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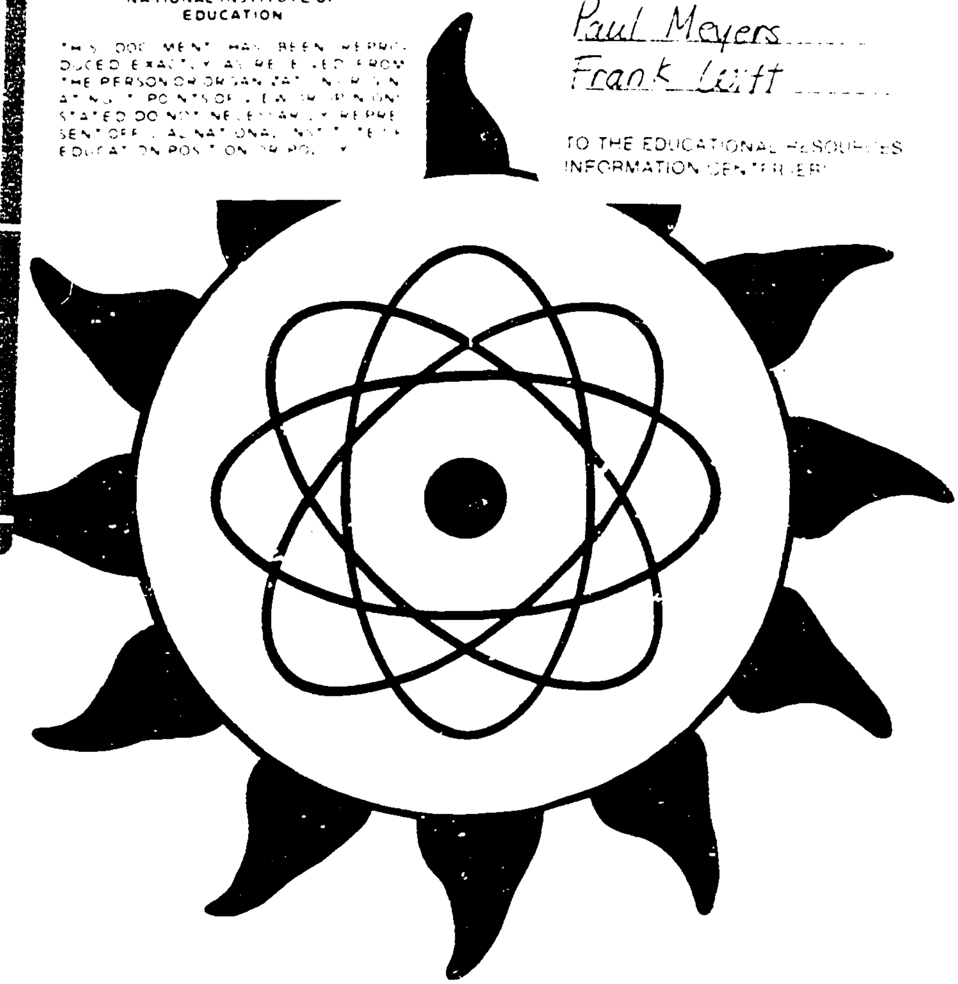
ABSTRACT

Presented is an analysis of alternatives available to the United States in dealing with energy problems. Options explained and evaluated include coal, solar, hydroelectric, nuclear, geothermal, wind, biomass, and energy conservation. The booklet is part of Project APEC (America's Possible Energy Choices), a nationally validated Title IVc project designed to educate teachers of grades 9-12 about energy and provide related study units and materials for students in these grades. (WB)

OUR ENERGY OPTIONS



PAUL MEYERS & FRANK WITT

APEC (America's Possible Energy Choices) is a Title IVC program that trains high school teachers (grades 9-12) in energy education and provides the teachers with study units and materials to teach their students about energy. Teachers participating in the program are provided a 10 hour training program conducted by the project staff. The high school curriculum comprises (32) lessons (in boxed kit form) divided into subunits on (1) Ways of Making Electricity (2) Present Energy Sources (3) Future Energy Sources (4) Atomic Theory & Radiation (5) Energy Conservation and (6) Pros and Cons of Nuclear Energy. Teachers are provided teaching materials which include: 37 color transparencies, a narrated filmstrip, 52 slides, 2 tapes, 102 duplicator masters, 60 energy articles, over two dozen supplementary materials, a copy of the "Our Energy Options" paperback, and directions for teaching each lesson.

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Superintendent, Rockford Public Schools

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F O R E W O R D

Dear Reader:

Problems relating to energy are playing an increasingly important role in the lives of every school child and adult in the United States. Especially serious is our dependence upon the Middle East for oil.

With this in mind, it is my pleasure to recommend the booklet that follows to you. It explains and evaluates the many options - coal, conservation, solar, hydroelectric, nuclear, geothermal, wind, biomass and others - available to us in dealing with these problems.

This booklet is an adjunct to Project APEC (America's Possible Energy Choices) a State of Illinois and nationally validated Title IVc project. Hopefully, it will help you achieve understanding in this vital area.

Good reading!

Sincerely,

Arthur T. Johnson
Superintendent of Rockford
Public Schools, District #205
Rockford, Illinois

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INTRODUCTION

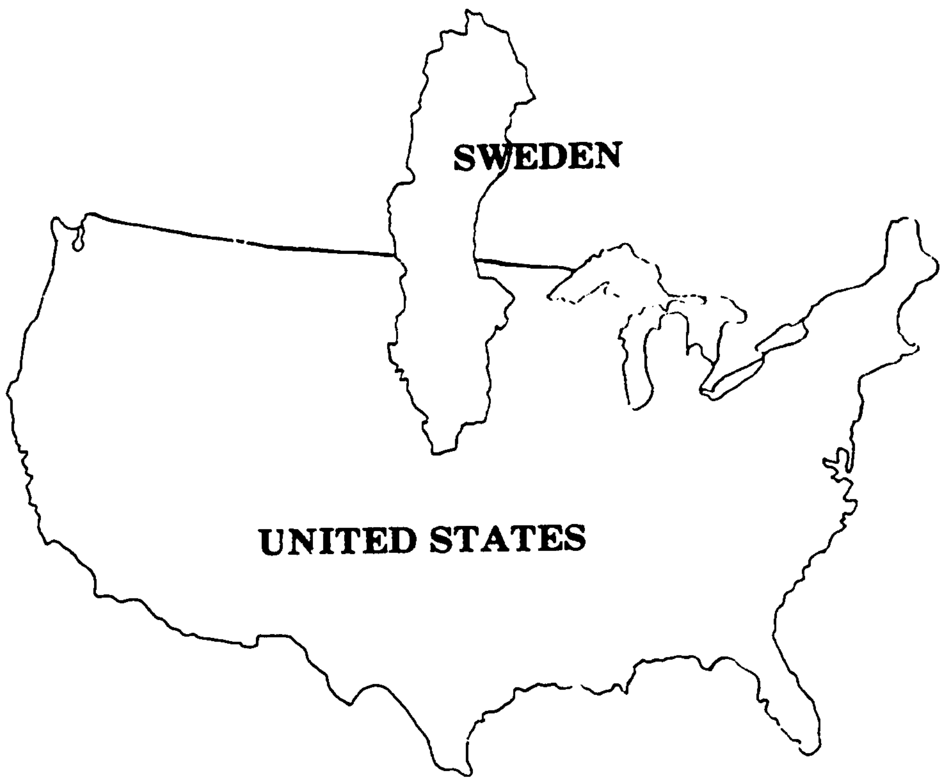
It is alleged that we have an energy shortage in the United States today. During the winter of 1976-1977, schools in Pennsylvania closed for weeks, over 1,000,000 American factory workers were out of work, and many homes in the Northeast went cold. Yet, these circumstances were mostly caused by failure to deliver fuel to areas in short supply.

In our country there is really a lack of energy availability, rather than a basic energy shortage. The failure lies in our economic production and economic distribution systems. We can solve our energy problems and we have *many* options in doing so. Conservation, nuclear power, and imaginative development and use of remaining fossil fuels all provide strong and significant possibilities. Solar, wind, geothermal, biomass, and tidal power have merit and are deserving of consideration and increased financial support for additional development in the future.

It is the purpose of this pamphlet to look at different energy options and compare their advantages and disadvantages, particularly in relation to each other. Because nuclear energy has become a controversial subject in some places, it will receive particular emphasis.

SWEDISH VS. UNITED STATES

ENERGY USE



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ENERGY CONSERVATION

Sweden has a standard of living at least as high as the United States, yet uses less than two-thirds as much energy per capita.[1]

Swedish pursuits are similar to ours as well. They travel a comparable amount at home and abroad, own proportionally the same number of refrigerators, washers, dryers, and TV's, drive almost as many automobiles, and have more vacation cottages. Temperature-wise, Sweden averages 50% colder than the United States.

Perhaps the United States cannot realistically hope to reduce the energy used per capita by one-third. American agri-business, accounting for 19% of our energy use, is more highly developed than that of Sweden. We have a greater development per capita of heavy industry — aluminum, steel mills, and other heavy manufacturing. Nevertheless, there are many Swedish energy economies that could be helpful.

How do the Swedes manage to use so much less energy? First, Swedish Volvo's and Saab's average 24 miles per gallon while American cars average about 13 per gallon.[2] Swedish cars are lighter and less powerful with the engines designed for more efficient use of fuel. They are nearly as roomy and comfortable as American medium-sized cars.

Secondly, Sweden has far more stringent insulation regulations. Swedish building inspectors for many years have made certain that heat loss does not exceed .06 BTU's (British Thermal Units) per hour per square foot from any newly constructed home, office, or factory. A BTU is defined as the amount of energy required to raise the temperature of a pound of water one degree Fahrenheit.

Typically, the United States does not have any insulation regulations, though homes built according to FHA specifications should not lose more than .12 BTU's per hour per square foot.[3] Needless to say, American homes designed according to these specifications are not often checked to see if they are up to standards.

Americans travel by public transportation 8% of their passenger miles. Swedish people go at least twice as far by public rail, bus, or plane; 18% of Swedish travel miles is done by common carriers.[4]

Good reasons provide for this higher percentage. Trains and buses depart frequently from major points. There is a comfortable streamliner every hour between Stockholm, Gothenburg, and Malmo, the three major cities. Well-kept roadbeds, clean pleasant buses, and on-time rail arrivals encourage comfort-conscious Swedes to travel by public transportation much more frequently than Americans. Tales of trains arriving two hours late, air conditioning that doesn't work, and bumpy roadbeds with derailments all too often discourage us from even considering Amtrak.

Flights between major cities in the United States are at least as often as Swedish commuters by rail and road, but the relatively high fares, in most cases, keep our air carriers from making up the percentage difference.

The last major area where significant savings are made has to do with a little-used American energy technique — co-generation. In Sweden many of the large coal and oil-fired utility plants are located near to, or in the midst of, cities and towns. After the steam has been used to generate electricity, it is piped to nearby factories, commercial buildings, and homes to provide space heating for the occupants. In Malmo, Sweden's third largest city (with 240,000 people), about 50% of space heating is provided by co-generation. Nationwide 19% of the heating for homes, offices, and factories is furnished by co-generation.[5]

Americans read much about turning off lights, eliminating such things as electric toothbrushes and can openers, and cutting down on occasional Sunday drives in the family car. Such niggling economies are of little significance when one considers that transportation accounts for 25% of total energy consumption and space heating accounts for another 25%. Improvement in automobile fuel economy, enforced improved insulation standards, better public transportation, and the development of co-generation would drastically cut our energy consumption. With our long history as a can-do nation of mechanics and fix-it experts, we can use Sweden as an inspiration to make more economical use of our energy. All that is required are practical incentives such as profits, cost effectiveness, or possibly, government subsidies to cause us to apply this proven know-how to our energy problems.

UNDEVELOPED SOURCES

GEOTHERMAL

Geothermal energy is one of our most exciting undeveloped sources of energy. Though this method of providing electricity has been feasible since 1904 when the first generating plant opened in Lardarello, Italy,[1] it has had little further development anywhere until recently.

