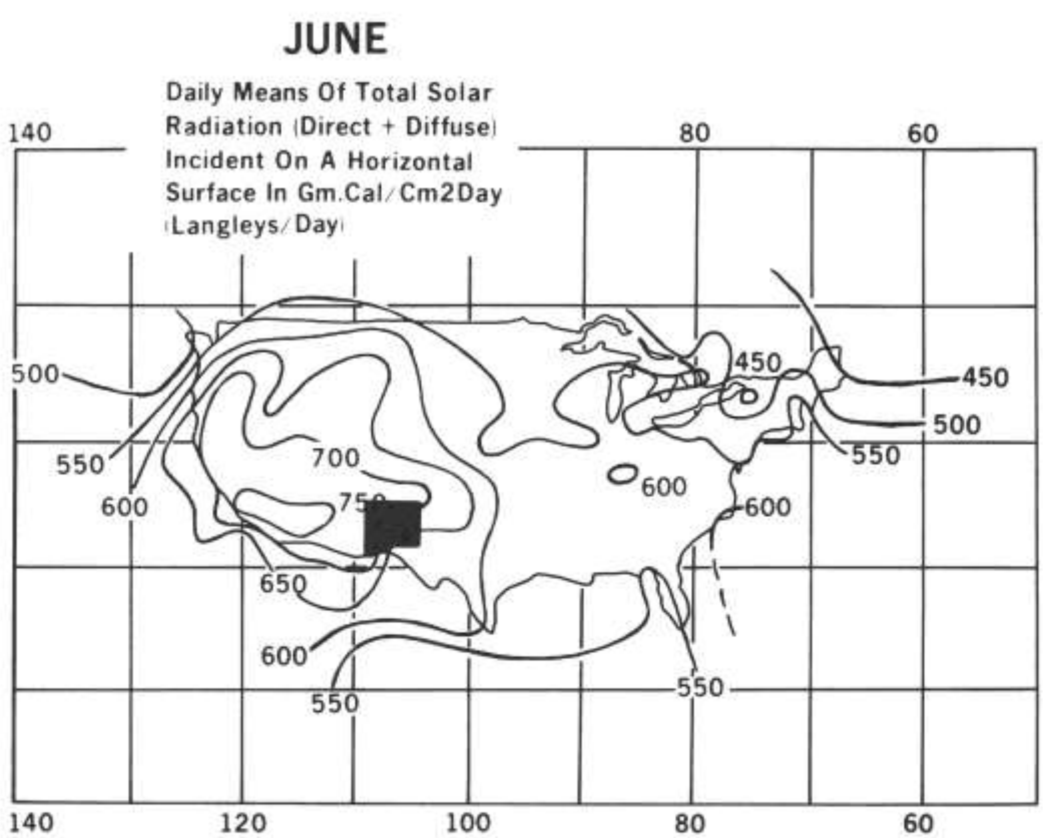
	SOURCE	CITY GATE	RESIDENCE
TODAY	0.25	0.50	1.40
NEAR FUTURE	0.60	0.90	1.75
1985 +	0.95	1.20	2.00
2020 +	1.25	1.50	2.25

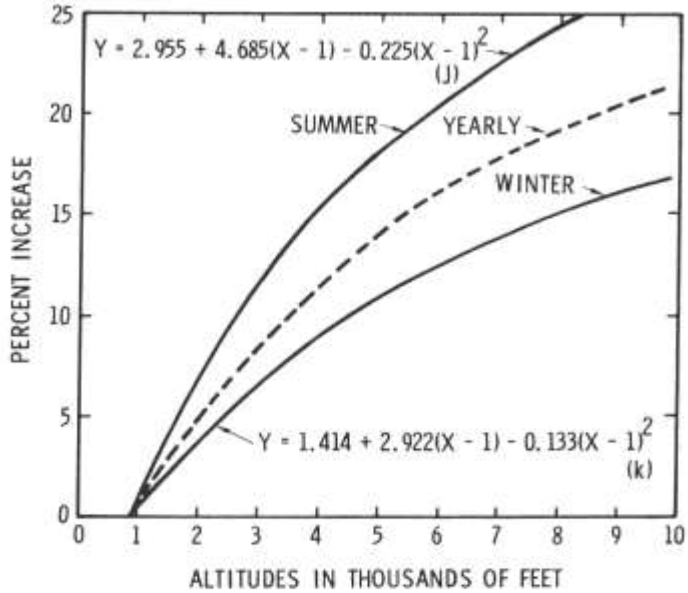
TOTAL ANNUAL ENERGY COSTS FOR NORMAL HOUSE AND A HOUSE IN A SOLAR COMMUNITY SUBDIVISION, 20 HOUSES IN SUBDIVISION, 2000 FT^2 PER HOUSE, 20,000 FT^2 OF COLLECTOR, IN ALBUQUERQUE



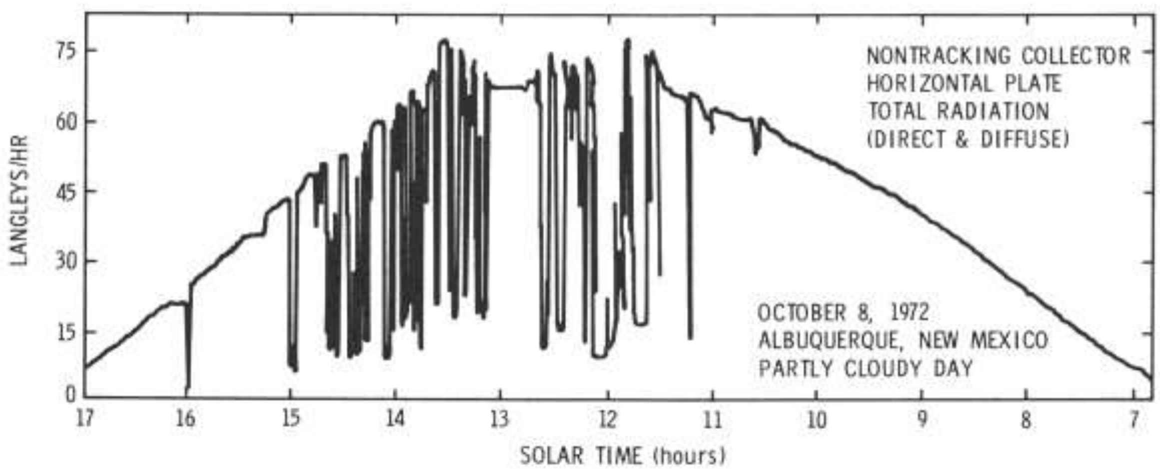
COSTS ARE BASED ON MEAN FUEL AND ELECTRICAL COSTS SHOWN IN TABLE VI.


DECEMBER
Daily Means Of Total Solar Radiation (Direct + Diffuse) Incident On A Horizontal Surface In Gm.Cal/Cm2Day (Langleys/Day)
140
120
100
80
60
100
150
150
200
250
300
100
150
200
250
300
140
120
100
80
60

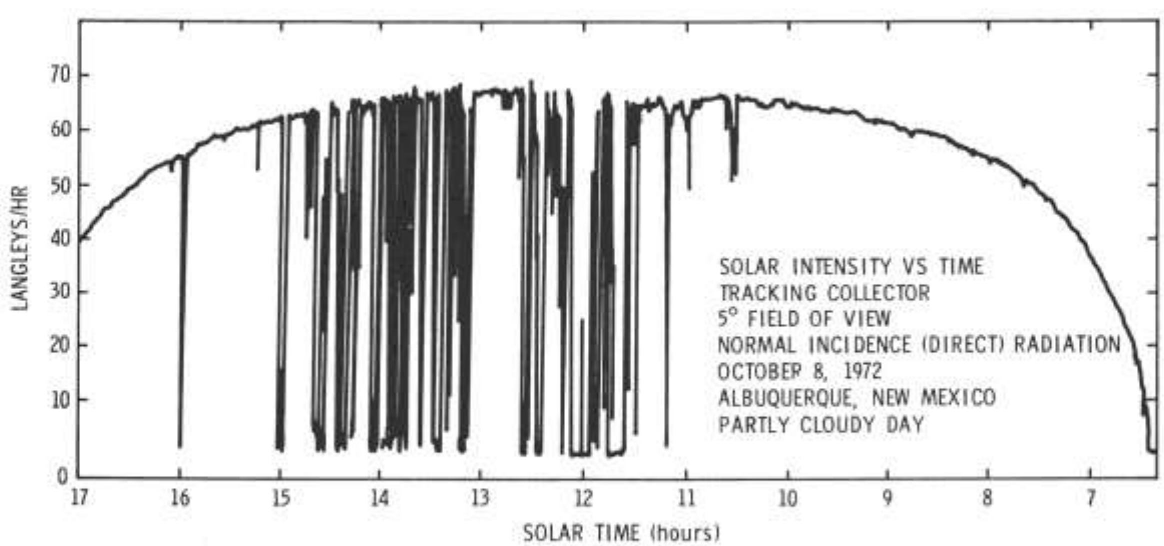

JUNE
Daily Means Of Total Solar Radiation (Direct + Diffuse) Incident On A Horizontal Surface In Gm.Cal/Cm2Day (Langleys/Day)
140
80
60
500
550
600
700
650
600
550
450
450
500
550
600
600
550
140
120
100
80
60



SOLAR INTENSITY VS TIME



SOLAR INTENSITY VS TIME



URANIUM RESOURCES OF NEW MEXICO

by
David C. Fitch
Ranchers Exploration and Development Corporation

New Mexico contains nearly one-half of the nation's uranium in ore remaining to be mined and has led the nation in uranium concentrates produced for each of the years from 1959 to the present. With this resource base and proven capability, New Mexico is expected to play a significant role in contributing to the nation's future uranium requirements in a rapidly expanding nuclear industry.

