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May 1981

Solar Energy Education

Energy, Society, and the Sun

MASTER

READER Part I

Release for Announcement in Energy Research Abstracts

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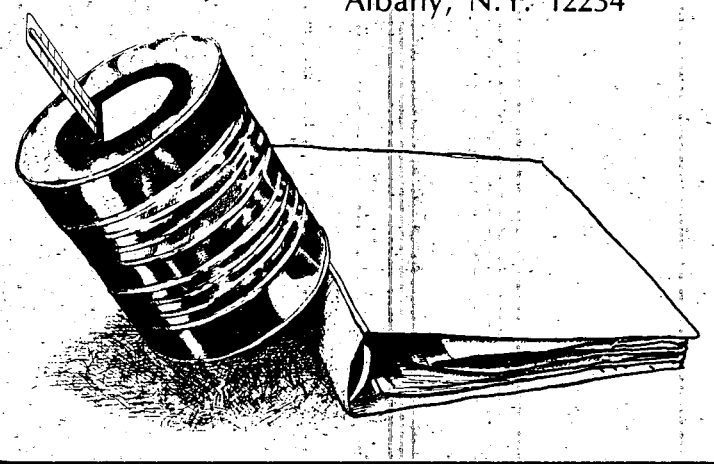

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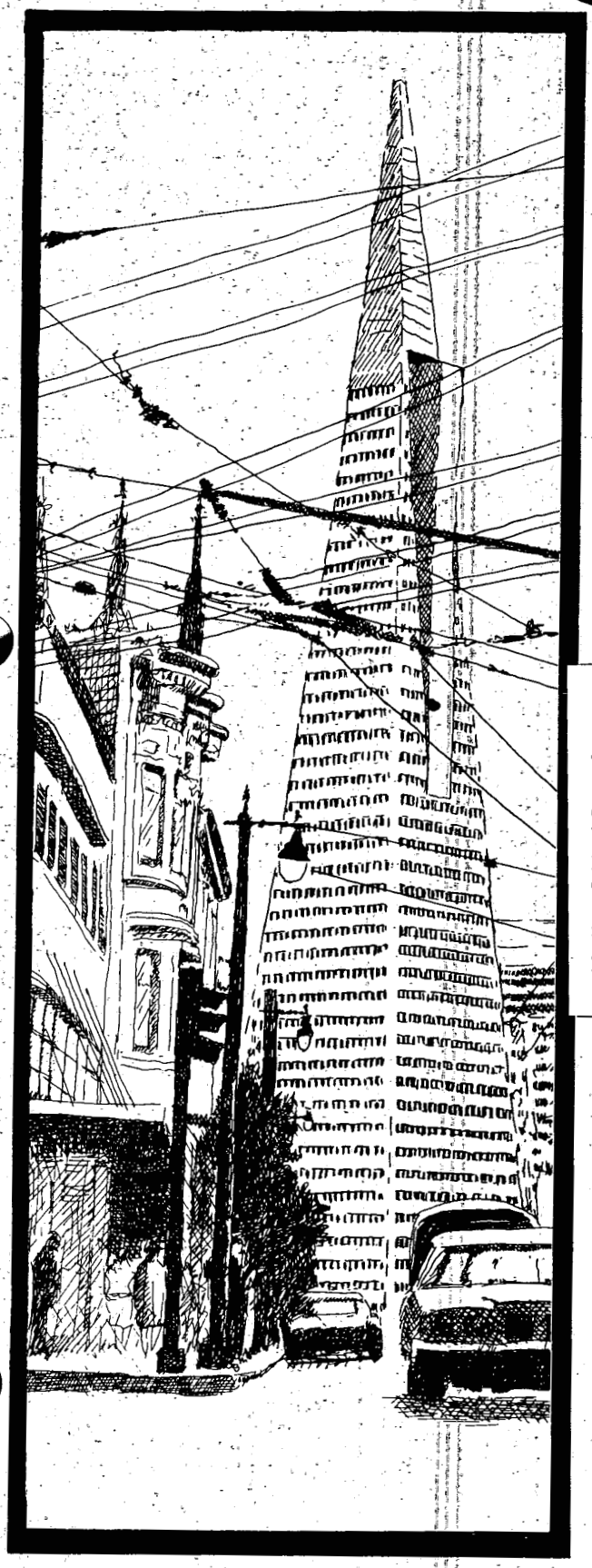
Solar Energy Education