Basically, geothermal power is derived by taking dry steam or hot water that issues from fissures within the earth and using it to turn turbines which drive generators. When hot water is brought up, either it may be allowed to change into steam or be kept under pressure and used to change another liquid system into steam. The latter method loses potential power in the process of exchanging the heat.

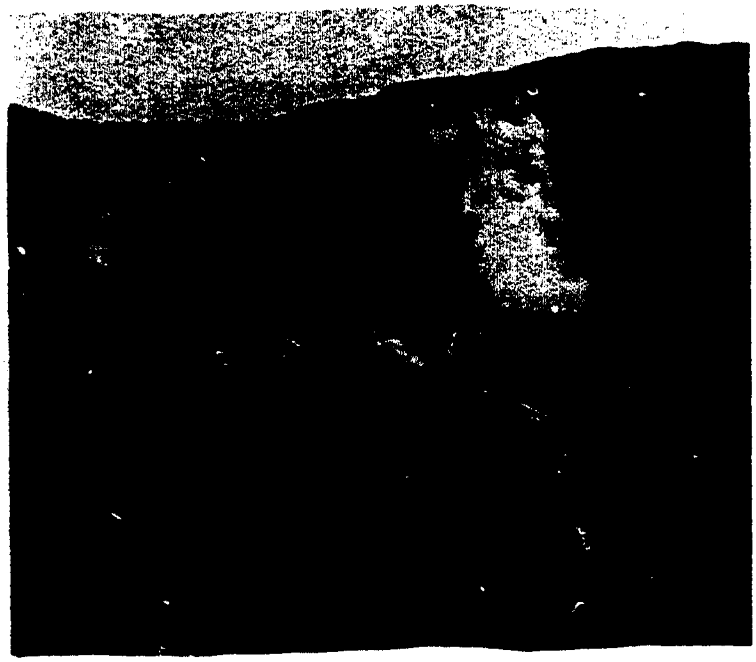
The advantages of geothermal power are many. It provides little atmospheric pollution; it does not burn valuable fossil fuel; there is no cost for fuel; the dangers of accidents and pollution in securing and transporting this energy source are relatively minimal.

There are problems, none of which are incapable of solution with our present level of technology. When hot water is brought up, it often contains chemicals that cause working parts to corrode. Hydrogen sulfide leaves an unpleasant smell as well as causing some environmental problems. In New Zealand where one large geothermal plant supplies about seven per cent of the country's electricity, the condensed steam is released into the nearby Waikato River causing significant chemical pollution.[2] Environmental studies show the mercury content found in fish there to be high. The Geysers Geothermal Plant, located near San Francisco and currently the largest in the world, solves this problem by injecting the condensed steam back into the ground near the area of origin. This procedure keeps the water table from being lowered as well as insuring the likelihood of continued geothermal production.

In addition to the plants that operate in Italy, New Zealand, and the United States, small geothermal generating units are also located in Mexico, Japan, and the USSR. Many cities use geothermal hot water for space heating, the most noteworthy being Reykjavik, Iceland, for which home heating is provided for 100,000 of its citizens.[3]

Prospects are good for using more geothermal power in the United States. When fully developed, the Geysers Plant will provide enough power for a city the size of San Francisco. By 1979 the federal government and private industry will have two demonstration plants on line — one at Raft River, Idaho, and the other in the Imperial Valley, California.[4] It is estimated that there is enough geothermal power beneath California's Imperial Valley to supply the entire Southwest with electricity. Estimates are that with proper development, about two per cent of our electrical power can be derived geothermally by 1985.[5]

There are institutions and corporate difficulties to be dealt with,



The Pacific Gas and Electric Company's Geysers Geothermal Power Plant located 90 miles north of San Francisco.

Total capacity of the plant is 502,000 KW, enough for a city the size of San Francisco.

Photos Courtesy of Pacific Gas and Electric Company.

however. The Federal Government's Energy Research and Development Agency has appropriated almost nothing for geothermal research to date. Four major companies, Standard Oil, Union Oil, Southern Pacific Land and Magna Power, have bought up the underground options in the Imperial Valley but have not developed the field yet.[6]

Geothermal power is a viable, significant source of energy. We should proceed with all reasonable speed to develop it. To do anything else is to do our country a serious disservice.

TIDAL

Another unused source of energy in the United States is tidal energy. In St. Malo, France, a tidal plant has been in operation for several years supplying enough electrical power for a city the size of Toledo, Ohio, or St. Paul, Minnesota.

The St. Malo Plant is located on the Rance River with a tidal rise and fall of about 45 feet. The incoming tide turns the big turbine blades causing the generators to spin, thus making electricity. When the tide goes out a few hours later, the turbine blades are reversed, generating power for a second time using the same water.[1]

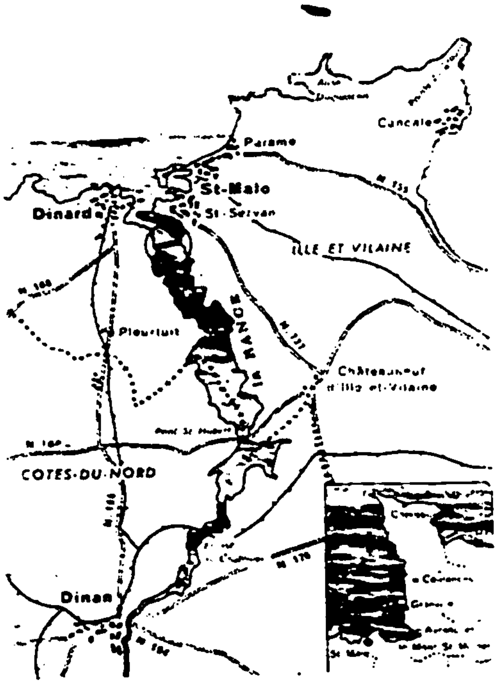
The biggest tidal project in the world has been proposed for the Bay of Fundy between Eastern Canada and Eastern United States. A carefully constructed power complex there could supply the electrical requirements for Greater New York City or all of New England.[2] In the late 1930's, during the administration of Franklin Roosevelt, money was appropriated for preliminary surveys. However, certain private corporations put considerable pressure on Congress to halt the project. World War II further delayed consideration of the Fundy Dams.

With federal money about to be appropriated in the 1960's, powerful lobbies were able again to keep construction at a standstill. Their chief argument pointed out that expensive federally subsidized dams costing from $200,000,000 to $9,000,000,000 each would provide unfair competition for private industry.[3] Private companies would be unable to compete with rates charged for federally subsidized power.

Last year Canada announced the appropriation of $3,300,000 in research funds to explore the potential of the project. Persumably, there will be little difficulty in securing funds through the Canadian government to actually complete Fundy.

The advantages of tidal power are obvious: constant power, no pollution, no necessary expenditure of fossil fuel, no difficulties in production, transportation, or waste. The greatest drawbacks are the large expense in dam construction and the fact that the world contains only about 15 locations with a narrow enough estuary and a high enough tidal fluctuation to make a power station feasible.

Nevertheless, a plant large enough to supply all of New England or New York City is not to be scoffed at. The next time a massive power

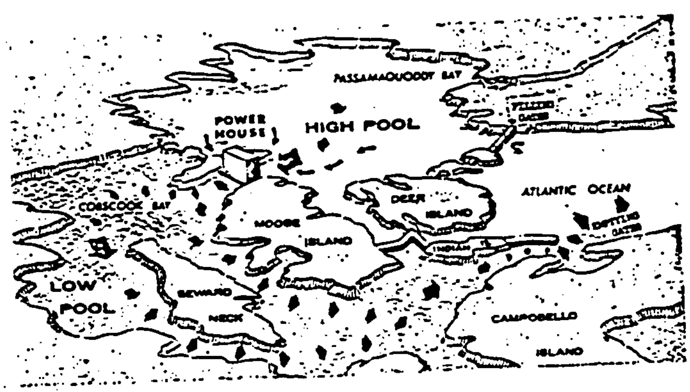


The Tidal Dam at St. Malo, France

Proposed

Tidal Dam at

Bay of Fundy



failure threatens New York City, will we be able to buy power from the Canadian tidal project? The real question is, how much longer are we going to ignore our self-interest and let the Canadians take the initiative away from us?

SOLAR

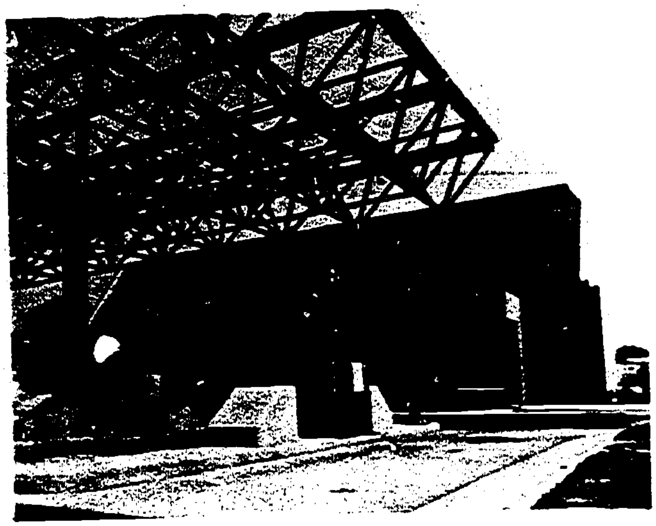
In the United States, solar energy is justifiably the most talked about undeveloped energy source. It should be pointed out, however, that harnessing sun power is not exactly a new idea. Archimedes, when defending Syracuse against an invading Greek armada, had his soldiers hold their shields at an angle so as to reflect the sun's rays on a designated spot against the lead ship's sails. Miraculously, the ship caught fire causing panic. One by one the attacking ships were set afire and Syracuse was saved.

In 1914, an American engineer, Frank Shuman, designed a solar thermal steam engine in Egypt that successfully pumped water to irrigate fields along the banks of the Nile.[1] Later, and more generally, solar panels were developed in the 1920's — 1950's to heat swimming pools and hot water heaters in Florida, California, and the Southwest. Only the coming of low-priced gas heat to those areas caused solar devices to be abandoned.

Although solar-heated homes, offices, and factories in the United States today only range into the thousands, those figures will soon approach the hundreds of thousands. Already we have solar-heated schools, banks, and office buildings. There is even a solar-heated McDonalds, located in Cherry Hill, New Jersey. Several private solar developments have been announced for construction in New England and Florida. North Lauderdale builder Dan Haley, for an additional $1350, will install an energy conservation package which includes a solar heating unit. Haley has many takers.

Needless to say, there are almost as many ways of collecting solar energy as there are companies with products on the market. Most typically they involve a metal panel painted black to absorb heat; over the panel is a glass or plastic sheet sandwiching a space between the two materials to contain heated air. The entrapped hot air may be blown to other parts of the house by fans, allowed to rise by convection, or used to heat piped water which is then pumped into the house. Ways of storing solar heat that are being developed include blowing it into tons of hot rock in the basement or pumping it into well-insulated containers. However, there are considerable technical problems still to be solved in storing solar heat.

Another major detriment to widespread use of solar space heating is cost. Although an acceptable solar water heater can be purchased and installed for $500—$700 with cost-free heat within five years, the purchase and installation of a successful solar space heating unit typically is about $4,000.[2] The costs of this solar heating system are not likely to decrease in the coming years to a major extent, either, inasmuch as solar heating is primarily labor intensive and hourly rates for plumbers, electricians, carpenters, etc., seem to go up and up.



Present day solar technology is typified by the First National Bank's Motor Bank in Rockford, Illinois.

Artist's concept of Boeing's solar-thermal power plant of the future. A field of reflectors, called heliostats, would reflect the sun's rays to a central receiving tower.

For those with "do-it-yourself" skills, of course, expenses will be considerably less. In any event, even at today's increased oil and gas rates, it will take many years to recover the cost of this installation vs. a conventional fossil furnace and fuel.