This paper will attempt to outline in general terms the occurrence and distribution of New Mexico's uranium resources and the relationship of these resources to the nation's uranium raw materials industry.

Although uranium-bearing minerals have been described as early as 1565, and radium was being produced from uranium ores in the Colorado Plateau in 1913, it was not until the formation of the Manhattan Engineering District in 1942 that uranium achieved importance. During the period 1943-1948, the Manhattan Project obtained about 12,000 tons of uranium oxide. Proven U. S . uranium ore reserves remaining to be mined at the end of 1948 contained only about 2,500 tons of U_30_8. (U_30_8 represents the conventional market unit for equivalent uranium contained in raw materials.) Since 1948 there has been a phenomenal growth of the uranium industry. The uranium raw materials market consisted at first of Atomic Energy Commission ore purchases that have been replaced entirely by the private industry market that exists at the present time.

In New Mexico, uranium minerals were first identified in 1904; however, it was not until 1950 that uranium came into its own in the state with the discovery of uranium ore in the Jurassic Todilto Limestone near Grants. In 1951 the first sandstone type uranium deposits were discovered near Grants and also were discovered near Laguna, resulting in the Jackpile Mine. In 1955, after several years of intensive exploration activity, the Ambrosia Lake uranium deposits were discovered. By 1956, according to Atomic Energy Commission reports, New Mexico had 41 million tons of uranium ore outlined by drill holes and mine workings.

Uranium, by comparison to other metals, is a relative newcomer in the mining industry and has experienced a dramatic growth. This growth is shown by the annual uranium deliveries and forecast demand for the United States as reported by the AEC (Fig. 1) . Purchases from domestic sources by the AEC reached a peak of 17,637 tons of $U30_8$ in 1960. Commercial deliveries began about 1966 and represent all of the present market and forecast demand. The forecast demand for 1976 is 20,500 tons and for 1980 is 37 , 000 tons U_30_8 . This is in sharp contrast to the present domestic production capability of about 19,000 tons of U_3O_8 per year, with current deliveries averaging 13,000 to 14,000 tons per year. New Mexico has produced about 40% of the nation's uranium through 1972.

The amount of uranium required to fuel and maintain a nuclear power generating plant of the types currently being built ranges from 2400 to 5300 tons of U_3O_8 over a life of 30 years (Fig. 2) . The amount of uranium ore at an average grade of 0.25% U_3O_8 or 5 pounds per ton that contains this amount of uranium ranges from 960,000 to 2,120,000 tons.

As of December 31, 1972, a total of 160 nuclear power generating units were operating, being built or planned in the U. S. During 1972 alone, electric utilities made known plans for 40 nuclear power generating units.

Although uranium is common in the earth's crust, it is almost everywhere widely dispersed; very rarely is uranium concentrated in quantities sufficient to mine at a profit. Average uranium ore deposits in the U. S. represents a concentration about 500 times that of the normal uranium content in the crust In nature, uranium never occurs in its elemental form; it always occurs as a mineral. The economic deposits of uranium occur in veins in igneous and metamorphic rocks and as disseminations in limestone, coal, conglomerates and sandstone.

The earliest known significant uranium deposits occur in veins in igneous and metamorphic rocks in the Belgian Congo, Czechoslovakia and northwestern Canada.

Most of the various geologic types of deposits are recognized in the United States; however, sandstone uranium deposits are by far the most important and comprise nearly 99% of the uranium ore reserves at the present time (Fig. 3) . The host sandstones were deposited in fluvial-continental environments containing vegetal organic material. Uranium deposits in the sandstone occur mostly as uranium-bearing carbonaceous matter cementing sand grains and as uranium-bearing coalified vegetal material.

Domestic uranium reserves remaining to be mined as reported by the AEC are shown by Fig. 4. These ore reserves consist of proven and indicated ore outlined by surface drill holes and mine workings that is available at a cost of $8 per lb. of contained U_3O_8. New Mexico is credited with a large part or about 49% of the nation's total uranium reserves. Potential reserves, or reserves calculated as possible in areas having favorable geologic criteria, mostly near existing deposits will probably result in significant additions to the proven reserves.

New Mexico also leads the nation in uranium produced through 1972 (Fig. 5) with an amount about 40% of the nation's total uranium produced. The distribution of uranium deposits as calculated by the AEC (reserves plus production) as of January 1, 1972 is shown by Fig. 6. About 9,000 tons $U_3 08$ have been added to the total during the year 1972, probably mostly in Wyoming and Texas. The location of the nation's major uranium districts is shown in Fig. 7.

Uranium deposits in New Mexico occur in widely scattered locations and in rocks of many ages and lithologic types

(Fig. 8); however, more than 95% of the total tonnage of uranium ore produced in New Mexico was from fluvial sandstone in the Jurassic Morrison Formation, mostly in the Grants Mineral Belt. Nearly all of New Mexico's proven uranium reserves remaining to be mined occur in this belt in the Morrison Formation. The Grants Mineral Belt, for the purpose of this paper, is an area enclosing all known uranium deposits in the Morrison Formation in the region extending from the Rio Puerco on the east to the Churchrock District on the west. This belt encloses an area 92 miles long and 10 to 18 miles in width. Known uranium ore deposits occur at depths ranging from the surface outcrop to depths of more than 4, 000 ft. Most of the production to date has come from deposits at depths of less than 1500 ft.

The principal producing area in the belt has been the Ambrosia Lake District located about 18 miles north of Grants (Fig. 9) . This district has produced about two-thirds of New Mexico's uranium and contains over half of New Mexico's proven reserves outlined at the present time. The Laguna district in the eastern end of the belt also has produced significant amounts of uranium ore totalling one-quarter to one-third of New Mexico's total production. Large reserves remain to be mined in the district. The Churchrock district located 16 miles northeast of Gallup in the west part of the belt has produced a lesser amount of uranium, but important ore reserves are known to exist and the potential for additional reserves is considered good. Less significant deposits occur throughout the mineral belt. Individual uranium deposits in the Grants Mineral Belt range in size from a few hundred to several million tons of ore. The average size of the 10 largest deposits in the belt as reported by the AEC January l, 1972 is about 12,900 tons of contained U_3O_8 which represents 5 to 6 million tons of typical uranium ore.

The Morrison Formation, deposited in a continental environment, consists of interbedded fluvial sandstones and clay-stones or mudstones. In the Grants Mineral Belt three members are recog-nized (Fig. 10) . These are, in ascending order, the Recapture Member, the Westwater Canyon Member and the Brush Basin Member. The Recapture Member contains only small uranium deposits and consists mostly of mud-stone with interbedded fine-grained sandstone. The Westwater Member, host for the largest uranium deposits in the Ambrosia Lake and Churchrock districts, consists of fluvial sandstone containing mudstone interbeds. The Brushy Basin Member includes the Jack-pile Sandstone, host rock for the large uranium deposits in the Laguna district. The Jackpile sandstone consists of fluvial-deposited sandstone with some interbedded mudstone. The remainder of the Brushy Basin Member consists mostly of greenish-gray mudstone with lenticular sandstone beds.

Uranium deposits in the Grants Mineral Belt are irregular in shape, are roughly tabular and elongate and range from thin pods a few feet in width and length to deposits several tens of feet thick, several hundred feet wide and several thousand feet long . The deposits are roughly parallel to the enclosing sand-stones. Many of the deposits form more than one layer and occur in clusters that form distinct trends (Figs. 11, 12 & 13) . Primary uranium ore in Morrison

Sandstones in the Grants Mineral Belt consists mostly of extremely fine-grained coffinite, a uranium silicate contained in dark-gray or brown carbonaceous matter that coats sand grains and impregnates the sandstone.

Uranium deposits also occur in the Morrison Formation outside of the Grants Mineral Belt; however, they are less important at the present time (Fig. 8) . The Shiprock and Chuska areas in northwest New Mexico have produced about 50,000 tons of uranium ore, mostly from the Salt Wash Member in the lower part of the Morrison Formation. The south limit of the Salt Wash Member, host rock for deposits in the Colorado Uravan mineral belt, occurs near the Chuska Mtns. A very small amount of uranium ore production has been reported from Morrison sandstones in Rio Arriba and Sandoval Counties.

Among rocks other than those in the Morrison Formation, the Jurassic Todilto Limestone, about 400 to 500 ft. below the Morrison Formation, has been the most productive. The Todilto Limestone has produced nearly 1 million tons of uranium ore equal to about 2% of New Mexico's production through 1972. Most of this ore was produced from the Grants region. Todilto uranium deposits, however, are typically small and irregular; therefore, economic considerations preclude exploration at drill depths greater than about 500 ft. except under special circumstances.

Next to the Todilto Limestone in importance of uranium produced from rocks other than the Morrison Formation is the Cretaceous Dakota Sandstone. Deposits in the Dakota Sandstone have yielded about 60,000 tons of uranium ore from McKinley and Sandoval Counties. Although these deposits are geologically similar to those of the Morrison Formation, they are typically small.

Uranium deposits in sedimentary rocks of Pennsylvanian, Permian and Triassic age have produced small amounts of uranium ore in New Mexico. Deposits in sedimentary rocks of Tertiary and Quaternary (?) age are typically small and of low grade.

Vein deposits of uranium that occur in igneous and metamorphic rocks in New Mexico are widely scattered and are not an important source of uranium at the present time. These deposits have produced a total of about 15,000 to 20,000 tons of uranium ore in New Mexico.