READER
Part I

Energy, Society, and the Sun

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Table of Contents

	PAGE
Introduction	4
The Readings	
STAR OF STARS by Albert Rosenfeld from Saturday Review	7
THE TRANSITION TO A POST-PETROLEUM WORLD by Denis Hayes from Journal of Home Economics	10
TINKERING WITH SUNSHINE by Tracy Kidder from The Atlantic Monthly	16
A CITY CHANGES ITS ENERGY FUTURE by Katherine Alvord and Michael R. Eaton from Sierra	31
THE SUN: WHO OWNS IT? by Earl A. Talbot and Dawn Walter from The Appraisal Journal	35
SOLAR POWER MEANS NEW UTILITIES' ROLE by Dick Kirschten from National Journal	41
To Teachers	49
Copyright Guidelines	53
Publications Address List	56
Glossary	57
Bibliography	62

Introduction

The energy picture is changing too fast to be captured in books. Before the ink is dry new experiments, technologies, and legislation make some of a new book's information obsolete. Magazines and newspapers are better able to keep pace with rapid change, and it is on these media that the well-informed energy consumer depends.

In your hands is a collection of magazine articles selected to help you focus on an important part of the changing energy picture: solar energy. This booklet is Part I of the Solar Energy Reader, a series of four booklets:

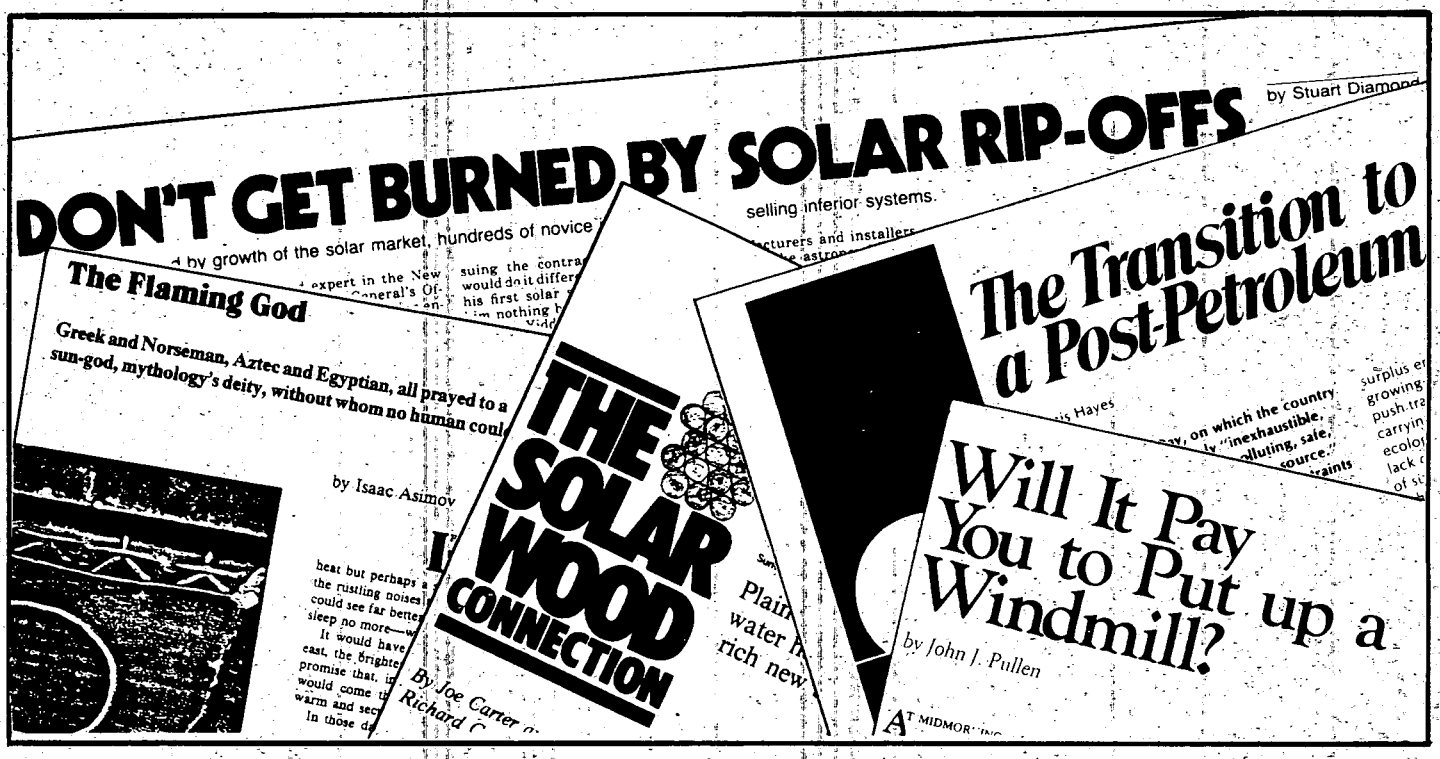
I. Energy, Society, and the Sun
(General readings on philosophical, political, and legal topics)

II. Sun Story
(Solar history, mythology, and poetry)

III. Solar Solutions
(Articles on the many applications of solar energy: heat, photovoltaics, wind, hydro, biomass, etc.)