Additionally, solar heat will only provide 65-75% of the needed heat in most states; a back-up fossil unit will be necessary. While solar energy appears to be excellent for heating swimming pools and hot water and worthy of consideration for space heating, there are greater problems in building solar-powered electrical generating plants. In Barstow, Arizona, to date, the United States' major effort in generating solar-powered electricity, a large field of 1,800 expensive mirrors focuses heat on an equally expensive steam-making apparatus located in towers high above. This demonstration plant will produce 10MW of electricity, though 15-20% of the energy produced will be required to wipe the dust from the mirrors. Hopefully, a less difficult and more efficient way of generating solar electricity can be found.

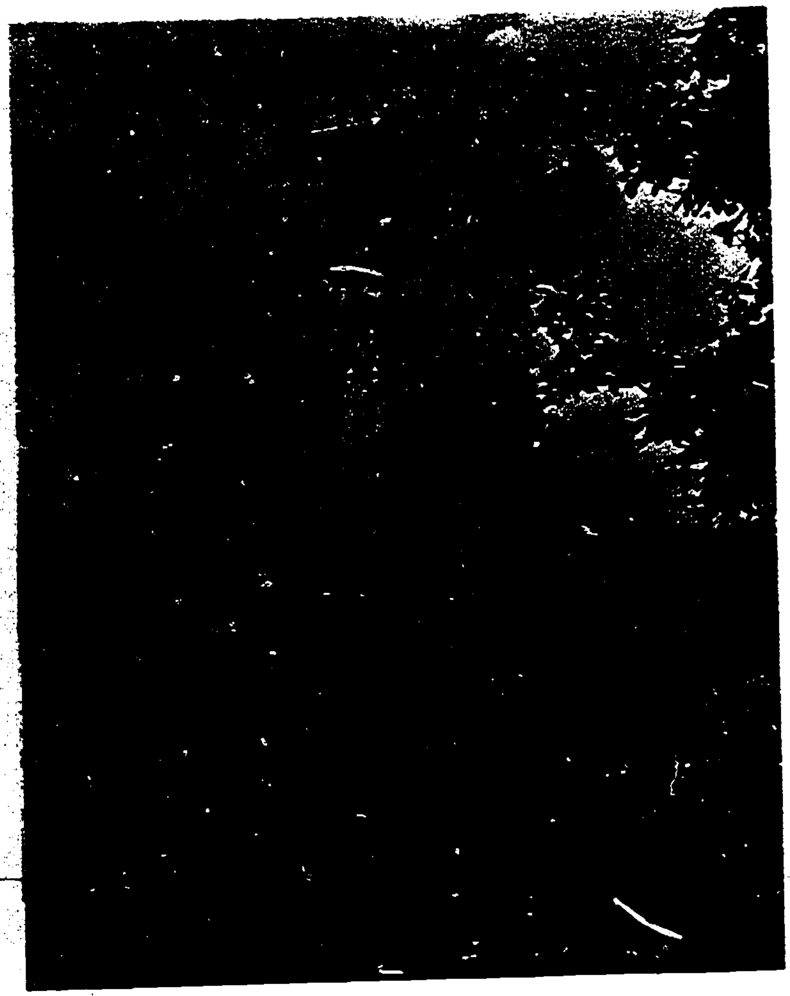
It is true that by locating solar generating plants in the Southwest, such as Barstow, few days of electrical generation would be lost due to cloudy, rainy, or snowy weather. On the other hand, a Southwestern location creates an additional problem, as much energy is lost transporting electricity the many hundreds, even thousands of miles, to major cities where it is needed.

Solar power of all kinds has not been developed to a greater extent for two major reasons. Until the energy crunch, it was cheaper to burn gas and oil and in many instances, still is. In addition ERDA, the federal government's energy research branch has been, until recently, tight-fisted with funds for solar research. Budgets were: 1973—$41,000,000; 1976—$89,000,000; 1979—$500,000,000; 1980—$650,000,000. In the same years fusion, light water, and breeder reactors each were receiving money totalling hundreds of millions per year.

In spite of these problems, non-polluting, solar heating is a feasible reality-and it is becoming more significant with each passing day. Estimates of our total energy production from this power source range from 1.5% to 3.5% within the next twenty years.[4] How high the percentage will go depends upon the determination of our government, businesses, and home owners to develop and make use of an energy source whose time has arrived.

WIND

The wind is not a brand-new energy source; man has used its power since time immemorial to drive his ships through the seas. For hundreds of years millers have ground grain with stones moved by the wind. Well into the 1930's, farmers used windmills to pump water and generate electricity in areas where the REA had not yet strung power lines. A casual drive into the country will reveal many remnants of these mills still standing today, though in most cases, they serve as repositories for television aerials, provide decorative interest, or simply haven't been torn down yet.



ERDA/NASA EXPERIMENTAL WIND TURBINE, SANDUSKY, OHIO

In the early 1940's, a determined effort was made at Grandpa's Knob, Vermont, to build a large 1250 kilowatt power station, enough to power a village of about 1000 people. The giant windmill was built having blades 175 feet in diameter and standing over 100 feet tall. It was hooked into Vermont's power grid and functioned successfully from 1941 to 1943. Finally one of the rotor blades broke and was not repaired. This power was not needed at that time because of higher production costs. Nevertheless, the experiment did prove that the wind, on a limited scale at least, could provide commercial electrical power.[1]

There are a number of significant limitations to wind power — it is intermittent and of varying intensity thus calling for more consistent back-up systems; the Southeastern part of the United States, in particular, lacks sufficient wind; windmills for electrical generation can most effectively be built atop hills, knobs, and small mountains thereby laying themselves open to destruction by tornadoes and criticism by lovers of scenic beauty. It will take eight hundred large windmills to equal the generating capacity of one standard-sized nuclear plant; to equal the present generating capacity of the United States, one million windmills strung out for 40,000 miles will be needed.[2]

Wind power proponents are optimistic in spite of these problems. Professor William Heronemus of the University of Massachusetts has proposed an offshore wind power system costing $22.4 billion to provide adequate power for all New England. Professor David R. Inglis of the same university believes 6,000 six-megawatt wind machines built offshore would provide enough power for this system.[3]

There is considerable cause for optimism at this time about the future of wind power in the United States. A consortium of NASA, the Department of Energy, Westinghouse, and Lockheed has just completed a wind turbine at Clayton, New Mexico. Costing $1,250,000, the rotor starts turning when the wind reachs 12 mph and while operating produces 200 kw or enough for 60 homes. Projects of a similar size are under way on Culebra Island, Puerto Rico, and Block Island, Rhode Island, to test the effectiveness of the wind under different circumstances. The Department of Energy is spending $38,000,000 for wind power in 1978 and has scheduled for completion a much larger wind turbine in the same year. Located at Boone, North Carolina, this turbine will provide 2000 kw or enough energy for 600 homes when operating.[4]

Predictions vary as to how much of our nation's electricity in the future will come from the wind. Some private experts say 10% by the year 2000; Department of Energy officials are more cautious, settling for [illegible] that time period. In the meantime, the government is studying the feasibility of erecting fifty, 2,000 kw wind turbines in Medicine Bow, Wyoming, where the wind blows at 17 mph 80% of the time. Such a power conglomerate would provide enough electricity for 30,000 homes or a city the size of Rockford, Illinois.[5] In Wyoming, a sparsely settled and relatively remote state, wind power obviously has a significant contribution to make. If successfully developed there on a community-wide scale, there are implications for the rest of the United States as well.

GARBAGE AND PLANT POWER

Although it is feasible to burn garbage and combustible plants in boilers to make steam, and although this source is being used today in Chicago, Milwaukee, and Ames, Iowa, among others, it is unlikely that this method will ever account for very much of our energy production.

In the case of garbage, there is the problem of collecting enough supplemental contribution to the burning of coal or gas. Experts estimate that of the millions of tons of waste materials that could be burned, it is only practical to collect 16% of it.[1] The rest is spread out over too broad a geographic area to make collection feasible.

Some authorities have suggested growing alfalfa or other highly burnable gas fuel, but it would be wasteful to devote arable land to the growing of crops solely for fuel when food throughout the world is in such short supply. Two hundred fifty to five hundred square miles of arable land would be needed to fuel one 2000 MWe steam cycle power plant, based on optimal dryweight biomass yields of 10 to 30 tons per acre annually. The cost in fossil fuels for cultivating and fertilizing this crop land would run about $150 an acre, considerably reducing the amount of energy and money saved by the energy plantation.[2]

If the plants are converted into oil instead of steam, about seven barrels per acre would be obtained at a cost of $20.00 a barrel, not including the processing of the oil which would probably add another $10. Oil costing $30 a barrel is so far above today's market price as to make it extremely uneconomical for commercial development at this time.

Some energy conversion proponents point out that significant savings of gasoline can be made by converting starch residues left from processed corn, wheat, potatoes, beets, and barley into a 200 proof grain alcohol. Approximately one part of this grain alcohol is mixed with nine parts of unleaded gasoline to form a new fuel named "gasohol."

State vehicles in Iowa, Nebraska, and Illinois recently underwent tests to determine the usefulness of this biomass product. The results in Illinois were particularly encouraging with similar results in the other two states. The gasohol-powered vehicles averaged 11.9 miles per gallon vs. 11.2 miles per gallon on gasoline. Carbon monoxide emissions declined 32% with gasohol while average hydrocarbon emissions dropped 7%. The greatest drawback of gasohol is the fact that cost of production is a few cents higher than for gasoline.[3] Development of mass production techniques could decrease the costs, however.

Another feasible use of biomass energy today is the growing of trees for firewood. It is estimated that with the right incentives the growing of wood could be doubled in the United States.[4] Trees provide a higher percentage return of energy than any other plant, store their energy well, and when burned add little in the way of pollution to the atmosphere. Problems standing in the way of future firewood development are the need to develop a demand for wood fuel as a replacement for oil or gas, need for equipment that will burn wood efficiently on a small scale, and the development of a wood fuel supply industry.

Some proponents of energy plantations have suggested harvesting kelp from the sea or using grassland not suitable for crop raising. While these are more reasonable suggestions, it remains to be seen just how much fuel fodder could be gleaned by either method.

In the meantime, use of garbage power is likely to continue and be expanded upon in our larger cities. Experts in Milwaukee point out that when garbage is burned in their boilers along with coal, energy production is supplemented by about 20%.

It should be kept in mind, however, that if the United States were to use all of its garbage, food, fiber, and wood supply, it would only supply 25% of our energy needs per year.[5] Biomass has an energy contribution to make under such circumstances, but it must be a limited one.

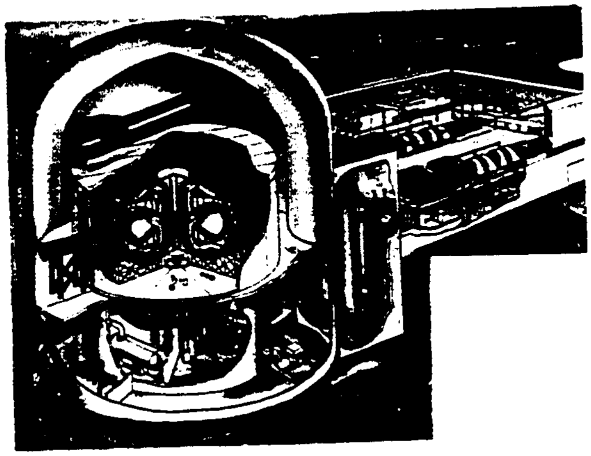
OTHER UNDEVELOPED SOURCES

Tremendous amounts of power are theoretically available from the process of fusion — the fusing of nuclei in the hydrogen isotopes of deuterium and tritium. The problems encountered so far in making any practical contribution to our energy pool have been staggering. Although ERDA has invested hundreds of millions of dollars yearly in magnetic fusion and laser pulse machines in such research centers as the one at Princeton University, the results have not borne fruit; in order to fuse these nuclei a temperature of 100,000,000° Fahrenheit must be achieved.[1] Much, much, more energy is put into achieving this high temperature than has ever been regained when the hydrogen nuclei fuse. No one knows how long it will take before this and other technological problems involving fusion are worked out. For this reason, fusion should not be considered a viable energy option for answering our immediate energy needs.