In order to visualize the economic significance of the total uranium produced and reserves remaining to be mined in New Mexico, a price of $8 per pound of U_3O_8 is estimated for purposes of calculation. This leads to an estimated gross value of nearly $3.7 billion for the 462 million pounds of U_3O_8 contained in production plus reserves presently outlined. This value may change considerably, depending upon a number of factors that are difficult to predict at this time, such as future uranium prices and future additions to ore reserves that are likely to be made. Previous domestic uranium prices paid by the AEC during the period 1948 to 1971 average $8.52/lb. of U_3O_8 for an amount of U_3O_8 that represents about 71% of the nation's total uranium produced as reported through 1972. (However, current delivery prices have been much lower than this average.) Preliminary U. S. Bureau of Mines data for New Mexico's uranium produced during

1971 and 1972 indicates a value of \$6.20/ lb. U_3O_8. Uranium price data usually are not published because the sales are covered by agreements between private companies in a competitive industry. Forecasted prices for uranium in concentrates are in controversy, but some sources predict a range of \$7.50 to \$8.00/1b. U_30_8 for 1975, \$8.00 to \$9.00/ lb. for 1980 and \$9.00 to \$11.00/lb. for 1985. The sales price, of course, has a major effect on the exploration and mining effort that will be made to recover New Mexico's uranium resources.

Most of the future uranium production in New Mexico will come from underground mines. Some of the new uranium deposits now being developed into mines occur at depths exceeding 1500 ft. and may be expected to reach depths of up to 3000 or 4000 ft. in the not-too-distant future.

Typical capital and development costs to bring a moderately deep deposit into production are estimated at about \$20-million for a 1000-tons-of-ore-per-day mine and mill. This cost will, of course, vary depending on a number of factors that are difficult to predict.

Typical lead times required to explore for, discover and develop uranium ore reserves into a producing facility as reported by the AEC are shown by Fig. 14. This lead time is shown as 8 to 9 years from the beginning of exploration to production of uranium oxide, assuming a successful exploration program.

A large part of future exploration efforts, some of which will be successful, will be committed to searching geologic environments known to be favorable for uranium deposits. Most of the emphasis will be directed toward favorable sandstones in the Morrison Formation, and a large part of these expenditures will continue to be made within the Grants Mineral Belt.

An increasing amount of exploration expenditures will undoubtedly be made outside of the Grants Mineral Belt in areas not previously known to contain large deposits. During the past six years, however, many of these areas were tested by various companies with an exploration effort that peaked in 1969 without any reported commercial discoveries.

The future potential appears excellent for finding additional uranium ore reserves in New Mexico. However, a large part of these reserves may be expected to occur at depths of 2500 ft. or more, which will require costly exploration and development.

Figures 1-14 follow on pages 87-99

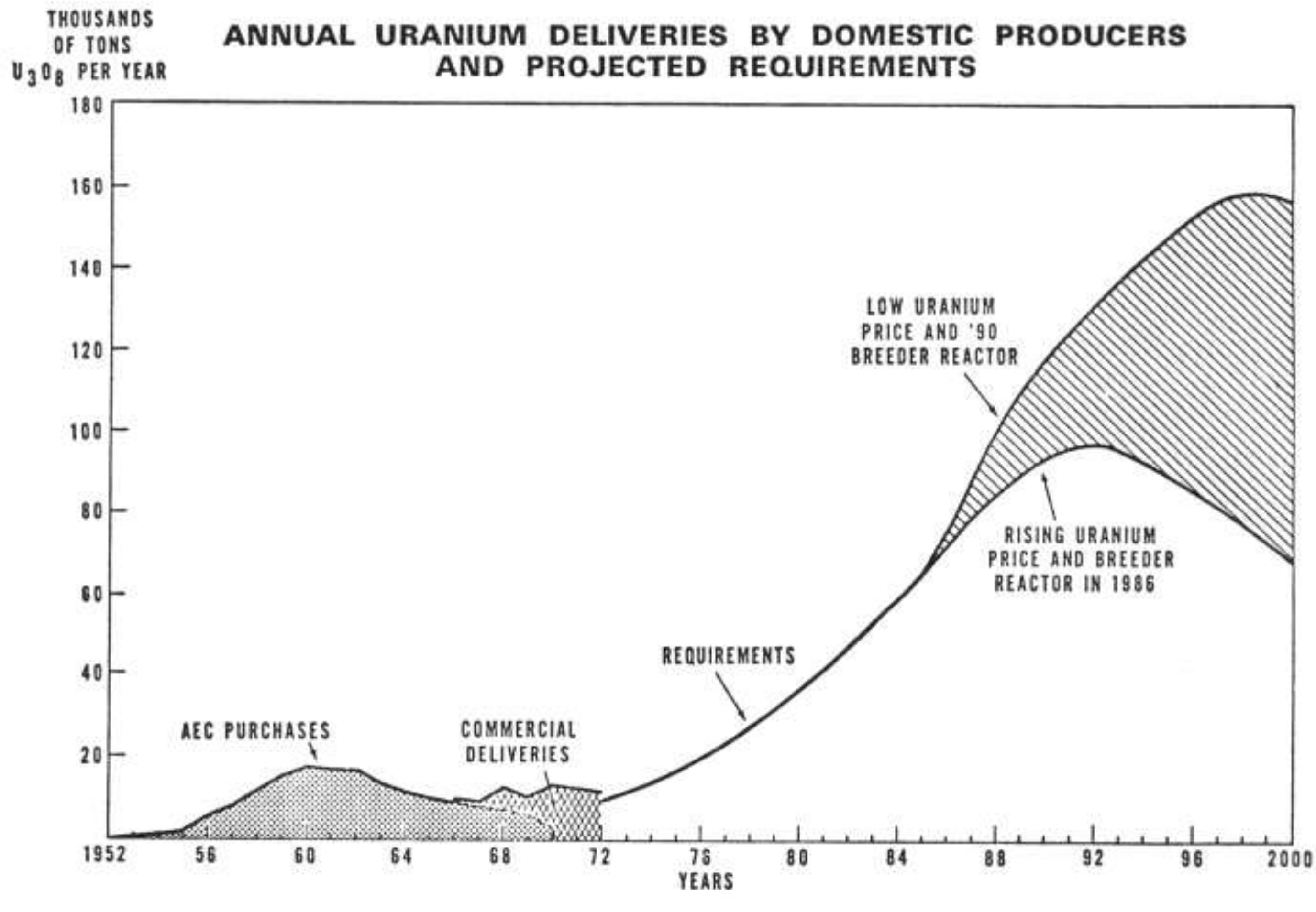


Figure 1. – From A.E.C. Publication.

TYPICAL REACTOR URANIUM REQUIREMENTS[1]

1000 Mwe Reactor

Tons U_3O_8

	Pressurized Water Reactors	Boiling Water Reactors	High Temperature Gas Reactors
Initial Core	460-500	620-680	330[2]
Annual Reload			
W/O Plutonium Recycle	170	160	---
W/ Plutonium Recycle	130	125	75[2] (U233 Recycle)
30 Year Requirement	4000-5300	3900-5300	2400

- -

Relationship between Tons U_3O_8 & Tons of typical Uranium ore.

- -

Contained Tons U_3O_8	Tons of Uranium Ore Required at a grade of 0.25% U_3O_8
500	200,000
2,400	960,000
4,000	1,600,000
4,500	1,800,000
5,300	2,120,000

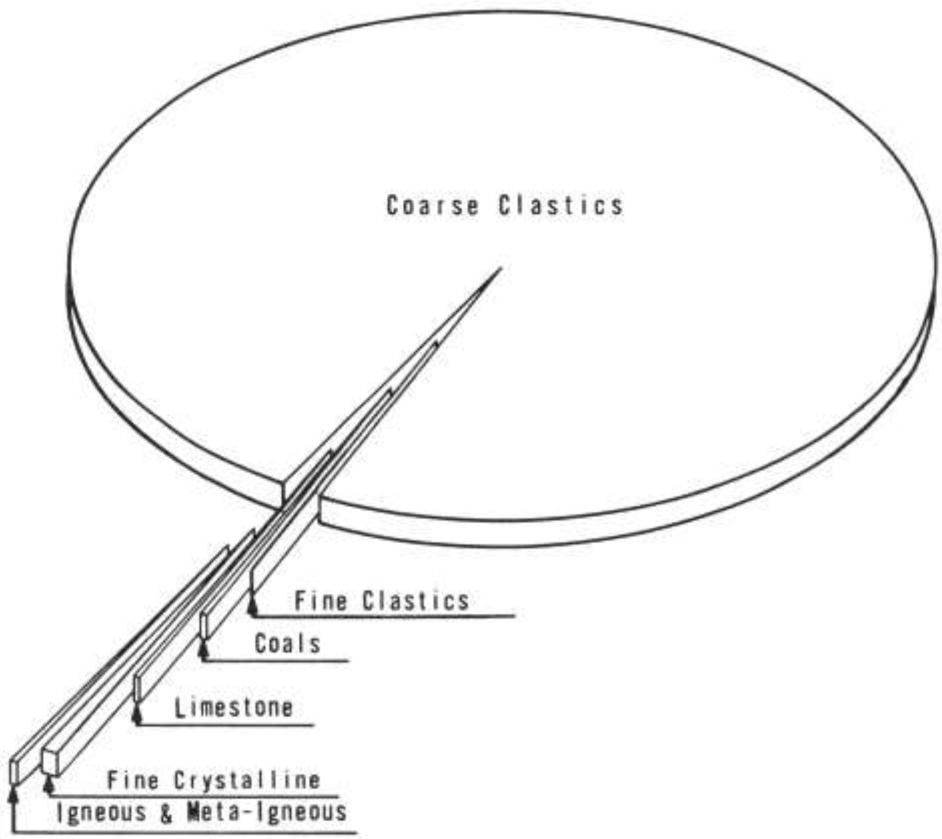
[1]Assumes 0.20% Enrichment Plant Tails Assay.

[2]Also requires thorium oxide; 42 tons for first cores and 7 tons for reloads.

Fig. 2. - Modified from A. E. C. published data.