IV. Sun Schooling
(Easy readings on energy and articles about teaching solar)

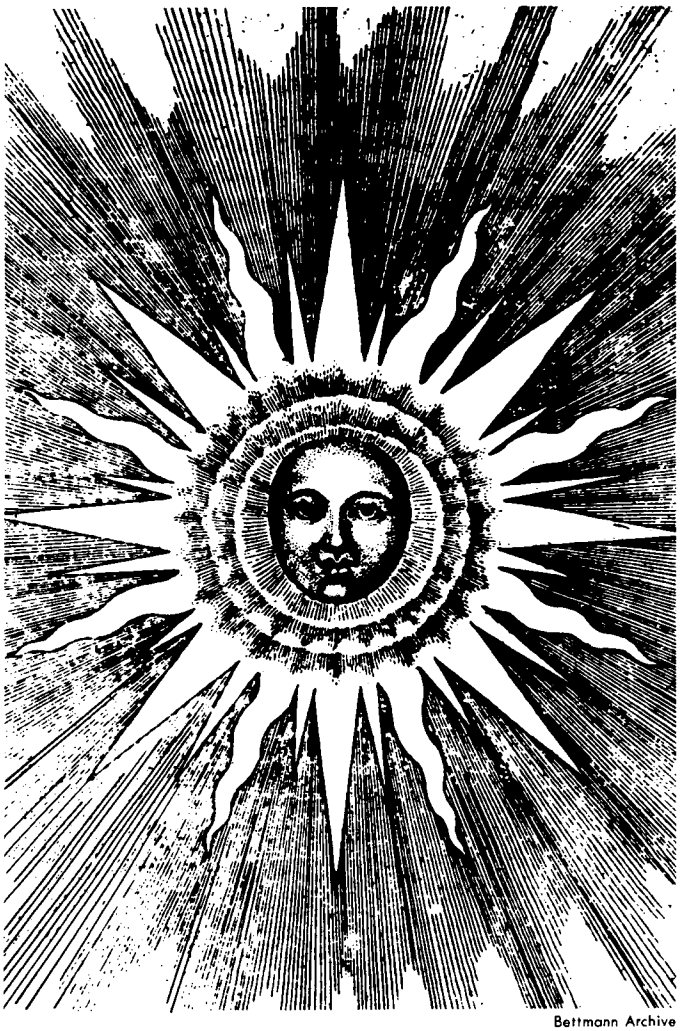
The bibliography at the end of this booklet will guide you to articles that time and space would not allow us to include here. But the magazines represented in the bibliography and the reader are continually publishing new reports on recent developments. The person who wants to be well-informed about the changing energy picture will follow these publications regularly.



The Readings

Star of Stars

In a series of fresh and startling metaphors, the author presents us with the most current information (and questions) about our sun. This vivid portrayal of our "star of stars" reminds us of its almost unimaginable power, but then takes us beyond the sun to all that we may yet discover about the universe.



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Star of Stars

Yes, the sun is just another twinkle and, as stars go, merely middle class, but anything hotter would make earth unlivable

by Albert Rosenfeld

PERHAPS it's just as well that, most of the time, we take the sun pretty much for granted. It's that friendly and familiar lamp up in the sky that provides us with warmth and with daylight—with nightlight, too, for that matter, its glow reflected off the moon. We do know, of course, that when it is shining at its brightest, it can scorch our skins; we squint and dare not look at it straight on. So we are not totally unaware of its power. But if we were able to comprehend, in anything remotely like their true dimensions, the incredible forces that play erratically within the fiery innards of the star that holds our planet prisoner in its gravitational field, we might be almost too awestruck to go about our daily business. We might live in terror of being vaporized at any moment without notice, just as the substance of the sun itself is vaporized by its own unimaginable temperatures, so that it is made of nothing but gases—all 2 billion billion billion tons of it.