The same can be said for power from ocean thermal gradients. Several plans have been put forward for tapping the energy from such warm water belts as the Gulf Stream. Theoretically, surface water at an approximate temperature of 78° would come in contact through a heat exchanger with a chemical liquid such as propane or freon that would boil upon contact.

The steam created would turn the blades of a turbine, which in turn, would spin a generator. Then cold water is piped up from a much lower depth to cool the chemical back into a liquid. There are no ocean gradient plants operating or planned at the present time; how much power they could generate and at what expense is unknown.

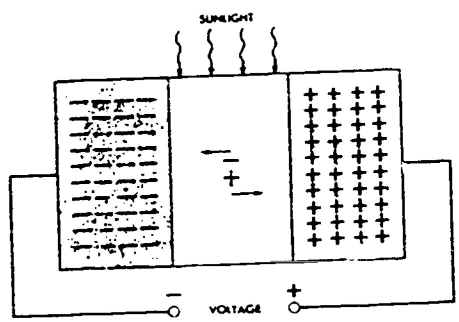
An energy option with more positive immediate benefits is the photovoltaic cell, originally developed as a part of the space program. Basically these cells are made of wafers of silicon and boron which when activated by sunlight make electricity. Other materials and shapes have been produced that use sunlight equally successfully to make electricity. Already this energy source has proven its usefulness.



FUSION POWER

Pictured above is a hypothetical Fusion Power Plant. the design for which was completed in 1974. The major structure is to be stainless steel while the reactor will be fueled by the hydrogen isotopes of deuterium and tritium.

PHOTOVOLTAIC CELLS



When internal photoemission takes place near a pn junction. the electric field forces conduction electrons energized by the light to go into the n-side. charging it negatively. Excess holes are similarly forced into the p-side. charging it positively. An electric circuit can use these charges in the same way that it uses the charge from a chemical battery. In this manner. silicon cells have converted as much as 12-15 per cent of the energy of incident sunlight directly into electricity.

Refrigerators on remote Indian reservations are powered by these cells to cool medicines so that the sick may continue to live and be cured. U.S. Coast Guard buoys which keep ships from colliding in Long Island Sound are powered by photovoltaic cells.[2] In Nebraska an 80-acre cornfield is equipped with 97,000 solar cells producing a peak of 25kw to run a pump which irrigates the cornfield as well as producing enough electricity to run fans drying 12,000 bushels of corn.[3] A contract was just awarded for solar cells capable of delivering 362 peak kilowatts of electricity to meet all the power needs of Mississippi County Community College in Blytheville, Arkansas.[4]

The advantages of photovoltaic cells are many: (1) they do not pollute, (2) they use a renewable energy source, the sun, (3) they produce electricity directly, by-passing such technology as steam generating plants, (4) solar cells contain no moving parts and as such have a very long lifetime, (5) solar cell arrays are modular in construction and as a result can be used as efficiently to power a 100 watt remote refrigerator as they can be to power a multi-megawatt central power station.

By far the greatest obstacle to further use of the photovoltaic cell is expense. Though the per watt cost has dropped from $200 in 1959 to $10 today, this is still considerably above the $.20 — $1.00 per watt cost of a conventional power plant. The Department of Energy estimates photovoltaic cost will drop further to about $.50 a watt by 1983. The federal government is assisting in this drive for cost effectiveness by allocating a total photovoltaics budget of $58 million for 1978.[5]

Closely aligned with the above problem in photovoltaic development is the need for more markets so that mass production will bring the per unit cost down. Again the federal government is providing assistance by buying solar arrays of 32, 50 and 70MW for the years of 1970, 1980, and 1981.[6]

Also facing the solar cell are problems of storage and maintenance. Keeping track of thousands of small solar arrays dispersed on residential rooftops is more difficult.

In spite of these difficulties the photovoltaic cell appears to have a bright future. Corporations ranging in size from Westinghouse and RCA to small one- and two-man inventor shops are enthusiastic; the federal government is becoming increasingly liberal with start up seed money each year; and the technology is already proving itself by working successfully under varying circumstances.

PROMISING FUEL CONVERSIONS

COAL GASIFICATION

One of the most economically and environmentally promising of the coal gasification processes is being developed by the Laramie Energy Research Center at Hanna, Wyoming. Coal is being gasified underground there to be used as low BTU heat for powering steam electrical generating plants.

In making coal gas underground, two wells 20 to 50 meters apart are drilled to the base of a coal seam. Burning charcoal is dropped into one well to ignite the coal while air is injected into the second well. Wyoming coal is permeable enough so that the air from the second well seeps towards the first well and draws the flame toward it. The fire then links the two wells at the base of the coal seam by a channel as large as one meter in diameter. Once linked the fire expands and consumes all the coal between the two wells. By appropriately controlling the flow rate of the injected air, it is possible to obtain partial combustion of the coal so that low energy gas is emitted from the first well.[1]

The Russians have employed successfully on a commercial scale an underground coal gasification process slightly different from the Hanna Project for more than five years, proving that with proper administration and engineering, this is a viable process.

The advantages of underground coal gasification are many. It is cheaper than above ground coal gasification because there is no need to build a processing plant. It is also quicker because it is not necessary to wait until a plant is finished. About 80% of the coal of a given seam is used as compared to about 50% when the coal is removed. About five times as much energy is likely to be produced over what is invested, though in a large project this return could run as high as eight to one.

Possible disadvantages are land subsidence after a seam has been used up and the pollution of nearby water resources. The Russians have had a somewhat similar underground process in operation for a number of years, however, and have yet to be faced with such pollution problems.

There are a number of other below and above ground coal gasification programs under way. Some of these include the Lawrence Livermore Lake Project in Wyoming, the Morgantown Energy Research Center project in West Virginia, and the Texas Utilities lignite gasification process being tried along the Gulf Coast. Large water requirements and additional environmental damage from this type of mining make these projects appear less desirable.[2]

Problems of cost face all coal gasification projects whether they yield high (synthetic natural gas), medium, or low BTU gas. This product, estimated at $3.00 per million BTU's is much more expensive than natural gas.[3] Each rise in natural gas prices makes the production of synthetic natural gas more feasible. And with sufficient coal on hand for the next 300 years in the United States, coal gasification, however mined, seems to have a place in the future.

OIL FROM SHALE

The process of obtaining oil from shale is one that has had its ups and downs over the years. First, it is seen as an answer to our growing dependence on Middle Eastern oil. Then, water resources are considered too meager or construction costs too high to make it a feasible reality.

Some recent developments by the Occidental (Oxy) Petroleum Corporation working in conjunction with Ashland Oil in western Colorado have given shale oil enthusiasts cause for optimism. Oxy has developed an in-situ (cn-site) demonstration project producing 2,500 barrels of oil a day which reduces water consumption by at least 66%, decreases land residues by 80%, and requires only one-third the work force.

Basically, Oxy's process is to first remove the soil over-burden and mine out a small portion of the shale nearest the surface. Then the rest of the shale is blasted creating a rubble-filled cavern. The shale at the top is then ignited, and separation of the oil from the shale begins (retorting). As the retort zone moves slowly downward, the released oil flows to the bottom where it is pumped into storage.[1]

In spite of the success of the Oxy project, there are still problems with shale oil. The 2.5% nitrogen found in the oil causes automobile engines to knock. The 1% sulfur in shale oil fouls refinery catalysts and pollutes the air. Paraffin waxes clog engines. Air quality standards will also have to be relaxed in such states as Colorado before realistic commercial development of this process can be expected.[2]

Standard Oil of Indiana and Gulf Oil are working on another in-situ project nearby, but progress is not as advanced.

However, due to these two projects, surface retorting developments have been neglected for a number of reasons, the chief one being cost. Surface and in-situ retorting plants of similar capacity are estimated to cost $1,200,000,000 and $400,000,000 respectively. Under such circumstances, no pilot plant will be built on the surface without strong government assistance.

As for future prospects of large scale development of shale oil, much depends on the price per barrel. So far there is little agreement on what this will be with estimates ranging from $12.00 a barrel (Oxy) to $26.00 (Conoco).[3] With current oil prices in the United States in the neighborhood of $19.00, this uncertainty is definitely in need of clarification before oil companies will be willing to invest their money even with strong governmental financial aid.

As for shale oil reserves, they must be characterized as incredible. According to the National Academy of Sciences, there is underneath the Green River Basin of Colorado, Utah, and Wyoming about 2,400 billion barrels of oil which at our current rate of oil consumption would last us nearly 100 years.[4]

GASOLINE TO ELECTRIC AUTOMOBILES

With transporation controlling 25% of our energy budget and automobiles making up 80% of our transportation energy budget, one is tempted, with gasoline in short supply, to find an alternative way of running automobiles. One way to do this is by converting to electric cars.

At present there are four commercial manufacturers of electric cars in operation in the United States. Costs for these vehicles range from $30,000 for the Transformer I produced by the Electric Fuel Propulsion Corporation of Troy, Michigan, to the $2,998 Citicar turned out by Sebring-Vanguard Incorporated of Columbia, Maryland.[1] These and other experimental models total less than 3,000 EV (electric vehicles) in America with U.S. Post Office Fleet Jeeps accounting for nearly 400 of them.

The advantages of these vehicles include no pollution, quiet rides, saving of fossil fuels, and no need for gas stations.

However, there are a number of problems that need to be eliminated. Most will not go over 45 mph, with even slower speeds for going up hills. Worse is their range — typically around 50 miles. Some drivers save battery power by turning off the ignition while waiting for a red light to change.

Batteries seem to be the key stumbling block to the electric car's future. The present generation of lead-acid batteries is far from satisfactory. They are heavy, expensive, run down after 50 miles, and take from six to ten hours to recharge. The Department of Energy is striving to develop the next generations of nickel-cadmium or lithium-sulfur batteries which are lighter and provide cars with a wider range of operations. Their problem is that they operate at a temperature of 575° to produce energy.[2]

In spite of these difficulties, the Department of Energy is pushing ahead and has appropriated money to put 2,500 electrics on the road by December, 1978, and another 5,000 by October, 1984. This is still a far cry from the some 30,000 electrics in America in 1912 but with hard work and a little luck, some auto industry analysts foresee 20,000,000 electrics on the road by the year 2,000.[3]

NUCLEAR POWER

Generating nuclear power is a relatively simple process that can be explained as follows:

When a fissionable atom, such as uranium or plutonium, splits into two or more unequal parts, it releases much energy. One fission event, for example, produces 50 million times more energy than the burning of one carbon atom, the primary energy source in coal.

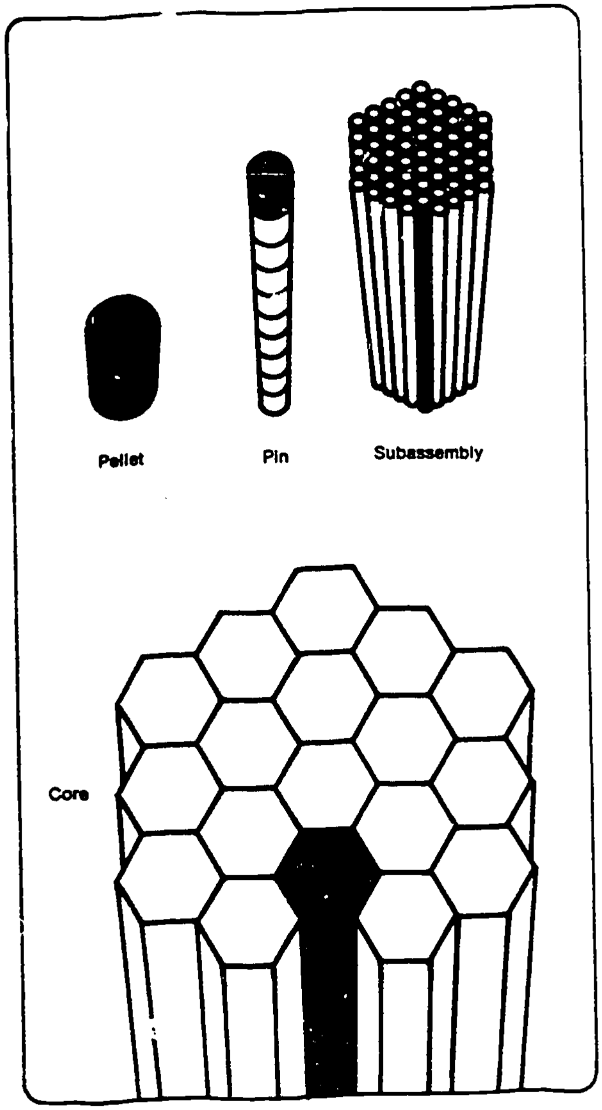
In fact, uranium is to a nuclear power plant what coal is to a fossil-fueled generating station: the firebox used to boil water to produce steam to run a turbine. Approximately 100 tons of uranium oxide is used in the most commonly built reactor. This material is processed to slightly increase the percentage of the Uranium 235 isotope (which occurs in nature at 0.7%) to about 3%; the remaining material is the Uranium 238 isotope. This process is called "enrichment." The uranium is used in the form of small, cylindrical oxide pellets just slightly bigger than the eraser tip of an ordinary pencil. There may be 6.5 million to 9 million of these pellets in a large, modern plant, with the pellets stacked atop each other inside long, narrow tubes like batteries inside a flashlight. Typically, there are 200 or more pellets in a 12-foot "cladding" tube, and 40,000 such tubes are bundled and clustered together to form assemblies. The assemblies constitute the reactor core.