Distribution of 1/1/72 Ore Reserves by Type of Host

$8.00 Reserves



Host Type	Tons Ore	Grade	Tons U_3O_8	% Total Tons U_3O_8	No. Deposits
Coarse Clastics	125,529,233	0.215%	269,930	98.798	662
Fine Clastics	26,480	0.291%	77	0.028	9
Coals	233,647	0.229%	535	0.196	44
Limestone	136,840	0.354%	485	0.177	7
Fine Crystalline	468,357	0.346%	1,621	0.594	4
Igneous & Meta-Igneous	127,120	0.445%	565	0.207	6
Totals	126,521,677	0.216%	273,200*	100.000	732

* Rounded

Totals at 1/1/73	128,000,000	0.21%	273,000

Figure 3. — From A.E.C. GJO-100.

DOMESTIC URANIUM RESERVES AVAILABLE AT A
COST OF $8 PER POUND OF U_3O_8 OR LESS
(as of Jan. 1, 1973)

STATE	TONS OF ORE	PERCENT U_3O_8	CONTAINED TONS U_3O_8
New Mexico	49,000,000	.27	134,000
Wyoming	55,500,000	.18	98,000
Texas	10,600,000	.15	16,000
Colorado	3,100,000	.27	8,000
Utah	2,500,000	.33	8,000
Others (Alaska, Arizona, Oregon, S. Dakota, Washington)	7,300,000	.12	9,000
TOTALS	128,000,000	.21	273,000

Fig. 4 - From A. E. C. GJO-100 and press release No. 626.

DOMESTIC URANIUM PRODUCED 1948 through 1972

STATE	TONS OF ORE	PERCENT U_3O_8	CONTAINED TONS U_3O_8
New Mexico	44,085,800	.22	96,744
Wyoming	21,629,136	.22	47,269
Utah	13,272,629	.31	41,423
Colorado	14,689,303	.25	36,602
Arizona	2,965,900	.30	8,950
Others*	6,389,120	.20	12,764
TOTALS	103,031,888	.24	243,752

*Includes Alaska, California, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Texas and Washington.

Fig. 5. - From A. E. GJO-100 and press release No. 626.

DISTRIBUTION OF URANIUM DEPOSITS BY STATES

January 1, 1972

State	Tons U_3O_8	Percent of Total	No. Properties
New Mexico	231,500	45.6	239
Wyoming	138,300*	27.2	350
Utah	49,500	9.7	1,229
Colorado	45,000	8.8	1,351
Texas	19,000*	3.7	59
Washington	11,700	2.3	15
Arizona	9,100	1.8	333
South Dakota	1,900	0.4	159
Others: California, Idaho, Montana, Missouri, Nevada North Dakota, Oklahoma, Oregon, Alaska	1,800	0.4	127
Total Jan. 1, 1972	507,800	100.0	3,862
Total Jan. 1, 1973	516,750		

*Probable significant additions during 1972.

Fig. 6 - From A. E. C. Published Data

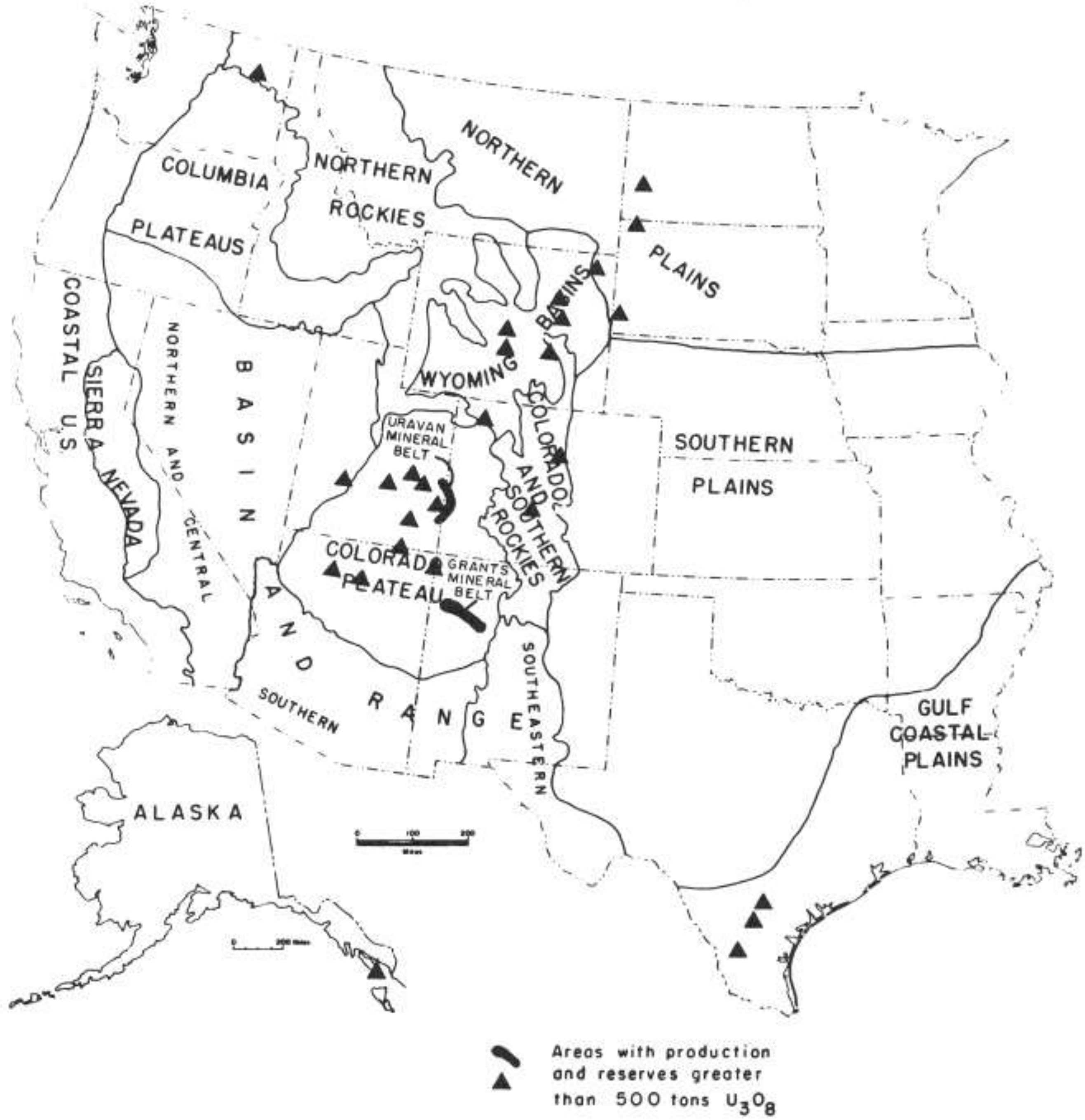
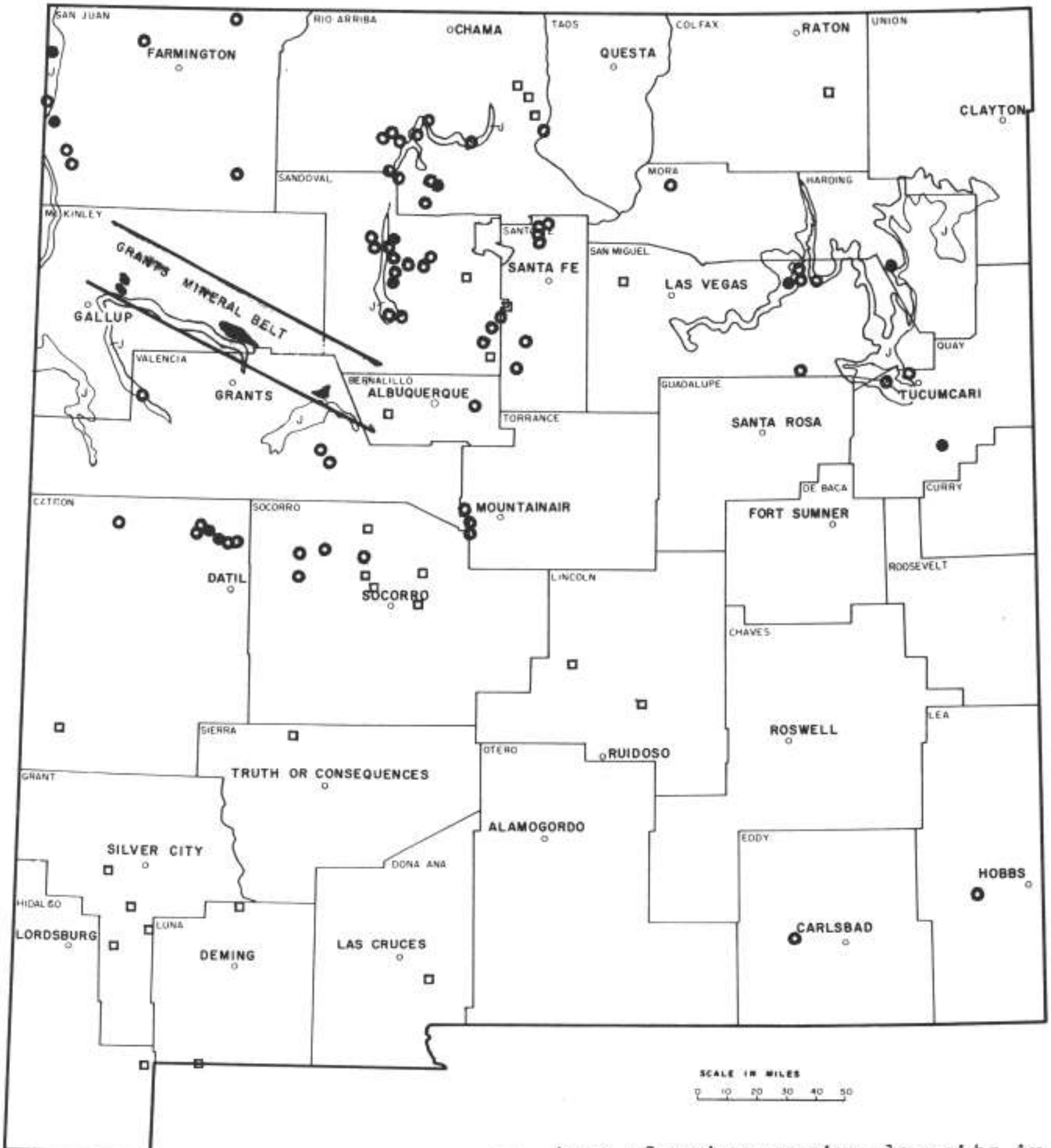