Only in modern times have we come to understand that our sun *is* a star. Or, to put it another way, what we once believed to be stars—those pinpoint-sized twinkles of light all over the night sky—turned out to be distant suns (except for those few that turned out to be nearby planets), many of them mightier than our own. In fact, the sun is no great shakes of a star, as stars go. It is one of the ordinary stars of the family that astronomers call the "main sequence." It is about average in size and in luminosity—a so-called fifth-magnitude star. If we look out at the constellation Orion, for instance, and find the star Rigel, we discover that it is a "blue supergiant," burning with the luminosity of 40,000 suns! Its life span, however, will be much shorter than our sun's.

Yes, stars, too, have finite life spans. It stands to reason that they must, considering the prodigal rates at which they consume their fuel. The realization that stars do possess life cycles also brought the realization that many stars—such as the "red giants" and "white dwarfs"—that seemed to belong to entirely different families of stars are really main-sequence stars at later stages in their life cycle. The sun, now about 5 billion years old, has just about reached the prime of its middle age. As more billions of years go by, it, too, seems destined to age and die in the main-sequence pattern.

For this moment in cosmic time, our sun is a middle-sized run-of-the-mill star. Anyone who wishes to downgrade it further need only point out that it is one of hundreds of millions of stars in this lens-shaped galaxy we call the Milky Way. Moreover, instead of being in the galactic center, as was once believed, it is located out on the periphery of the lens, about three-quarters of the distance from the galaxy's core. (Just as the earth orbits the sun once a year, the entire solar system revolves around the hub of the galaxy in a majestic swing that takes some 200 million years.) To emphasize further the immensity of the universe we inhabit, this galaxy of ours is one of a "local cluster" of galaxies—there are millions of such clusters—and the *light* from our closest neighboring galaxy takes *2 million years* to reach us. Thus, our sun, from this cosmic perspective, is an inconsequential lightspeck lost on the outskirts of a minor galaxy.

All that said and admitted, still, the sun is *our* star of stars—and anything much more impressive would soon render our planet uninhabitable. Its diameter measures 864,000 miles across—not so enormous—roughly 144 round trips between New York and Los Angeles, though traveled in a straight line, right *through* the sphere of the sun, not over its surface. On the other hand, the sun is almost a million times heavier than the earth (2 octillion tons versus 6.6 sextillion tons) and more than a million times as voluminous (335 quadrillion cubic miles versus 260 billion cubic miles). And all that is hot gas in ceaseless turmoil. The sun is not a rigid body; its gases seem to be in separate globs that don't even rotate in unison. For example, a given point on the rim of the sun's equator takes about twenty-five days to make a complete rotation, whereas a site in the polar regions may take thirty-five days. What holds it all together and makes it possible for the sun to retain its stability is precisely its main-sequence dimensionality; that is, it is just the right

Albert Rosenfeld is science editor of SR.

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size so that there remains a delicate balance between the force of gravity pressing its mass inward and the fierce internal temperatures exerting a balancing force outward. This will not always be so, but, according to the astronomers, we can count on it for another few billion years anyway.

If you should happen to be reading this article by natural light—say, on some sunny beach—it would not ordinarily occur to you that the page is illuminated by light waves that have just completed a 93-million-mile journey from the sun, traveling at (what else?) the speed of light, 186,000 miles per second—the speed limit of the known universe. So the light has taken about 8.33 minutes to reach you. And the light keeps coming. For the sun to maintain this order of luminosity, it must shine steadily with the power of millions of billions of billions of watts. This light, of course, pours out in all directions, and we receive only a tiny fraction of it. But in order to radiate that much energy at a constant rate from its surface out into space, what must be going on in the turbulent furnaces at the sun's core?

Temperatures on the sun's hot surface measure in the thousands of degrees, but at the core they go up—whether you measure them on the Fahrenheit, centigrade, or Kelvin scales—into the millions of degrees. The sun's core is, in effect, a gigantic thermonuclear reactor, creating its power—as hydrogen bombs do—by the fusion of hydrogen atoms into helium.

If you snap your fingers—as you read this page on the beach—in that fingersnap of time 4.5 million tons of hydrogen will have been consumed in order to give you enough light to read by (a pretty heady thought, that). Even at that extravagant rate of consumption, fortunately, the supply of hydrogen is sufficient to last billions of years longer.