The atoms of Uranium 235 undergo a nuclear reaction called fission which breaks them into small particles releasing energy, as well as emitting neutrons. The neutrons go on to trigger the splitting of adjacent uranium atoms. The process is a continuous one and is called a "chain reaction."

The pellets become quite hot in the reaction and the heat flows outward to the cladding (made of a steel-zirconium alloy called Zircaloy). So much heat is generated that both pellets and cladding would melt rapidly if it were not for a cooling bath of water that is circulated up and through the fuel-rod assemblies.

In one type of reactor, called a boiling-water reactor, the water picks up the heat and boils directly to become steam. In another type, the pressurized-water reactor, the water is kept under great pressure (about 2,200 pounds per square inch) and is prevented from boiling. Then the super-heated water is run through a series of tubes that are immersed in a second, separate and independent water system. It is the water in this secondary loop that boils and becomes steam. In both types of reactors, the high-pressure steam that is generated is directed into a turbine generator, turning it to produce electricity.[1]

As of early June, 1979, nuclear electricity, coming from 72 commercial reactors in the United States, supplied almost 10% of the nation's electrical energy.[2] With 77 more reactors under construction,[3] it is probable that in less than ten years, 25% of our electricity will be



FUEL & CORE

To be used in a reactor, the enriched uranium is formed into cylindrical pellets. These pellets are placed in hollow tubes made of stainless steel or an alloy of the metal zirconium. The filled tubes are called fuel pins, and are of small diameter—about ½ inch or less. The fuel pins (40,000 or more are in a reactor) are then bundled into fuel subassemblies. The subassemblies are fitted into place in the reactor as part of the reactor core.

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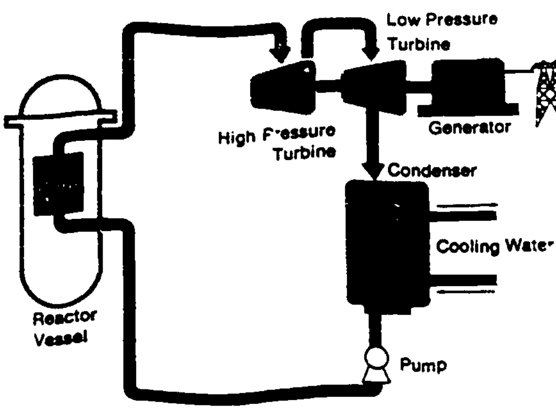
nuclear-generated. A government-ordered moratorium (halt in plant construction, halt in nuclear electrical production, or both) could drastically lessen this figure, however.

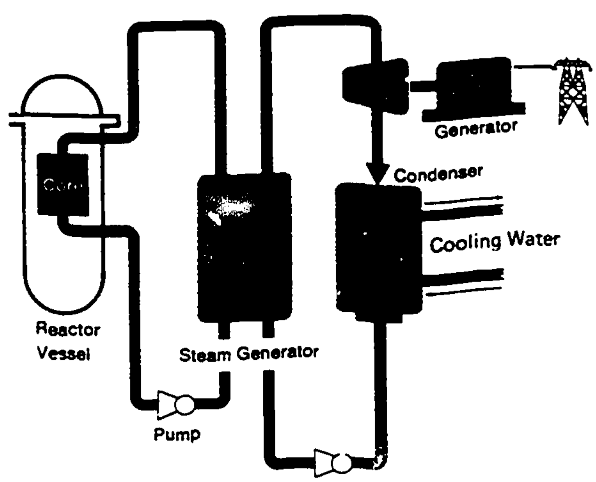
Ralph Nader and a number of other critics are working vigorously to stop construction of nuclear plants. In Washington, D.C., recently, Nader stated that all construction of nuclear plants will be stopped in five years. There is little evidence that the majority of the people agree with him, however. A recently released Lou Harris poll shows that the American people favor continued construction of nuclear energy plants by a margin of 52-42%.[4] In June and November of 1976, voters rejected proposals in California, Montana, Washington, Oregon, Colorado, Ohio, and Arizona which could have all but halted construction of new plants. In Missouri a proposal on electric rate design that tends to curb nuclear energy was successful.



BOILING WATER REACTORS

In the U.S., there are two distinct types of Light Water Reactors. In both, the heat extracted from the core is used to make steam. In a boiling water reactor (BWR), the steam is generated directly by the heat from the core. This steam runs a turbine to generate electricity. Thus, it is a "direct-cycle" system.

PRESSURIZED WATER REACTORS



In a pressurized water reactor (PWR), the water heated by the core is circulated through a closed system, called a "loop." This first loop carries the heat from the core to a steam generator where the heat is transferred to a second loop. It is in this second loop that the steam is generated to produce electricity. The PWR operates at 2,[illegible]0 pounds per square inch and 600°F.

NUCLEAR SAFETY

As the safety of nuclear power is considered, it should be kept in mind that all present forms of electrical energy production contain dangers to human life. For example, a recent study by UCLA engineering Professor David Okrent casts unexpected doubts upon hydroelectric power under certain circumstances. His projections show that the accidental collapse of the Stone Canyon Hydroelectric Dam in the hills above UCLA could cause between 125,000 and 200,000 deaths—considerably more than the worst possible death toll projected for a nuclear meltdown. The dangers to human health in coal mining, production, transportation, and power generation are well-known with many cases of heart condition, asthma, and lung disease accounting for 10,000 deaths per year.[5] Spills from oil tankers coming into the country are a grim hazard to life and the natural environment. American Petroleum Institute fire statistics[6] estimate an oil fire with 10 or more deaths to the public at 1 in 10,000; this is twice as high as the probability of a corresponding severe nuclear accident. Indeed, oil fires in Bayonne, New Jersey, in January, 1973, and in South Brooklyn in January, 1976, caused air pollution more severe than the December, 1952, London air pollution disaster which killed 3,900. Luckily the winds blew them away from populated areas. Tankers carrying LNG (Liquified Natural Gas) are a serious threat too; in 1944 an LNG tank exploded in Cleveland killing 133 in an accident involving 1/20 of the LNG a tanker carries. Lastly, the threat of American involvement in international war should we continue to be dependent upon Middle Eastern fuel sources is perhaps the most serious threat to the American people.

With the above energy problems stated, consideration will now be given to nine nuclear energy safety problems and some possible solutions to them.

ENVIRONMENTAL

Before a nuclear plant can be constructed, the power companies are required by the Nuclear Regulatory Commission to order independent, detailed studies to determine how construction of a nuclear plant will affect human, animal and vegetable life in the area. Likelihood of earthquakes, tornados, tidal waves, and other factors are considered as well. Hearings are held to make it possible for citizens to object. Only if the planned nuclear station satisfies the Nuclear Regulatory Commission and any challenges in our court system, may construction and ultimate licensing to produce electricity be permitted. Often after a plant is in operation, changes are ordered as well. A case in point is Commonwealth Edison's Cordova, Illinois, plant which was ordered to limit to emergency periods the continuous use of the Mississippi River for reactor cooling. It was alleged that the processed water raised the temperature of the river causing damage to fish, plants, and microorganisms in the Mississippi. Instead a spray canal was ordered to be built in which the same water would be recycled without being returned to the river.

Great care is taken in choosing the proper place to build nuclear plants. Recently it was discovered that the Diablo Canyon plant in California is located near a projection of a geologic fault line. The NRC has held up the license of this plant for more than a year while further studies are conducted.

PLANT OPERATION

One hypothetical story of a nuclear reactor disaster is described in the popular press like this: Sensitive instruments in the control room of a nuclear power plant warn that temperatures inside the reactor are rising toward a danger point. Somehow the main pipes carrying water to the reactor core have been broken or clogged. The back-up water systems also fail. Without fresh cool water to control its temperature, the reactor begins melting from its own heat. The machine and its fuel collapse into a molten mass that converts the surrounding coolant water into steam. The pressure rips a hole in the massive concrete dome, releasing a cloud of radioactive gas. Tens of thousands of people living nearby are contaminated by radioactivity. Many die within days. Others suffer lingering illnesses and develop cancer years later.[7]

The probablity of such an event occurring is minimal. To date, after about 25 years of operation, not one single person has been killed in an operating commercial nuclear plant accident in the United States. The Federal Government commissioned a study by Nuclear Physicist Norman C. Rasmussen about reactor safety, and Rasmussen concluded that an accident similar to the one described above could happen less than once in a million years if 100 U.S. nuclear plants were in operation. Nuclear critics have tried to raise doubts about Rasmussen's report on a number of grounds: (1) He is biased — the report was commissioned by the Federal Government and the Federal Government favors nuclear power. (2) Rasmussen is using only statistics in drawing his conclusions, and he needs to substantiate these conclusions with actual tests of plants in operation. (3) Rasmussen does not take human error into account. (4) How does Rasmussen account for some 1,400 "abnormal occurrences" in nuclear plants each year?

Nuclear proponents are quick to defend Dr. Rasmussen on the following grounds: (1) Rasmussen's reputation and scientific credibility is far greater than his most vociferous critics. (2) The Rasmussen statistics are based on actual component operation. There are no statistics on major accidents because none have occurred. (3) Rasmussen's analysis did take human error into account in every step. (4) The abnormal occurrences are used in the data for the study itself.

Perhaps the most significant "abnormal occurrence" took place in March, 1979, at Unit 2 of the Three Mile Island nuclear power station near Harrisburg, Pennsylvania. As of June, 1979, most authorities agree the scenario for trouble went approximately like this: First, a water pump in the secondary (steam) line failed. When the pump failed, the turbine and generator automatically shut off and the control rods, which control the rate of nuclear fission, dropped.

As a result of the failure of the pump in the secondary line, the primary loop overheated. The overheated primary loop activated the backup water cooling system automatically. This system would have removed the excess heat from the primary loop by transferring the heat to another area. However, according to several sources, the operator thought the signal was erroneous because he either didn't believe, or couldn't interpret what the gauges said, and he deactivated the backup cooling system.

Much later, according to many reports, it was determined that the primary loop had gotten much too hot, and the operator opened several valves to reduce pressure. Part of the primary loop that had valves to reduce pressure circulated to another building, the radioactive water was released there, was flashed to steam, and was vented to the outside.

When so much water was let out of the reactor vessel, the fuel rods became partially uncovered and started to melt. The remaining water became acidic in the intense heat, started reacting with the metal in the fuel rods, and generated hydrogen gas which collected at the top of the containment vessel. Further trouble was avoided by pumping and circulating more cold water into the reactor vessel. Cold water increases the rate of absorption of hydrogen. Thus, the water gradually absorbed the hydrogen gas. The water was run through a device that removed the hydrogen, operating in the fashion of a dialysis machine. This process gradually cooled the reactor and absorbed the hydrogen which was vented to outside containers.