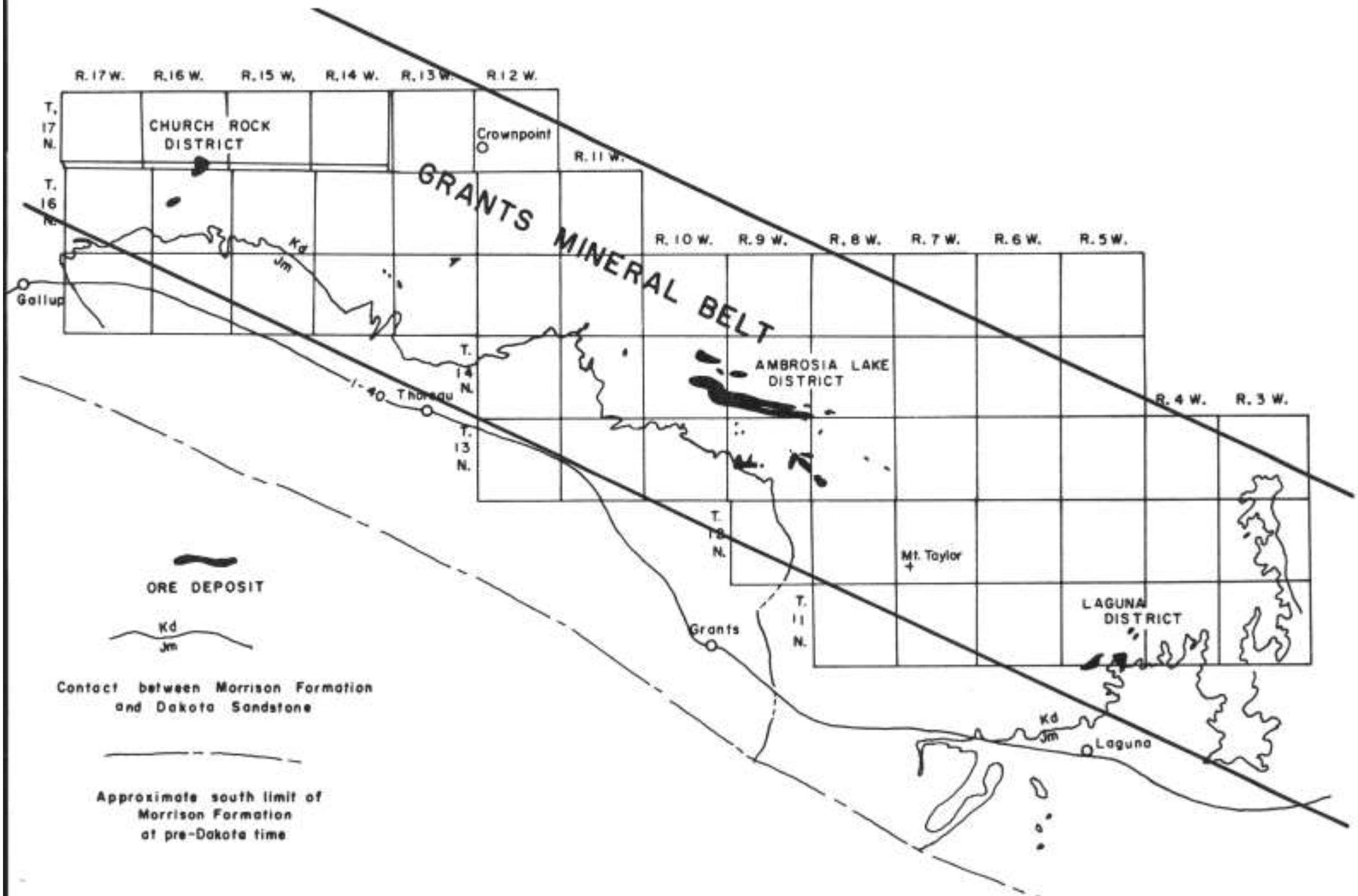
Figure 7 – Uranium Resource Regions, Western United States
From A.E.C. published data.

URANIUM DEPOSITS IN NEW MEXICO



- Area of major uranium deposits in the Grants Mineral Belt
- Some uranium produced from deposits in sedimentary rocks
- Uranium occurrence in sedimentary rocks
- Vein deposits

Figure 8.



GRANTS MINERAL BELT
Figure 9.

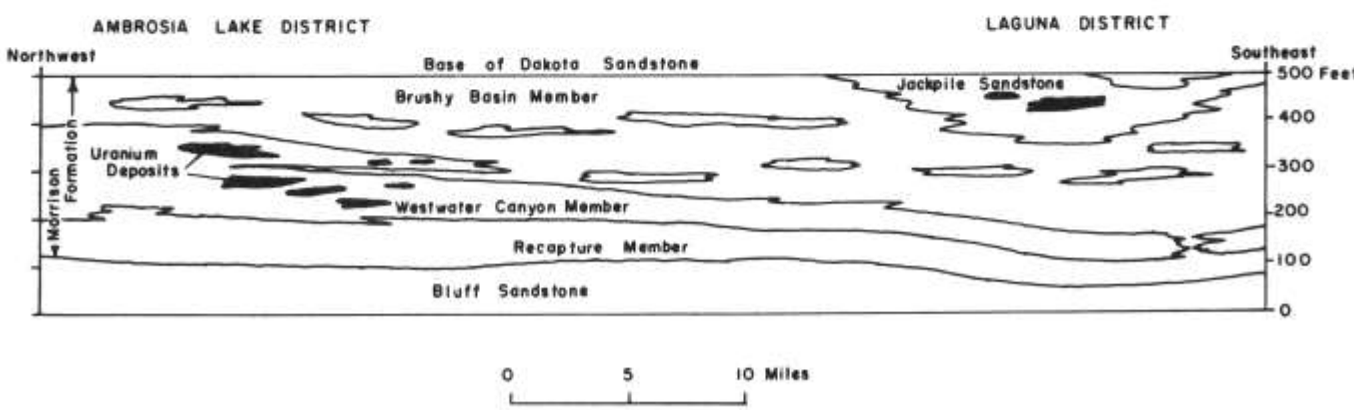


Figure 10 – Generalized geologic section showing the stratigraphic relations of the Morrison Formation between Ambrosia Lake and Laguna. From L. S. Hilpert (1963, p. 16).

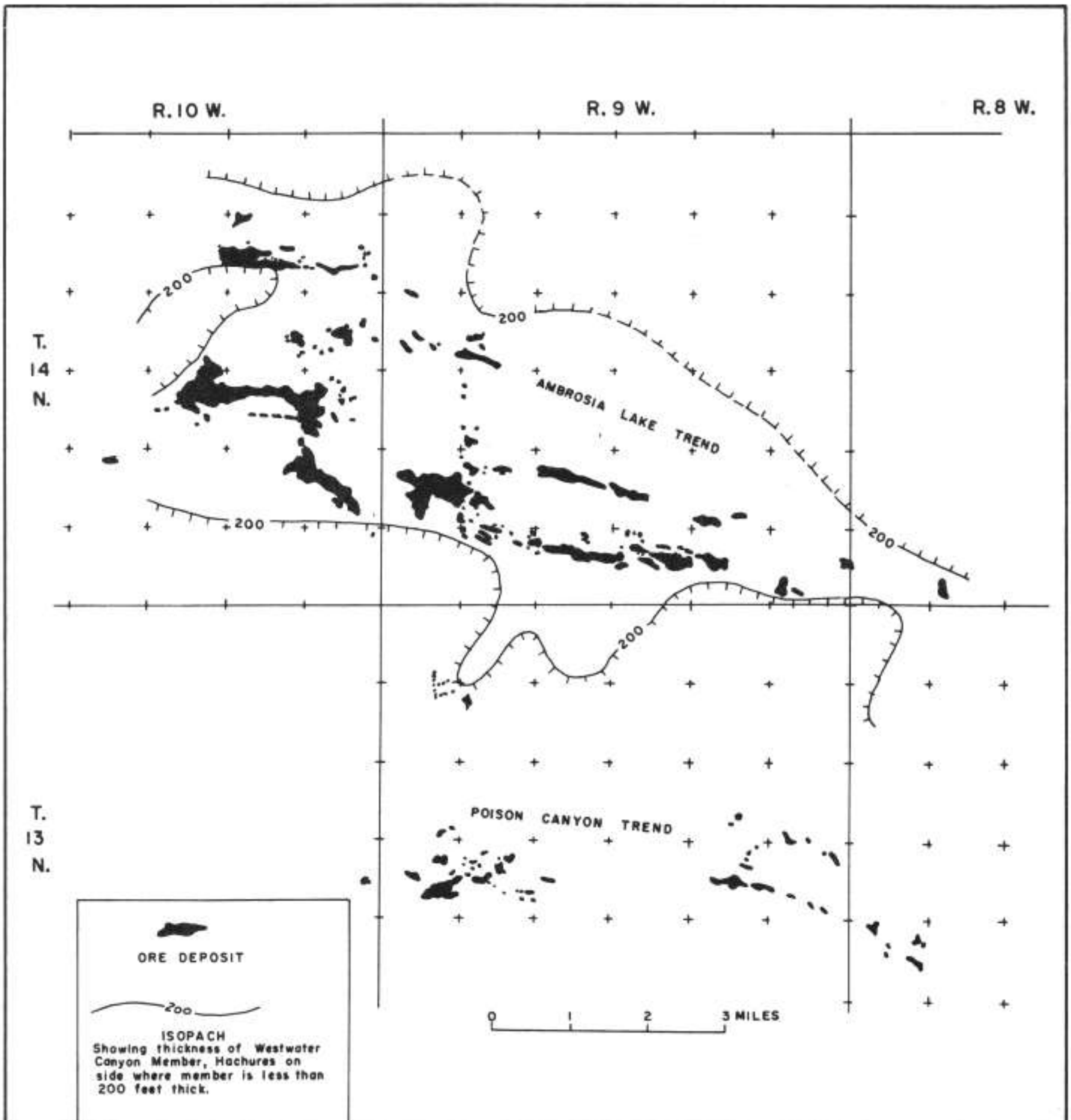


Figure 11. – Ore deposits in the Morrison Formation, Ambrosia Lake district. Modified from E. S. Santos (1963, p. 56) and L. S. Hilpert (1969, p. 67).