If the energy from the sun's fusion reactor were to be released raw, in the form of high-frequency, shortwave gamma radiation, it would kill everything in its path, since a quantum of it is several million times as penetrating as the gentle rays of the visible-light spectrum that do fall upon us. Fortunately, the radiation must fight its way out of the sun's core through about 300,000 miles of restless gases, including the 80,000-mile-thick layer called the photosphere, which culminates in the sun's surface "skin." During this journey the gamma rays interact with other particles, releasing less lethal X rays and ultraviolet rays; they, in turn, interact with other particles until finally most of what escapes from the sun is the product of excited electrons' jumping their orbits just enough to release energy in the visible-light range. As added protection there are the two layers of the sun's atmosphere, the thin chromosphere and the far-reaching corona; and what's left gets a final screening by our own protective atmospheric layers and radiation belts.

Of course we receive a diversity of further radiation from the sun's roiling surface. The virtually impalpable "solar winds" go all over the solar system, and the solar flares that erupt from the magnetic-storming surface in their eleven-year cycles arrive here and disrupt our radio communications, create the spectacular polar auroras, and affect our weather cycles. In view of all this and of other recent data from space vehicles, many astronomers now consider the earth to be located in the sun's own extended atmosphere, even at this "safe" distance.

Though our galaxy is 10 billion years old, it took half that time for our sun to be born, out of its matter, as a glowing star. It has now burned for some 5 billion years and is scheduled to burn for roughly another 5 billion. But sometime before that (though still a few billion years hence), astrophysicists predict that as the sun's hydrogen fuel begins to run down, the thermonuclear fires will begin to cool. Gravity, inexorably pressing inward, will again take over; but the very compression will soon (by astronomical standards) send up the temperatures again as the inert elements begin to fuse into heavier elements. Then the sun will gradually start to expand and heat up again until the temperatures on earth are such as to melt lead and bring the oceans to a boil.

It will then continue its expansion into a full-fledged red giant, growing to encompass the earth—and even the orbit of Mars and beyond—before gravity once more wins out and the sun begins to contract again. This process will not necessarily be a smooth one—perhaps it will consist of erratic spurts accompanied by some explosions—but this time it won't stop until the sun has become a densely packed, feebly glowing white dwarf star, no bigger than the earth itself. Finally, even that glow will fade, and our former sun will have become a blackened cinder floating in the void, awaiting the fate of the galaxy and, indeed, the rest of the universe—whose own life span, according to most cosmologists, may also be finite.

But all this need not be a cause for instant despair.

For one thing, the mathematicians and the astrophysicists and the astronomers and the cosmologists are a long way from knowing everything about anything. Their scenarios may turn out to be based on theories and calculations that are erroneous. (It's been known to happen!) Even now there exists, for instance, what is known as the "angular-momentum problem": although the planets contain only about one seven-hundredth of the matter in the solar system, they possess 98 percent of the angular momentum; whereas the sun, with well over 99 percent of the matter, has only 2 percent of the angular momentum—a situation that grossly violates the law of the conservation of angular momentum. This remains a still-unresolved perplexity.

Then there is the "mystery of the missing neutrinos": measurements of solar emissions have been able to detect only a small percentage of the neutrinos that ought to be coming out of the sun if the fusion theories are correct. Unless something is wrong with the equipment (which seems unlikely but can't be ruled out yet), the solar theorists may have to go back to their blackboards and start over again.

Even if they turn out to be right, remember that for only a few centuries has the human brain been learning how to do things like weigh and measure the sun at long distance and explore the stars and map the galaxies with ingenious instruments and formulations. In a sense, the mind has created the entire universe out of intangible radiations and inferences about them. If we've been able to do all that in a few hundred years, starting from scratch, what solutions might we not discover, starting from where we are now, in a few thousand years or a few million?

For this moment, be fascinated, be filled with wonder. But it's too soon to run scared. Stretch out on your blanket. Relax. Enjoy the sun. Doomsday is billions of years away, and a billion years is a long time. ◉

The Transition to a Post-Petroleum World

Written for Sun Day, May 1978, this article raises the questions that still remain fundamental to the world's energy future: How is our use of energy affecting the earth? What are the constraints on future energy growth? How can we make the transition to a safe energy future?

The Transition to a Post-Petroleum World

By Denis Hayes

May 3, 1978 is Sun Day, on which the country celebrates the world's only "inexhaustible, predictable, egalitarian, nonpolluting, safe, terrorist-resistant, and free energy source." After a description of the current constraints on energy growth, the author—who is Sun Day's chairman—concludes that solar energy is by far our most attractive energy source.

We are *not* running out of energy, but we *are* running out of cheap oil and gas. We are running out of money to pay for doubling and redoubling an already vast energy supply system. We are running out of political willingness to accept the social costs of continued rapid energy expansion. We are running out of the environmental capacity needed to handle the waste generated in energy production. And we are running out of time to adjust to these new realities.