One area of controversy about Three Mile Island has to do with the amount of radiation released into the atmosphere and its possible harmful short and long range effects. A report issued by the National Academy of Science states that the Three Mile accident will produce no more that 2 to 5 additional cases of cancer beyond the normal 45,000 cases that would ordinarily be expected to be found in people within 10 miles of the plant (Newsweek, May 14, 1979, p. 129).

To try to reach more definitive conclusions, governmental agencies are conducting additional investigations. HEW Secretary Joseph Califano recently announced four such studies. One, financed for $300,000 and funded by the Center for Disease Control and the National Cancer Institute, will collect vital statistics and health data from the some 50,000 people living within five miles of the plant to determine the amount of radiation to which they might have been exposed. The other three studies will collect information of a similar nature. Even these studies, according to Califano, will not provide final answers, though they will produce much valuable data (Science News, June 9, 1979, p. 14).

EMPLOYEES

Care and consideration are given to the health and safety of workers in the nuclear plants themselves. Those employees working in the vicinity of the reactor area are required to wear a dosimeter or a film badge at all times; careful readings of these dosimeters and badges are made by trained technicians. When radiation levels on the badge reach a point that has been determined by the Nuclear Regulatory Commission to be unsafe, these workers are required to be moved into less radioactive areas for their job assignments.

SABOTAGE

Some nuclear critics worry about possible sabotage to nuclear installations by terrorist groups breaking through plant security forces and planting satchel charges, plastics, or other explosive devices. In March of 1976, the Nuclear Regulatory Commission released figures revealing 99 threats of violence directed against commercial nuclear facilities between 1969 and 1976.[9] Not too long ago, one mentally unstable former employee of a nuclear facility scaled its eight-foot fence and entered a top-security area. The public-electric company involved was fined $8,000 for lax security.

Defenders of nuclear plants point out in rebuttal that since the first commercial nuclear reactor opened in Shippingport, Pennsylvania, twenty-five years ago, there has been only one instance of plant sabotage in the United States by any domestic or foreign terrorist group. They further point out that nuclear plants are well-guarded with closed circuit TV at plant perimeters, are armed with security guards, have quick access to state and local police reinforcements, and have nuclear reactors well-nigh impregnable with steel and concrete walls over three feet thick. Additionally, the majority of the estimated 25,000 people who work in nuclear plants throughout the world are technicians, guards, and security officers whose prime function is safety.[10]

THEFT

As for stealing commercial nuclear materials while in transit, this is unlikely in the United States at the present time. Most uranium removed from the reactor core is maintained in large swimming pool-like tanks on site. The exception to the rule involves out-of-state nuclear waste shipments to a site near Morris, Illinois.

Plant workers are checked by a metal detection device which they walk through upon entering and leaving the plant. Should they attempt to bring in explosives or try to steal uranium, this device would register their illegal materials, and security guards would subject violators to a thorough search.

Fuel assemblies used in large, water-cooled reactors contain radioactive uranium, are about 14 feet in length, about 5-8 inches square in cross section, and weigh from 500 to 1500 pounds each. In the future when this spent fuel is shipped, it will be loaded into a ribbed, cylindrical, steel vessel about 16 feet long, several feet in diameter and weighing 20-25 tons.

Equipment of such weight would be exceedingly difficult to hijack. The fuel assembly would lie lengthwise in a central cavity surrounded by 8-9 inches of lead shielding. Once the assembly is in place, it is sealed by a lead plug and gasket arrangement. The heat generated by the spent fuel is fed by conduction through the lead shielding and the steel jacket to the outside. Regulations require that the external surface of the jacket be kept below a prescribed temperature limit, and it is designed accordingly. The cask has withstood testing under various types of vehicular accidents, including collision and fire. For example, it has maintained integrity after being dropped 30 feet onto a flat unyielding surface and withstood puncture by a drop of 40 inches onto the top of a vertical 6-inch diameter cylindrical, steel bar.[11]

A program currently being implemented requires that the vehicle transporting spent fuel be escorted by at least one other vehicle in continuous radio contact with nearby security forces.

AIR ATTACK

Although American nuclear reactor buildings are designed to withstand direct impact by a large jet, nuclear bombs or intercontinental ballistic missiles equipped with a nuclear warhead do pose serious threats. There is no atomic energy plant or, for that matter, any other structure yet constructed that can withstand a direct nuclear hit. The result of such a hit could well lead to a steam explosion with resulting radioactive gas escape and/or a core meltdown with resulting radiation pollution of the ground water underneath the plant.

WASTE MATERIAL

Safe storage of low-level and high-level nuclear waste material is probably the most difficult problem for defenders of nuclear power to solve. High-level waste has long-lived radioactivity. Plutonium, a part of this waste, has a radioactive half-life of over 100,000 years, and once a tiny speck of plutonium finds its way into a person's lungs, it can produce deadly cancer.

The United States Government is possibly the worst offender, storing low-level contaminated nuclear military waste above ground in barrels and tanks that have leaked excessively throughout a 20-year period of storage. High-level waste leakage has occurred repeatedly from underground tanks in the state of Washington. So far, it has been reported that such leakage has been detected before it seeped into the ground water, thus avoiding radiation contamination.

Other countries handle their waste in different ways. Britain reprocesses much of it for reuse in breeder reactors; the remainder is encased in concrete and dumped at sea. The Germans, French, and Russians are busily engaged in reprocessing some of their nuclear waste for use in breeder reactors; the remainder is encased in glass, steel, and/or concrete and sealed in abandoned salt mines. The Japanese plan deep burial of their waste on one of their nation's small uninhabited islands.

In the United States, the Nuclear Regulatory Commission has yet to make a final decision about commercial reactor waste storage. Nuclear waste is the responsibility of the commercial utility for the first five years of its existence; after that, it becomes the responsibility of the Federal government. At present the Commission is seriously considering encasing the waste in glass, concrete, and metal and burying it deep in the earth in stable geological formations. Nuclear vaults being studied include subterranean salt beds in New Mexico, shale deposits in the Midwest, and granite deposits in the East. A decision on disposal sites is expected before 1980.[12]

BREEDER REACTOR

The next development in atomic reactors, "the fast breeder," is very efficient (It uses 60-70% of the energy in its fuel vs. 1-2% in today's reactors.), and creates more fuel than it uses. Development of the breeder would extend nuclear fuel supplies for hundreds of years. Critics say it creates deadly plutonium and uses large amounts of research money that should go to develop alternative power sources. In July, 1977, a U.S. House and Senate committee cut appropriations for the Clinch River Breeder Reactor, our first large breeder, to $80,000,000. The political battle over the breeder is likely to continue with proponents and opponents endlessly citing its advantages and disadvantages.

NUCLEAR PROLIFERATION

Unfortunately and most seriously, there is no way the United States can stop other countries from making atomic bombs. However, nuclear power plants are not prerequisites for producing bomb material. None of the nuclear-weapons nations used power plant material to get into the "nuclear club."

Critics of nuclear-powered electricity argue that there are dozens of countries with nuclear reactors in operation or under construction that do or will produce plutonium that can be converted into bombs. A typical light-water reactor that generates enough power to supply the needs of a city of one million people also produces enough plutonium in a single year to make bombs that could destroy more than a score of cities of similar size. Nuclear proponents are quick to add that the plutonium used in bomb building can only be separated in a reprocessing plant that can be safeguarded and audited to prevent diversion.

The technology of making atomic bombs is a genie that cannot be put back in the lamp. India has already made a test bomb with the by-products of a nuclear research reactor supplied by Canada. It is only a matter of time before such politically volatile countries as Libya, Pakistan, Jordan, Lebanon, South Korea, Israel, Taiwan, South Africa, or Syria construct bombs of their own with or without the assistance of commercial nuclear reactors.

Americans can only hope that when these countries have atomic capabilities, U.S. political leaders are wise enough, shrewd enough, and courageous enough to prevent unstable governments from using them.

ECONOMIC COSTS OF NUCLEAR POWER

The increasing expense of building nuclear plants and of buying uranium has already cut into the economic advantage that nuclear energy has over coal. Commonwealth Edison's 2,240 megawatt Byron, Illinois, plant is estimated to cost $1,000,000,000 and take 10 years to build.[13] Before it is finished in the 1980's, it is likely to cost well over one billion dollars and to take longer than the scheduled ten years. Environmental and reactor safety standards, rising labor costs, and equipment and material shortages all serve to increase cost and construction time. In the meantime, uranium prices have skyrocketed from $7.00 a pound in 1973 to $25.00 in 1976 to an estimated cost of $43.00 by the early 1980's.[14]

With domestic and foreign uranium reserves running surprisingly low, by the year 2000, the result will be to force prices even higher than the present. A comparable coal plant was built in about seven years with significant savings in construction costs. Now coal plant costs appear almost equal to nuclear costs and the lead time is almost ten years. These costs, along with reduced estimates of energy demand, have caused public utilities in the United States to cancel or defer many orders for nuclear reactors and coal-burning power plants.

In short, nuclear energy is a recently developed energy source that has already proven itself worthwhile; the percentage of our electrical power generated by the atom increases monthly. The extent to which it answers our energy needs will be determined both by the public's willingness to accept its use and the willingness of government and private utilities to finance the high construction costs nuclear power entails.

ENOUGH COAL FOR 300 YEARS

Photo Courtesy of the National Coal Association

COAL

President Carter proposes doubling coal production as one of the cornerstones of his energy program. He and Energy Secretary James Schleisinger hope to increase American coal production from about 600,000,000 tons per year to well over 1,000,000,000 tons.[1] The basis for this whopping projected increase is the tremendous coal reserve in our country; experts agree that even at this supercharged rate of consumption, we have enough for at least 300 years.

Coal has other advantages as well as being in abundant supply: (1) Coal generating plants do not present such potential catastrophies as core meltdowns or radioactive contamination in nuclear plants. (2) Then there is the cost factor. A large coal plant costs about $450,000,000 while an equivalent nuclear plant comes to well over $1,000,000,000.[2] When scrubbers are added to a coal plant, costs are approximately the same, however. (3) Coal as a fuel is more expensive than uranium but costs considerably less than gas or oil to produce a like amount of electricity. On balance, coal commands a strong position costwise. Doubling coal production will provide more jobs in regions where unemployment is chronic and general income levels are low. West Virginia, Pennsylvania, Kentucky, Tennessee, and Illinois are noted for their coal reserves. Miners who work regularly are well-paid and a boom in coal production will go far towards reviving Appalachia and similarly depressed areas.

Critics of coal are quick to point out, however, that there is more to life than a substantial paycheck Coal mining is one of the world's most dangerous occupations.

Every year hundreds of miners are killed in mine cave-ins, gas explosions, and accidents with machinery; countless more are injured and maimed for life. Black lung disease, brought on by breathing coal dust over the years, kills on a cumulative basis an estimated 10,000 miners and former miners per year. Is doubling these personal tragedies yearly a prudent way to go about solving the energy shortage, critics ask.

Unfortunately, it is not just miners whose lungs suffer the ill effects of coal. Most coal-fired electric generating plants have scrubbers and electrostatic precipitators to prevent sulfur from going into the outside air, but these devices do not remove the tiny submicrosized particles. Carrying toxic substances, these penetrate deeply into the bronchioles of the lungs making it very difficult for people with lung problems to breathe.

Though air pollution and physical harm to miners are the chief problems involved in using large quantitites of coal, they aren't the only drawbacks. Others are: (1) Strip mining, which accounts for approximately half of all coal mining,[3] often leaves the countryside scarred with ugly holes, slag piles, eroded fields, and consequent chemical run offs which pollute nearby streams and rivers with toxic substances. There is also considerable danger from surface subsidence when abandoned mine shafts collapse. (2) Labor unrest, as evidenced by the winter coal strike of 1977-1978, makes coal at times an unreliable energy source as many coal plants were forced to close or substantially reduce power production. (3) Our nation's railroads are so rickety there is considerable difficulty in getting present coal to power plants, let alone doubling the amount. (4) Western coal is required to use the same scrubber systems in power plants as "dirtier Eastern coal." Shipping Western coal long distances to market, plus forcing scrubbers on the Western coal makes competition with other fuels difficult. (5) The coal industry does not, at the present time, have the capital to drastically increase production by opening many new mines.[4]

INCREASING DOMESTIC OIL & GAS PRODUCTION

Dramatically increasing domestic oil and gas production is one energy option often overlooked. This is eminently possible, though our oil companies have not done it.