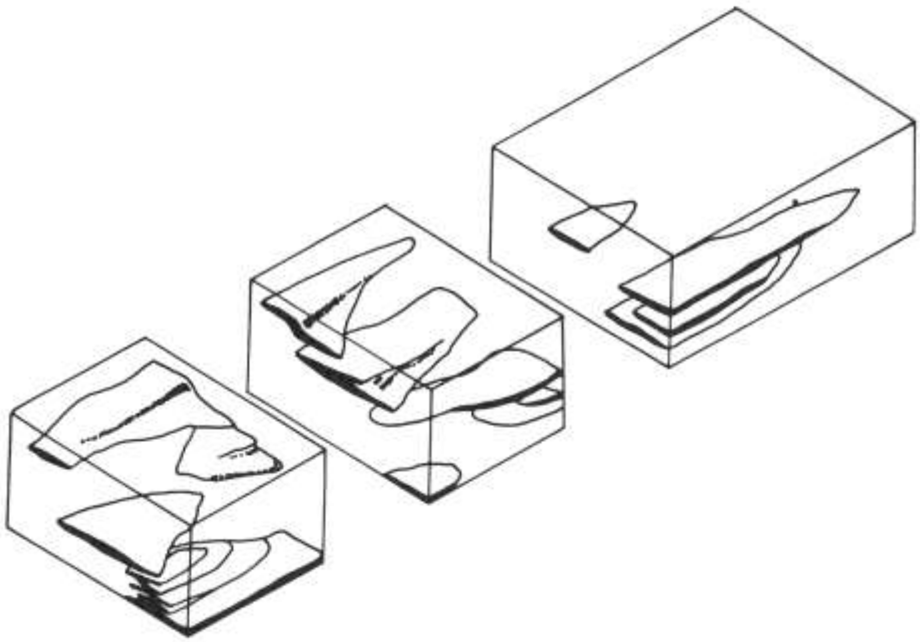


Figure 12 – Idealized exploded block diagram showing typical relationships of prefault orebodies in the Ambrosia Lake district. From Granger, et. al. (1961, p. 1189).

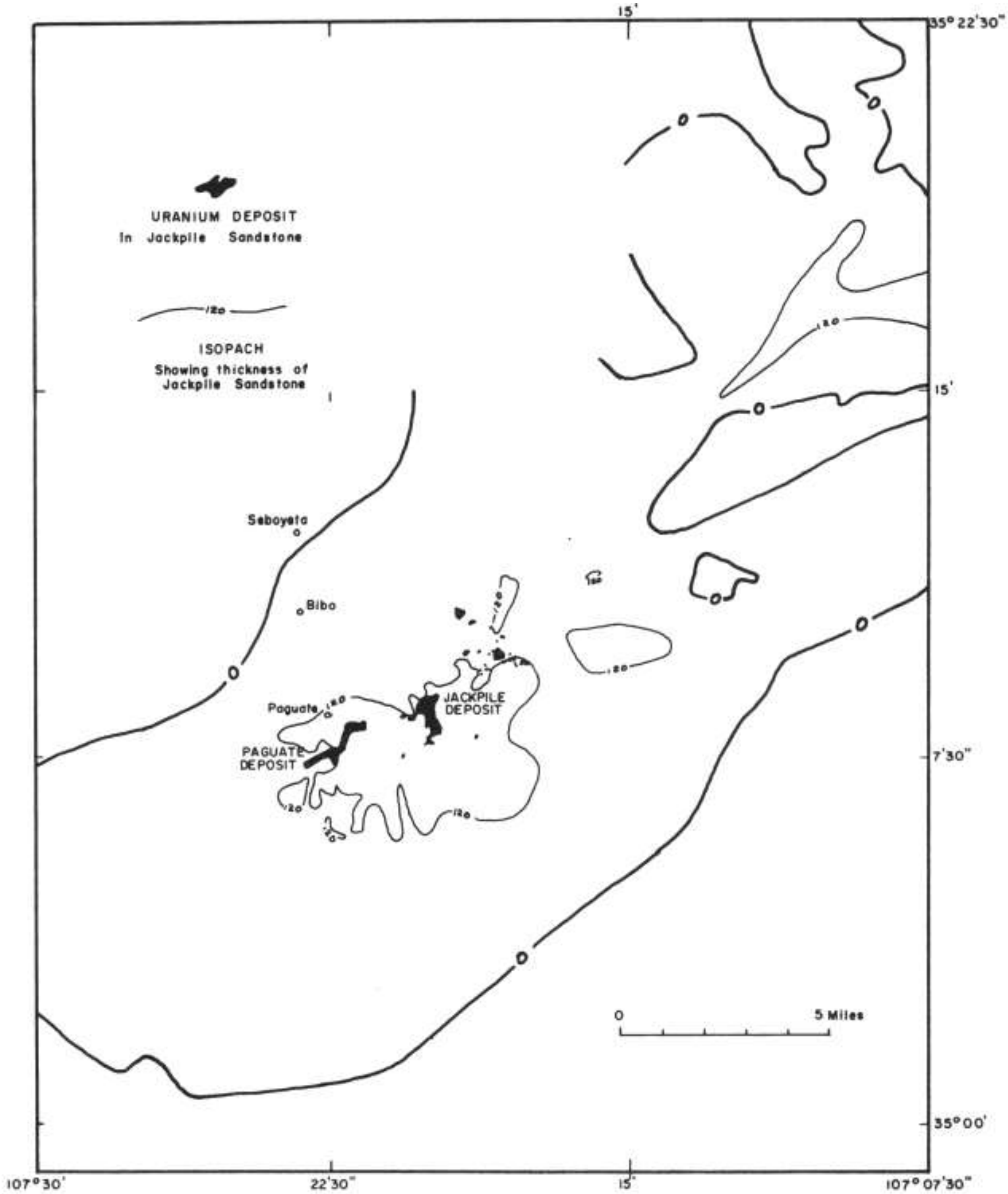


Figure 13 – Map of ore deposits in the Jackpile sandstone in the Laguna district, showing thickness of the Jackpile sandstone. Generalized from R.H. Moench and J.S. Schlee (1967, pl. 3).

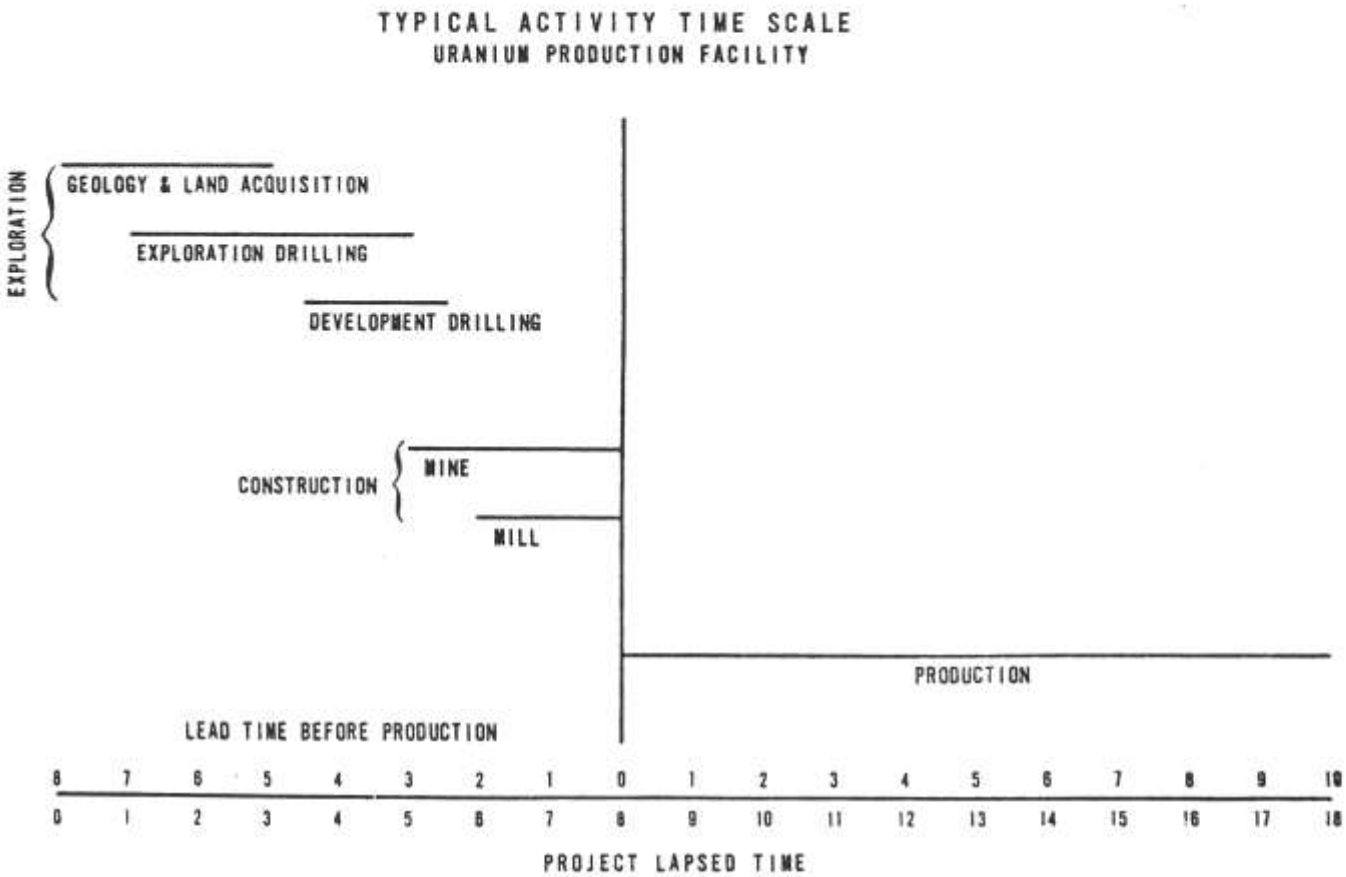


Figure 14 – From A.E.C. Publication.