For two decades, we have pursued a chimerical dream of safe, cheap nuclear energy. That dream has nearly vanished. Nuclear fission now appears to be linked inextricably to weapons proliferation and to a broad range of other intractable problems. Every week new evidence buttressing the case against nuclear power is uncovered; every week worldwide opposition to nuclear power grows stronger. Nuclear fission now appears unlikely ever to contribute a large fraction of the world's energy budget.

Consequently, humankind is no closer today than it was two decades ago to finding a replacement for oil. Yet the rhetoric that public officials in the world's capitals lavish upon the energy "crisis" is not being translated into action. Most energy policy is still framed as though it were addressing a problem that our grandchildren will inherit. But the energy crisis is *our* crisis. Oil and natural gas are our principal means of bridging today and tomorrow, and we are burning our bridges behind us.

In both the Third World and the industrial world, various physical limits on energy growth have begun to assert themselves. In the Third World, mountains are denuded by scavengers in a desperate quest for firewood, and ever-hungry draft animals have little surplus energy for tilling the fields. The growing demands of an expanding population push traditional energy systems past their carrying capacities—leading in some cases to ecological collapse. In the developed nations, lack of water in the American West, scarcity of suitable land in the Netherlands, and lack of healthful air over much of Japan have all acted as brakes on energy growth.

In addition to such physical limits, energy supplies are also influenced by social factors. Despite the best efforts of powerful supporters in all quarters, energy growth is already pressing against social limits in much of the industrial world. Farmers are opposing strip mines; environmentalists are fighting petroleum refineries; and skyrocketing construction costs have led to the cancellation of plans for many nuclear reactors.

Every energy source is under the heels of both physical and social constraints. Some such limits are absolute—when natural gas runs out, natural gas consumption must stop—but more often they manifest themselves as increasingly severe hindrances on growth. Depending upon the mix of technologies employed, different types of constraints will come into play; however, at some point these accumulated constraints will halt further energy growth completely.

Heat: The Ultimate Limit

The earth has passed through many climatic epochs, ranging from ice ages to ice-free ages. The global climatic system appears to be delicately balanced; rather small alterations can trigger vast changes.

For example, ice and snow tend to reflect sunlight instead of absorbing it as heat. When an outside heat source melts the ice and snow on the ground, both the runoff and the bare ground itself absorb additional heat from the sun, melting still more ice and snow. Because small events appear capable of causing large climatic changes—some of which may be irreversible on any time scale of interest—even small changes must be executed with utmost caution.

Electrical power plants, industrialized cities, and various other energy-intensive sites each

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radiate several times more heat than they receive from the sun. Such "hot spots" affect local weather; they can help determine the frequency of snow, hail, thunderstorms, and even small tornadoes. Consequently, the number of energy facilities that can be built in any one area must be limited.

Carbon dioxide (CO_2), a byproduct of all fossil fuel combustion, poses a greater problem. Adding CO_2 to the air raises the earth's temperature by retarding the radiation of heat into space—a phenomenon known as the "greenhouse" effect. Since CO_2 can linger in the atmosphere for hundreds or perhaps thousands of years, the impact of CO_2 emissions is cumulative.

Climatic problems are incredibly complex. Before we have had a chance to understand all the variables fully, human energy use could trigger far-reaching consequences. A decision to retard the rate of energy growth would reduce the chance of making a dreadful mistake. Such a decision would have to be made in the face of much uncertainty, but the consequences of not doing so could prove irreversible.

Pollution: Troubled Waters

All conventional energy sources—even the so-called "clean" ones like natural gas and geothermal power—generate pollution. As the use of these sources increases, the problems of pollution control grow more formidable.

The world's experience with oceanic oil illustrates some of the risks and costs that pollution entails. Through the ages, about 600,000 metric tons of oil have entered the ocean every year from natural seeps, all of which the ocean has successfully assimilated. But as oil has come to play an increasing role in human affairs, the volume of oil entering the ocean has multiplied manyfold. Two-thirds of all the oil produced in the world is now shipped by sea. Although transportation practices have been improving over the years, these improvements have not kept pace with the growth in the volume of oil shipped. More than 6 million metric tons now flow into the seas annually, more than one-third of which comes from such routine tanker operations as spillage while loading and unloading, discharging ballast, and cleaning tanks. The floating lumps of tar that can be found in the oceans and on many beaches bear witness to this calamitous trend.