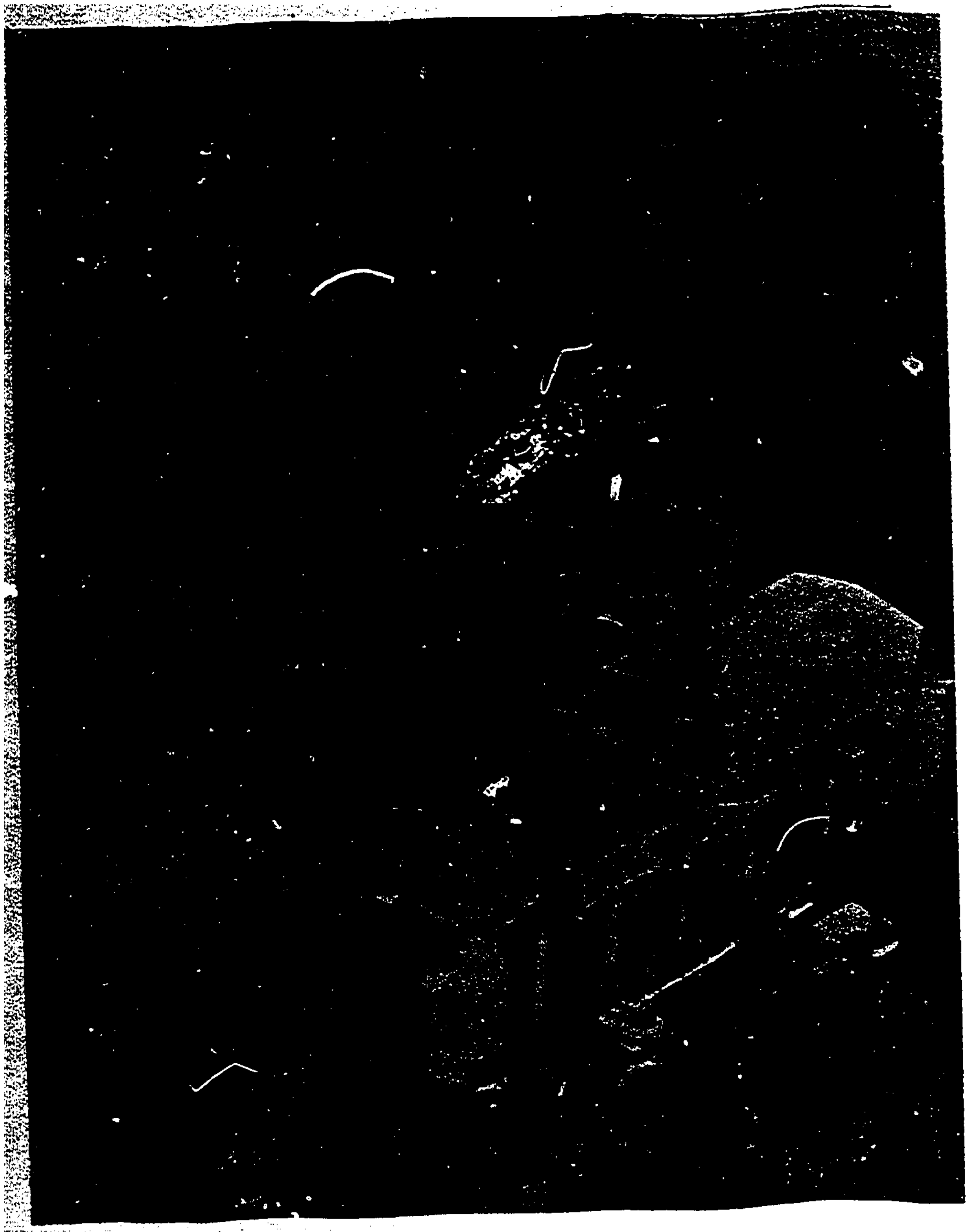
Geologists, government analysts, and oil industry spokespersons are not entirely in agreement, but a general consensus concludes we have underground enough oil and gas that can be economically brought to the surface to last for the next 30 years. This can be done even if we increase production by one half to eliminate importation of oil.[1]

We are not tapping remaining oil and gas reserves as much as we might because these reserves are found in smaller pools, require more drilling exploration, more wells, and deeper drilling. Development of equipment able to tap gas in areas where geological pressures mix it with water will also lessen supply problems.

Oil companies have found that such additional expenses would decrease their profits substantially. Bigger profits can be made by investing the same money abroad in foreign fields where the cost of bringing oil out of the ground and shipping it to the United States is less than current domestic pumping and shipping expenses. This changed attitude was reflected in a decrease in exploratory drilling in the United States from 16,000 such wells in 1956 to 7,000 wells in 1971.[2]

To actually get oil and gas companies to increase their domestic production will require changed circumstances. Price controls will need to be removed (especially on gas); the price of oil produced abroad will have to rise dramatically; the government will have to impose stringent import restrictions on foreign oil, or subsidies will have to be provided to oil; companies as compensation for producing more domestic oil.

With the profit motive dominant, privately-owned oil companies can hardly be expected to voluntarily develop domestic reserves as an act of charity. Yet, it is unwise to continue as we are, being virtually helpless at the hands of Mideastern oil sheiks and dictators should they become angry with our foreign policy and as a consequence, turn off the oil and gas spigots to the United States. This brings up another energy option — continuing our pattern of energy consumption without change.



The offshore oil drilling rig has become the symbol and mainstay of American domestic oil production.

CONTINUING AS WE ARE

Twenty years ago Dr. Harrison Brown, Professor of Geology at the California Institute of Technology, published a seminal book entitled "The Next Hundred Years" in which he anticipated the beginning of the end of the petroleum era. He was recently quoted as saying that when he wrote the book, "I never dreamed for a minute that we wouldn't have done something about it by now."[1]

Dr. Brown is right. For all practical purposes, we haven't done anything about the problem. Actually we are still increasing our yearly consumption of oil and gas by increasing imports, rather than holding the line or decreasing use. The only alternate energy source we have expanded to any significant extent in the last twenty years has been the nuclear one, and that has been used almost entirely in the development of electricity.

There are arguments that favor continuing to import between one third and one half of our oil. Some say that importing so much oil is a boon to such relatively underdeveloped nations as Ghana, Mexico, Libya, Iraq, and others. Our oil payments provide them with the working capital to attack disease, illiteracy, poverty, lack of industrialization, and to provide consumer goods for their people. This argument is a tenuous one, however. With oil in short supply throughout the world, these same countries would have little trouble making lucrative sales to Western Europe, Japan, and other countries with tiny oil reserves.

A better argument for continuing our oil and gas dependence is that it encourages world trade interdependency and, as a result, helps maintain an admittedly uneasy world balance of power.

As a matter of fact, should this world balance of power be upset by another oil embargo, there would be those in this country advocating armed interventiuon to seize those Middle Eastern oil fields vital to our national interest. This option was given serious consideration by Kissinger and Nixon during the Arab oil embargo of 1973. The option was dropped due to expense, the probability that world public opinion would severely condemn the United States for its action, and the fact that we were getting enough oil from domestic and non-Arab foreign countries to keep our economy running. If the United States should find itself without sufficient oil in the future, the military opinion could be more attractive.

Another argument used for continuing as we are points out that a really serious and thoroughgoing attempt to develop alternate sources of energy will require tremendous sacrifices in energy and expended capital. Whether it be for individually heated solar units, geothermal or tidal energy, masses of wind-operated electrical plants, or considerable retooling to fully implement conservation, any one or more of these projects will cost time, money, energy, and frequent economic dislocations. There are those people in American society that venerate and revere the status quo and, in this argument, find good reason for keeping things as they are.

Government slogans and higher prices aren't going to force me to give up what I need.

There are compelling arguments for not continuing our dependence upon other countries for energy. This dependency places our foreign policy at their whim; a threat, either overt or implied, of cutting off oil imports forces us to be more cautious, circumspect, and at times almost cowardly in making accommodations to the exigencies of the world scene. In the case of war, which at times cannot seem to be avoided, the implications are even more fearsome. This is not a healthy situation for any foreign nation to be in, let alone one with a tradition as independent as our own.

Even if our foreign energy supplies are not cut off, the threat of economic blackmail remains. The united front of OPEC nations could, on a short-term basis of a year or two, or even on a medium-term basis of ten years, almost totally wreck our economy by raising oil and gas prices so much that American products would not be able to compete on foreign markets. Worse, it is conceivable that on a short-term basis, petroleum prices could soar leaving us to stagnate economically or possibly even bankrupt ourselves trying to buy the fuel. It is likely that under such circumstances our economy would grind to a halt causing mass unemployment and ensuing depression.

Although continuing as we are is an option to consider, the arguments in favor are considerably weaker than the negative aspects of doing nothing. In short, the do-nothing attitude runs counter to the more positive aspects of American tradition. Let us hope that we have not become so alienated, soft, and socially indifferent in the last few decades that we will allow ourselves to continue following such an option. In our present situation, no action is likely to be the worst action.

AN AGRARIAN LIFE STYLE

An improbable solution to our energy difficulties would be a return to an agrarian, pre-industrial life style. Horses would replace autos and tractors, fireplaces would be the major means of heating, and our clothing would be homespun — to mention a few of the changes.

There are advocates of this solution in America today. They argue that our society is too complicated and is chronically on the verge of collapse. The 1977 New York power blackout is simply a precursor of the future. Advocates of this simpler life style believe that cancer, which is more frequent and acute now as a result of industrial society, would all but be stamped out. Psychological problems stemming from fast-paced living, as well as the monotonous routine of assembly line work that many now face, would disappear. Such improvements are to be taken seriously.

On the other hand to change our living habits so drastically would require efforts almost greater than we can imagine. It is difficult to picture Americans at home in the evening in these changed circumstances. There would be no TV or radio; they would be reading by candlelight, and receiving warmth from the stove. Their reading material would be reduced as only hand-operated presses could produce publications.

In every other phase of our lives, changed conditions would prevail. Our large mechanized farms, which make it possible for one agricultural worker to feed 30 others, would disappear; tens of millions would be forced into back-breaking labor to secure enough food to stay alive. Towns and cities of all sizes would become impossibilities as they are now constituted; lighting them, heating them, and moving about in them would be horrendous, if not impossible. As for the functions of government, effective police and fire protection would be knocked out over large urbanized areas; our national defense (infantry and cavalry formations only) would be easy prey for virtually any aggressive foreign power. The very future of the United States as a sovereign nation would be in serious peril.

In short, in spite of the advantages of an extreme agrarian society as mentioned above, such a reversal in living would be almost universally unpalatable.

There are others who advocate a lessening of energy consumption to a degree not quite so extreme. They cite the energy savings made in Sweden by having smaller and more efficient automobiles, the attractions of improved public transportation, better insulation, and use of boiler steam for making electricity and space heating (co-generation). They advocate energy sources that require the work of many human hands, such as solar and windpower, as opposed to those that require the expenditure of much money for technology, such as nuclear-powered electrical generating stations and coal-powered electrical generating stations equipped with scrubbers. As with any of the options mentioned in this primer, there are almost as many variations in a general basic belief as there are people advocating them.

SUMMARY – WHICH WAY TO GO – THE TRADE-OFFS

Every one of our energy options has its positive and negative sides. In weighing these pluses and minuses, we should consider first whether the source is worthy of continuing or developing at all; secondly, we will need to determine the extent of implementation advisable.

Energy conservation would seem a valuable policy to follow because a truly positive energy conservation program would provide a large number of jobs for many Americans. Improved insulation in our homes would offer literally hundreds of thousands of additional jobs. Upgrading our public transportation system, especially our railroad rolling stock and roadbeds, would offer another opportunity to drastically reduce the unemployment rolls. Using the same steam energy to heat homes as well as to make electricity would provide a bonanza for the building trades.