TARGET FOR TOMORROW - CONVERSION OF NATURAL GAS TO ELECTRICITY VIA THE FUEL CELL

Campbell McMordie
Southern Union Gas Co.

The purpose of this presentation, entitled "Target For Tomorrow," is to acquaint you with the natural gas fuel cell and the program behind its development. The program, if successful,- will lead to a new single source utility service with many benefits to the consumer and society. This new all gas service would rely on the fuel cell to provide all of the customer's electrical needs.

Our test period began late in 1971, during some pretty severe winter conditions and continued until the removal of the test unit on August 8, 1972. The unit had recorded 3,739 hours of operation.

I would like you to keep in mind the fact that our involvement with the Pratt & Whitney Company was on a field test basis. Therefore, we are committed to release of data that is "not too technical" at this time.

The organization which is responsible for this program is called TARGET, which is the name of a not-for-profit corporation - The Team to Advance Research for Gas Energy Transformation. Actually the name TARGET applies to an organization and a program. It is a combined effort by major utility companies in the United States and elsewhere - including gas transmission companies, gas distribution companies, combination gas and electric companies and Pratt & Whitney Aircraft Division of United Aircraft Corporation. Funds of over $50 million have been committed to this program by these utilities and Pratt & Whitney Aircraft. This is all private money.

The goal of the program is to develop a natural gas fuel cell system capable of providing competitive electricity efficiently, cleanly and quietly at the point of use. This would permit the gas industry to offer a competitive single source utility service with high environmental and conservation value.

The fuel cell powerplant research and development activities are being conducted in a Pratt & Whitney Aircraft facility with a floor area of about 170,000 square feet. There are about 700 people involved in all of Pratt & Whitney Aircraft's fuel cell programs.

Technologically, the fuel cell power-plant has already proven itself. In terms of availability for use by individuals, it is still some time in the future. But before we look at the future, let's see where we are today.

Southern Union has been in the gas business for over 40 years. Today, we provide service to more than 450,000 customers in over 135 cities and towns in New Mexico, Texas, Arizona and Oklahoma. Obviously, we have a big stake in the energy business.

But just what is the condition of the energy business in the United States? You are well aware of the need to protect our environment...and to preserve our natural resources--two areas of concern, incidentally, which have been receiving close attention from Southern Union for many years.

Now, in the midst of this situation, is a seemingly contradictory need - our appetite for more energy; abundant, reliable, clean, low-cost energy. It comes as no surprise then that there is in this country an energy crisis.

What is being done about it? There are a number of approaches, and a number of organizations, associations and individual companies working on the problem.

Among the ways the gas industry is trying to solve the problem is through an ever-widening and increasingly active search for new gas supplies. In addition to drilling in regions of the nation that are believed to be gas productive, the search encompasses many distant areas--places like Alaska, offshore the continental United States, the Artic, Canada. Large amounts of natural gas are known to exist in each of these places. Getting the gas out of the ground and obtaining it for the nation's markets are the major challenges.

The gas industry is also engaged in several other gas supply projects, such as importing liquefied natural gas by way of large ocean-going tankers from gas-producing foreign countries; manufacturing pipeline quality gas from coal and naptha by special gasification processes; and using nuclear stimulation techniques to increase gas production.

As a matter of fact, the world's only two experimental tests conducted to date to free natural gas from tight underground formations by nuclear stimulation have occurred not too far from the Albuquerque area. One test has been conducted in the San Juan Basin gas fields near Farmington and the other one has taken place in western Colorado.

In the case of Southern Union, we are more fortunate than most gas utilities in that we have facilities located in the heart of some of the most prolific gas producing regions in the nation.

Right here in New Mexico in the Four Corners area, for example, we have large gas reserves owned and under contract. In addition, we carry on an active exploration and oil and gas well drilling program--activities in which we have been successfully involved for over 40 years.

So far we've been talking about efforts to obtain more energy for the future. Another approach is to make the most efficient use of that energy. That's the essence of natural gas fuel cell energy service. It's an exciting new means of supplying all energy, including electricity, for a business, residence or industrial plant--all from one source, pollution-free natural gas!

All-gas energy service is made possible by a development of space-age technology--the natural gas fuel cell power-plant. And we have just such a unit operating now at a home here in Albuquerque.

The fuel cell powerplant serving this home is the first installation of its kind in the southwest. The only other one scheduled to be installed in this part of the country for testing purposes will be in Tulsa, Oklahoma.

This installation is part of an experimental program to test the practical application of all-gas energy service. All of the energy needs of this home are met with natural gas. For heating, cooking, and water heating purposes, natural gas is used directly. The fuel cell powerplant, operating on natural gas, produces all the required electricity for the home efficiently and economically, as well as cleanly and quietly.

This experimental installation represents a research investment by Southern Union as a participant in a national gas industry program called TARGET. The letters stand for Team to Advance Research for Gas Energy Transformation, Inc. The purpose of this organization's efforts is to help solve the nation's energy and environmental needs. The immediate aim is to establish whether or not fuel cell energy service is a practical concept and acceptable to the public.

The search for this imaginatively new and better energy service started in 1967 when a nationwide group of gas companies formally organized TARGET as a non-profit organization operating with funds derived from private sources. Pratt & Whitney Aircraft Division of United Aircraft Corporation was selected as the prime contractor for this long-range, multi-million dollar research program. Pratt & Whitney developed the fuel cell powerplant technology and hardware for America's Apollo space missions.

Today there are 32 member companies, including Southern Union, in TARGET. These companies, together with Pratt & Whitney Aircraft, are in the process of installing and testing natural gas fuel cell powerplants in a number of locations and under a variety of conditions throughout the United States. The unit Southern Union is testing here in Albuquerque will be operated at intervals over the next three months and at the end of the test period will be taken out of service and returned to Pratt & Whitney for further evaluation. The other units undergoing tests across the country will be handled on a similar basis.

Hopefully, in the not too distant future, the gas industry will be able to offer an attractively priced, single source utility service with many economic and service advantages, plus high environmental and conservation values.

The fuel cell powerplant installed at this home generates electricity from chemical energy stored in natural gas. In this respect, the fuel cell provides the same function as a conventional electric generation system. However, the manner in which the fuel cell generates electricity is dramatically different from presently more conventional methods of generating power.

This fuel cell combines natural gas with oxygen in the air to produce electricity directly--without combustion.

In conventional energy conversion systems, the combustion process is needed to convert the chemical energy stored in fuel to thermal energy which is then transformed into mechanical energy by means of a rotating generator. There is a loss of efficiency at each step.

While the conventional energy conversion system requires a number of intermediate steps to produce electricity, the fuel cell accomplishes the same job simply, directly and more efficiently by means of an electrochemical process.

The fuel cell produces electricity on demand, in the amount, and at the same time it is actually needed. The electrochemical process takes place in a single cell, consisting of a fuel electrode, air electrode and electrolyte. Each cell in the fuel cell powerplant produces enough electric power to sustain the illumination of a 60-watt light bulb at a potential of one volt. The powerplant Southern Union is testing here has capacity to generate 12-1/2 kilowatts of power which is more than ample to meet the peak electrical needs of the average single-family home.

To produce a higher voltage and power level, the single cells can be connected in a series to form a modular assembly called a "stack." The stacks may be connected in parallel for even greater power levels. The one-volt single cell may be used to provide power capacities to meet a load or demand of anywhere from a few kilowatts to serve an individual home to many kilowatts to serve a large industrial requirement.

This building block or modular approach to power generation provides a very flexible power system which can be tailored to the specific needs of a wide range of installations.

In addition to the fuel cell modules, the powerplant contains a reformer, which, in this installation is housed in the same compartment as the fuel cell and an inverter.

Natural gas is supplied to the reformer, which uses a chemical process known for more than a century. It takes the natural gas through a chemical transformation process in the presence of steam and a catalytic medium and dissociates the carbon and the hydrogen elements of natural gas. The carbon is transformed to carbon dioxide and together with the released hydrogen is fed as fuel to the fuel cell itself.

The processed fuel, together with air, is then converted in the fuel cell to direct current electricity. The inverter then transforms the DC electricity into alternating current (AC).

These three components--the reformer, the fuel cell modules and the inverter--combine to form a fully automatic fuel cell powerplant capable of unattended operation.

Since the fuel cell eliminates the intermediate steps of combustion, it uses fuel more economically. This direct conversion of chemical energy into electricity is far more efficient than any system of electric generation that relies on the combustion process.