No one knows what all this oil will ultimately do to marine fisheries or to the complex ocean ecosystem. A United Nations report has noted that "the fact remains that once the recovery capacity of an environment is exceeded, deterioration can be rapid and catastrophic; and we do not know how much oil pollution the ocean can accept and still recover" *(2)*. Yet many standard projections show the volume of ocean oil traffic expanding up to six times by the end of the century.

Similar phenomena beleaguer other forms of energy growth. To be sure, we can apply increasingly stringent controls, but the costs of enforcing and complying with such controls eventually operate as a capital constraint. Pollution controls now commonly constitute more than one-third of the total cost of a new energy facility, and in many cases it is far from clear that such controls are adequate. Moreover, some kinds of pollution, such as carbon dioxide, simply cannot be controlled except by burning less fossil fuel.

Material Constraints

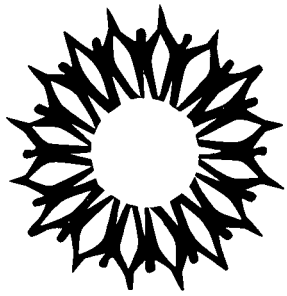
We have paid scant attention to the material requirements of various energy technologies. While we now have a reasonably clear idea of the energy requirements of steel production, we have no similarly detailed accounting of the steel requirements of energy production. Yet various types of steel will be absolutely necessary for the construction of oil wells in the Middle East, pipelines across the Soviet Union, power plants in Europe, transmission facilities in Brazil, and virtually every other energy-related device.

Politics as well as general scarcity may lead to material shortages. Scattered unevenly through the earth's crust, some crucial minerals are concentrated in relatively few lands, many of them Third World nations. Such countries have for years been selling in a competitive market, but buying from what they perceive as multinational cartels. In the wake of the oil-producing countries' success, and in the midst of calls for a new international economic order, the mineral-rich nations may well decide to turn the tables.

Various material shortages may hinder energy growth in different ways. For example, although water is obviously in great global abundance, lack of sufficient local water makes impossible the construction of synthetic fuel facilities at otherwise suitable sites. Sometimes lack of spare parts, manufacturing capacity, or transportation equipment will delay production temporarily. Coal production in the United States may be limited for the next 10 years by a simple lack of railroad cars.

Financial Constraints

Capital represents the "seed corn" of all



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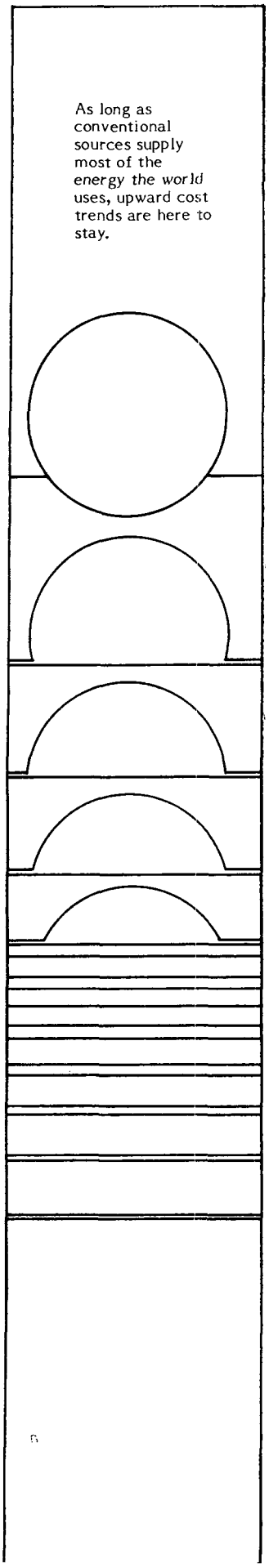
Mr. Hayes is the author of Rays of Hope: The Transition to a Post-Petroleum World *(1), a recently published book on the outlook for energy. This article is based on and adapted from his book.*



As long as conventional sources supply most of the energy the world uses, upward cost trends are here to stay.

economies, the capacity for sustained production. A society that eats its seed corn—in our case, spending too much of our income on goods and services, and saving too little for investments in future production—has a bleak future. The argument over whether the world faces a capital crisis has generated almost enough heat to solve the energy crisis. The issue is complex, and contrary opinions are rooted in different assumptions about economic growth, government spending, inflation, business cycles, and a host of other variables.