Even with conservation, though, there would be drawbacks.

There would be great expense redesigning our autos so they would double their mileage; it would be expensive in time, money, and energy use to double the effectiveness of American insulation; improved public transportation would require billions to upgrade railroad roadbeds and build new rolling stock alone; co-generation of electricity and space heating would require enormous sums to relocate power plants so that their excess energy would also heat nearby homes, offices, and factories. These are the major steps that would be necessary to place energy conservation on a par with Sweden.

Perhaps the price is too high. Perhaps it would be wiser to use the money to build more light-water nuclear reactors to replace oil and gas fired electrical generating units. The oil and gas thus saved could go for autos, space heat, and private transportation. But wait, nuclear stations have problems, too. American uranium supplies, located primarily in the Rocky Mountain States, are in 30-60-year supply. Each station costs over $1,000,000,000, takes ten years to build, and presents the possibility, though low probability, of a terrible radiation accident. There are serious problems in the disposition of radioactive waste as well.

Coal plants are better, right? Without scrubbers they are less expensive, their fuel comes from an abundant energy source, and best of all, they don't present the spector of a catastrophic accident. But there are difficulties with coal. Are we willing to see 20,000 miners die yearly of the black lung disease? Are we willing to double, in the lungs of millions, the amount of toxic, submicrosized particles not removed by scrubbers? Are we willing to accept the alleged "greenhouse effect" whereby world climatic temperature could be raised an average of 5°? Then there is the harm that surface and underground mining do to the environment in terms of erosion, water pollution, unsightly slag piles and pits, and cave-ins.

Coal gasification has merit, particularly if coal is gasified while in the ground (in-situ). There are vast coal reserves readily available and in-situ conversion to low BTU gas for electrical production eliminates much of the pollution problem because of the clean-burning quality of gas. Cost is an unknown inasmuch as in-situ gasification is in its infancy. Excessive use of water and scarring of the environment are two additional negative tradeoffs often cited.

Obtaining oil from shale has similar tradeoffs. The United States contains large areas of shale, and the oil extracted, when burned properly, provides relatively little pollution. Excessive conversion expenses, marring of the environment, and heavy demands for water in processing provide negative considerations.

It is a mind-boggling proposition to weigh the drawbacks of conservation, nuclear, and coal power against each other.

Maybe it is best to develop more intensively our known and potential oil and gas reserves, and everything will go smoothly for awhile at least. But we must temper this emphasis with the knowledge that these are finite sources. At some point in the next century, we really will run out of oil and gas or else reach a point where it will become exceedingly uneconomical to pump these sources from the ground. Incentives or regulations will have to be given private businesses to encourage them to push exploration. The only other route is government-owned gas and oil companies with attendant problems in inefficiency, corruption, and distribution too well-documented in other countries to detail here.

Geothermal power offers a bit of hope to the West and Southwest; tidal power is a potential panacea for New England. But together these two renewable energy souces do not make the difference as far as the vast heartland of America is concerned. Wind power would be expensive, intermittent, and difficult. It would take hundreds upon hundreds of tall, unsightly towers to supply just one city the size of Minneapolis — St. Paul with electricity.

Perhaps solar power, literally and figuratively, offers the brightest new option of all. Even so, it should be kept in mind that at most it can be practically installed to heat space and hot water in millions of American homes. The cumulative cost is staggering — $120,000,000,000 if solar water and space heaters are installed in 30,000,000 dwellings at a minimum cost of $4000 each. Who will pay for this? Who will provide the incentive for effecting changes of such magnitude? And then after the job is completed, it should be remembered that in many areas, solar energy will provide a maximum of 75% of the space heating needed. A fossil-fueled back-up system will need to be purchased, installed, and fueled ready to go on short notice when a succession of cloudy days spells a halt to solar-provided heat.

In spite of its cost and lack of dependability at times, solar energy offers the possibility of tremendous reductions in the burning of fossil fuels which are a finite energy source and pollute the atmosphere with carbon dioxide as well. Once a solar boom does get underway, these units can be installed rapidly and offer increased employment to armies of carpenters, electricians, plumbers, sheet metal workers, and other tradesmen. There will be no five- or ten-year delay as is the case with a large electrical generation station. Once the owner of a home, office or factory makes up his mind to install solar heating, it can become a practical reality in a matter of weeks at most.

Electricity generated by the photovoltaic cell is pollution free. In addition, the sun provides an energy souce that can't be used up. Major drawbacks to this process are high production costs — enough cells to light a 100 watt bulb cost at least $100, in spite of significant cost cutting in the last five years. Other negative tradeoffs include high use of energy per watt in constructing photovoltaic cells and large areas needed for collectors. (To provide an average-sized house with electricity often requires more square footage than the house's roof provides.) Photovoltaic cells only operate in sunlight, and widespread use of photovoltaic cells could provide for serious fluctuations in power use, depending upon whether the sun is shining or not.

This explanation of our energy options ends now. We are not lacking in choices. We even have the choice of doing nothing, for a time at least.

Which options are chosen and how much we develop each option will be decided in the coming months and years by a mix of consumer choice, government action, and the predilections and choices of private industry. A balanced diverse development of energy sources or a possible decision to eliminate one or more of them is difficult to make.

It could well be that with our expanding population and a promotion of concurrently expanding economy, the best choice is to proceed full steam ahead with all options. To quote Dr. Harrison Brown of the California Institute of Technology again we would be well advised to pursue all technological approaches "to diversify so that if anything goes wrong with one, we will have spread the load and not be caught short."[1]

FOOTNOTES

[1]Lee Schipper and Allan J. Lichtenberg, "Efficient Energy Use and Well-Being: The Swedish Example," *Science*, December 1976, p. 1001.

[2]Ibid, p. 1004.

[3]Ibid, p. 1005.

[4]Ibid, p. 1006.

[5]Ibid, p. 1007.

Geothermal Power

[1]*Atomic Industrial Forum*, "Background Info," Washington, D.C.: by the organization, November 1975, p. 1.

[2]Robert C. Axtmann, "Environmental Impact of a Geothermal Power Plant," *Science*, 7 March 1975, pp. 796-9.

[3]"Background Info," op. cit., p. 1.

[4]"Geothermal Energy: ERDA Leaves It Lay," *Nation*, 12 November 1977, p. 487-.

[5]"Geothermal Energies," *Science Digest*, October 1977, p. 76.

[6]"Slowdown on Geothermal Land," *San Francisco Chronicle*, 4 October 1974.

Tidal Power

[1]Kark Keyerleber, "Tidal Dam at St. Malo," *The Nation*, 11 June 1973, p. 756.

[2]"Tide Power for Canada," *Science Digest*, October 1976, p. 15.

[3]"Best Energy Source Can Be Tides," *Science Digest*, October 1977 p. 62.

Solar Power

[1]D.S. Halacy, *The Coming Age of Solar Energy* (New York: Harper & Row, 1963), pp. 209-212.

[2]Ralph Nader, "Ralph Nader Reports," *Ladies Home Journal*, September 1976, p. 50.

[3]National Recreation and Park Asso., *Energy Manual for Parks*, Arlington, Virginia, by Lee Stephenson, p. c-25.

[4]John J. Berger, *Nuclear Power: The Unviable Option*, (Palo Alto: Ramparts Press, 1976), pp. 258-259.

Wind Power

[1]Berger, op. cit., p. 301.

[2]Frank Von Hippel and Robert H. Williams, "Solar Technologies," *Bulletin of Atomic Scientists*, November 1975, p. 29.

[3]Berger, op. cit., p. 302.

[4]"Electricity from the Wind," *Time*, 13 February 1978, p. 53.

[5]Gwynned and Clark, "Power in the Wind," *Newsweek*, 20 February 1978, p. 78.

Biomass – Garbage & Plant Power

[1]John W. Fowler, *Energy Environment Source Book*, Washington, D.C.: National Science Teacher's Assoc., 1975, p. 206.

[2]"Plant Crops as a Source of Fuel and Hydrocarbon-like Materials," *Science*, 2 December 1977, pp. 942-944.

[3]"Alcohol Mixture Hikes Mileage," Rockford Register Republic, 10 May 1978, p. 3.

[4]"Solar Biomass Energy: An Overview of U.S. Potential," *Science*, 10 March 1978, pp. 1041-1048.

[5]Ibid, pp. 1041-1047.

Other Undeveloped Sources

[1]Fowler, op. cit., p. 215.

[2]United States of Department of Energy, "Solar Electricity from Photovoltaic Conversion," Washington D.C., p. 5.

[3]Margaret Laliberte, "The Sun on a Semi-conductor," *EPRI Journal*, March 1978, p. 23.

[4]Bruce L. Welch, "The Reality of Solar Power," *The Nation*, 21 January 1978, p. 45.

[5]LaLiberte, op. cit., pp. 21-22.

[6]Welch, op. cit., p. 45.

Promising Fuel Conversions – Coal Gasification

[1]"Underground Gasification: An Alternate Way to Exploit Coal," *Science*, 16 December 1977, pp. 1132-4.

[2]Ibid., pp. 1332-4.

[3]John M. Fowler, "New Fuels from Coal," *Aware*; May 1978, p. 14.

Promising Fuel Conversions – Oil from Shale

[1]"Shale: The Answer to Domestic Oil Supply," *Business Week*, 30 January 1978, p. 55.

[2]"Oil Shale: Prospects on the Upswing. . .Again," *Science*, 9 December 1977, pp. 1023-7.

[3]*Business Week*, op. cit., p. 55.

[4]Ibid., p. 55.

Promising Fuel Conversions – Gasoline to Electric Automobile

[1]Neil Gluckin, "Electric Vehicles," *Science Digest*, September 1977, pp. 7-11.

[2]"The Future Car's Future," *Forbes*, 15 October 1977, pp. 12 and 15.

[3][illegible], op. cit., pp. 7-11.

Nuclear Power

[1]Don G. Meighan, "How Safe is Safe Enough?" *New York Times*, 20 June 1976, pp. 9, 41.

[2]Handout from Nuclear Power Assembly Report, "Nuclear Power: Facts and Figures," Washington, D.C. 1977.

[3]"Update" *ERDA*, 1 August 1977, p. 1.

[4]Atomic Industrial Forum, "Info 101," Washington D.C.: by the organization, December 1976, p. 1.

[5]Peter Gwynne "How Safe is Nuclear Power?" *Newsweek*, 12 April 1976, p. 73.

[6]C. Stam and Others, "Report to the State of California on Safety of Steam Generating Plants," *UCLR*, 1972.

7"The Great Nuclear Debate," *Time*, 8 December 1975, p. 36.

8"Why Atomic Power Dims Today," *Business Week*, 17 November 1975, p. 105.

9Gwynne, op. cit., p. 71.

10Gwynne, op. cit., p. 72.

11Leonard A. Sagan, *Human and Ecologic Effects of Nuclear Power*, (Springfield. Illinois: Charles C. Thomas, 1974), p. 181.

12"One Reason Atomic Power is Under Fire" *U.S. News and World Report*, 21 June 1976, p. 36.

13Commonwealth Edison, "Byron Nuclear Power Station," p. 3.

14*Business Week*, op. cit., p. 106.

Coal

1"President Carter's Energy Message," *Rockford Register Republic*, 21 April 1977, p. A5.

2Institute of Nuclear Science and Engineering, Oregon State University, *Electric Power Generation: Comparative Risks and Benefits*, by C.H. Wang, by the organization, 1973, p. 23.

3Hurbert E. Risser, *The U.S. Energy Dilemma*, Urbana: Illinois State Geological Survey, N. 64, July 1973, p. 42.

4"Some Second Thoughts About Coal" *U.S. News*, 13 March 1978, p. 25.

Increasing Oil and Gas Production

1Barry Commoner, *The Poverty of Power*, (New York: Alfred A. Knopf, 1976), p. 57.

2Ibid., p. 53.

Continuing As We Are

1John N. Wilford, "The Good Life Has Found a Limit," *New York Times* 19 July 1977, Section "News of the Week," p. 8.

Summary — Which Way to Go — The Tradeoffs

1Wilford, op. cit., p. 8.

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