Conventional electric generation systems must be built on a large scale to achieve practical levels of efficiency. The fuel cell, on the other hand, exhibits a high level of efficiency almost independently of size. The same high level of efficiency, or fuel economy, may be obtained from a fuel cell powerplant tailored to provide a few kilowatts for residential needs or from one sized to meet large industrial demands.

Equally important, the fuel cell powerplant is a very clean power generator. The main byproducts of generation of electricity by way of the natural gas fuel cell powerplant are air, a relatively small amount of heat, water vapor and harmless carbon dioxide. Sulfur dioxide, nitrogen oxides, hydrocarbons and particulets, all major pollutants, are almost non-existent with the production of electricity by the natural gas fuel cell powerplant.

The fuel cell is also quiet in its operation. It has no moving parts. Thus, noise is minimized. There is no need for locating the powerplant near a source of cooling water, such as a river or lake, since cooling of the fuel cell is accomplished directly with air. This combination of features provides a unique power generation system that is not restricted by use or location.

Natural gas fuel cell service has reliability advantages, too. Natural gas is supplied by an underground pipeline system directly to the fuel cell powerplant. As a result, the generating device eliminates most of the causes of conventional power interruptions and customer inconveniences. The simplicity of the fuel cell's direct energy conversion process also contributes to its long life and reliability.

Locating the fuel cell at the point of use provides the potential for a new energy service option. By combining the advantages of gas and electricity into a single energy service, the customer can enjoy clean, modern natural gas for such purposes as water heating, heating, air conditioning and cooking, and electricity for powering other appliances and for lighting purposes. With the fuel cell energy service, all of the customer's energy needs are supplied by natural gas.

How much will natural gas fuel cell energy cost? Assuming all technical objectives of the research project are achieved, it's anticipated that the cost for fuel cell energy service will be competitive with the cost for both gas and electric service as now provided separately.

All in all, the potential for the customer and society are the driving force for the fuel cell research investment by Southern Union and other member companies of TARGET.

The effort to realize these benefits with natural gas fuel cell service began in 1967 as a three-phase program to be conducted over a nine-year period.

Phase 1, successfully completely in 1969, explored the technical and economic aspects of fuel cell energy service and established the requirements that would have to be met for the various potential applications in the marketplace.

Phase 2, now in progress, involves

a continued investigation of the technology and a deeper probe into the realities of the actual application to obtain answers to questions about the technical and economic practicality of natural gas fuel cell energy service.

Phase 3, contingent on the success of Phase 2, anticipates actual marketing of fuel cell energy service through a relatively small powerplant capable of years of reliable, unattended operation.

Concurrently with continued technology development on fuel cells during Phase 3, TARGET member companies are conducting a Comprehensive Installation Program. Known as CIP, this program is aimed at obtaining real-life experience with fuel cell powerplants. To accomplish this objective, a limited number of experimental fuel cell powerplants are being, or will be, field tested in various parts of the country.

Up to 60 natural gas fuel cell powerplants are scheduled for installation by various TARGET member companies at 37 locations in 19 states. Installations are planned for apartments, stores, restaurants and office and industrial buildings, as well as for homes, like we have here in Albuquerque.

Since this search for a better energy service was launched, significant progress has been made in the development of the natural gas fuel cell power-plant. But much remains to be accomplished.

The efforts of Southern Union Gas Company and the other member companies of TARGET are aimed at establishing a solid basis for determining if, and when, the industry will offer fuel cell energy service. The outcome of this program will decide whether natural gas fuel cell powerplants can be produced and marketed commercially.

Using nature's clean source of energy, pollution-free natural gas, the fuel cell may help reduce air and water pollution, conserve our natural resources and help meet the country's ever-increasing demands for energy.

Your reaction to this bold, pioneering effort--natural gas fuel cell service--will be very helpful in establishing this TARGET FOR TOMORROW.

The experimental TARGET powerplant, which has been installed by various TARGET member companies in a variety of locations in the United States, Canada, and Japan is called Powercel 11, which is a Pratt & Whitney Aircraft trade name for a first generation hydrocarbon-air fuel cell powerplant.

The Powercel 11 is an experimental powerplant which uses natural gas to produce conventional alternating current electricity over a wide range of loads up to 12-1/2 kilowatts peak load. While this is an experimental unit, it has demonstrated many of the inherent features of fuel cell powerplants. These features offer potential benefits to both the users of the energy service it provides and to society in general.

As we have indicated, these experimental natural gas fuel cell powerplants were installed in a variety of locations providing energy service to many different types of buildings. Apartments, stores, homes, restaurants, office buildings, industrial buildings and electric utility substations were included in this research program. The installation, operation and maintenance of the powerplants were conducted by the TARGET member companies. The first installation was a condominium home in Farmington, Connecticut. The fuel cell powerplant successfully provided the electrical requirements for the home's lighting, appliances, and air conditioning equipment during this 3-month test.

The Powercel 11 consists of two units: the D.C. powerplant, which houses the reformer and the fuel cells, and the inverter, which converts the D.C. electricity from the fuel cells into utility grade A.C. electricity.

Both indoor and outdoor locations were used in the experimental installations. Larger installations were accommodated by connecting multiple powerplants together in modular fashion and the system provided either single phase or three phase A.C. electricity.

A variety of homes were included in the test in addition to the Southern Union experimental home here in Albuquerque. In addition, in Milwaukee, four mobile homes were powered by one experimental natural gas fuel cell powerplant. In Riverside, California, an air conditioned mobile home is powered by an experimental unit. Multi-family dwellings such as a nine-unit apartment in Chicago, and a thirteen unit apartment near Pittsburg. A variety of commercial buildings were included in the testing such as a branch bank near Buffalo; a convenience food store in Barrington, Illinois; a drugstore in New York City, and an office building in Flint, Michigan.

Industrial type buildings were included in the testing such as a greenhouse located near Cleveland; an automobile repair shop, and a manufacturing plant near Columbus, Ohio. Three powerplants were operating in parallel at this location.

The experimental 12-1/2 kilowatt powerplant has demonstrated many unique features which are important in on-site energy generation. The quality of the electricity produced by this experimental unit is high. Voltage regulation is excellent and the frequency is held accurately at 60 cycles per second.

While the Powercel 11 is an experimental unit, the powerplant is quiet and completely automatic in operation. No one need be in attendance. Automatic shutdown and safety controls are provided to insure proper operation. The unit has demonstrated that very low levels of pollutants are emitted and high efficiency levels are possible. In the course of the program, experience has been gained in operation from sea level to altitudes here in Albuquerque of 5900 feet. Powerplants installed out of doors have been exposed to a wide variety of weather and temperatures over 100°F and down to 20° below zero. I would like to point out that the Powercel 11 is an experimental powerplant designed a few years ago specifically to obtain field operating experience in this program. Advances in the program indicate that future powerplants could be of considerably smaller size for the same power output.

If the TARGET program reaches a successful outcome, more advanced units may be used by gas companies to provide their customers with an energy service based on nature's clean fuel, natural gas. In this way, the fuel cell could help to conserve our dwindling natural resources, reduce air and water pollution and help meet the country's ever-increasing demand for energy.

THE LOS ALAMOS SCIENTIFIC LABORATORY HOT DRY ROCK GEOTHERMAL ENERGY PROGRAM 1/

R. Lee Aamodt
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The concepts discussed in this paper were first published in a study of the Laboratory's Rock Melting Drill (E. Robinson, et al, "A Preliminary Study of the Nuclear Subterrene," Los Alamos Scientific Laboratory report LA-4547, April 1971). One application of such a drill appears to be the drilling of very deep, relatively low-cost, holes. Since such holes will end up in hot rock, it became of interest to consider energy extraction from the rock. Since rock has a very low thermal conductivity, it is necessary to contact a large surface area of rock in order to remove interesting amounts of heat. One way to do this appears as follows:

1. A hole of about 7-inch diameter is drilled and cased into rock of 250-300°C.

2. A portion of the hole below the casing is filled with water and the pressure increased until a crack forms in the rock. Water is pumped into the crack at lower pressure to enlarge it.

3. At the growing edge of the crack, growth proceeds intermittently, accompanied by bursts of noise which may be located by an array of geophones. Using the geophone data for guidance, a second hole is drilled to intersect the top of the crack. After a liner is cemented into place, a secondary hydrofracture is created to facilitate flow between the pipes.

4. The pipes are connected by a heat exchanger at the surface. Water is pumped down the first pipe and up the second, while pressure is maintained high enough to prevent boiling. Once circulation has been established, a convective driving force of 1,000-1,500 psi, arising from the difference in density of hot and cold water, will maintain the circulation.

The advantages of operating with an all-liquid system are fourfold:

1. Several times as much thermal energy can be brought up a given pipe as water than as steam.

2. Problems of precipitation of dissolved substances are brought to the surface, where they may be more readily handled.

3. In the water phase, viscosity decreases as temperature increases. If two geometrically similar paths exist in rock of different temperatures, the flow through the hotter path will be higher than the flow through the cooler path.

4. Dissolved gases, such as H2S, will remain in solution and be reinjected into the reservoir, greatly reducing environmental problems.

As the rock cools on the surface it will tend to contract, but the contraction will be opposed by the hotter rock behind it. This is expected to cause cracking which will expose new areas of hot rock. The coldest water is near the hottest rocks near the bottom of the reservoir, so the cracks should grow preferentially

1/ Written under the auspices of the U.S. Atomic Energy Commission.

downward. This process has been studied in some detail on a computer (F. Harlow and W. Pracht, "A Theoretical Study of Geothermal Energy Extraction," Jour. Geophys. Res. 77, 7038-7048, 1972), and earlier hand calculations indicating that the reservoir life might be extended indefinitely were confirmed. Even without this process, calculations indicate that an average electrical power of 25 MW can be drawn from a crack of one square kilometer area over 20 years.