From the end of World War II until quite recently, the capital cost of producing fuel remained low. For example, the investment needed (in wells and pipelines) to produce Middle Eastern oil at the rate of one barrel per day ranges from $50 to $250. Amortizing these investments over the lifetime of the oil field reduces the cost of oil to just a few cents per barrel. In contrast, oil from the North Sea is expected to require an investment of $10,000 per daily barrel; Arctic oil and gas will require between $10,000 and $25,000 per daily barrel; and synthetic fuels from coal will demand an investment of from $20,000 to $50,000 per daily barrel. To obtain the thermal equivalent of a daily barrel in the form of electricity from a new power plant requires an investment in excess of $100,000.

The capital costs of fuel production, which include the costs of extraction and of combustion, increase greatly as higher environmental standards and tighter health and safety regulations are put into effect. Generally, however, this simply means that prices are being adjusted to "internalize" costs that were previously inflicted on society but were not explicitly accounted for. These higher prices reflect the cost of preventing black lung disease among coal miners or of decreasing the likelihood that a catastrophic accident will take place at a nuclear power plant.

As long as conventional sources supply most of the energy the world uses, upward cost trends are here to stay. Fuels will not become more plentiful and accessible; on the contrary, the best deposits will be exhausted. And as the biosphere becomes more saturated with pollutants, even more rigorous and expensive environmental controls will have to be imposed.

Much of the capital we now spend pursuing conventional energy options could be better used to refashion our living environments, redesign our transportation systems, and reshape our industries to obviate the need for much of this energy. Because capital is limited, huge investments in energy supplies may be taking money away from far more productive investments in increased efficiency.

Political Limits

Every energy unit, regardless of its source, entails costs, and the true costs are often not borne by the beneficiaries. The losers in the trade-off have grown restive in recent years, and energy battles are now being fought in every corner of the political landscape. Nuclear power plants, strip mines, oil refineries, deep-water ports, hydroelectric facilities, and high-voltage power lines are both the issues and the plunder of a struggle that transcends traditional ideological boundaries.

The opposition is both private and public. Carolyn Anderson, a Wyoming rancher whose land lies over a rich coal vein, draws the line clearly. "Don't underestimate us," she says. "We are descendants of those who fought for this land, and we are prepared to do it again." The Governor of Colorado, a state rich in coal and oil shale, was elected on a platform that promised Coloradans that their state wouldn't "become the nation's slag heap."

Fuel use harms the environment more than any other human activity: it scars the landscape, heats the atmosphere, generates tons of pollutants, and creates dangerous radioactive byproducts. We can justify some of these energy costs for necessary purposes. But to increasing numbers of people, the costs of continued energy growth now seem to outweigh perceptible benefits.

Opposition to expanded fuel facilities is most pronounced in industrial countries. Building a centralized energy facility anywhere in Europe, Japan, or North America has become difficult indeed. Although a majority of the citizens in those regions would probably not ask for zero energy growth, very few want a new power plant in their neighborhood, and every possible site is in *somebody's* neighborhood.

In effect, the developed world has run out of space: geographical space, environmental space, and psychological space.

The Coming Energy Transition

During the last 25 years, world fuel consumption tripled, oil and gas consumption quintupled, and electricity use grew almost sevenfold. Clearly, such trends cannot be sustained indefinitely; nature abhors exponential curves as well as vacuums.

The world has begun another great energy transition. In the past, such transformations have always produced far-reaching social change. For example, the substitution of coal for wood and wind in Europe accelerated and

refashioned the industrial revolution. Later, the shift to petroleum altered the nature of travel, shrinking the planet and completely restructuring its cities. The coming energy transition can be counted upon to reshape tomorrow's world. Moreover, the quantity of energy available may, in the long run, prove much less important than where and how this energy is obtained.

Most energy policy analyses do not encompass the social consequences of energy choices. Most energy decisions are based instead on the naive assumption that competing sources are neutral and interchangeable. As defined by most energy experts, the task at hand is simply to obtain enough energy to meet the projected demands at as low a cost as possible.

But energy sources are *not* neutral and interchangeable. Some energy sources are necessarily centralized; others are necessarily dispersed. Some are exceedingly vulnerable; others will reduce the number of people employed. Some will tend to diminish the gap between rich and poor; others will accentuate it. Some inherently dangerous sources can be permitted unchecked growth only under totalitarian regimes; others can lead to nothing more dangerous than a leaky roof. Some sources can be comprehended only by the world's most elite technicians; others can be assembled in remote villages using local labor and indigenous materials. In the long run, such considerations are likely to prove more important than the financial criteria that dominate and limit current energy thinking.

Appropriate energy sources are necessary, though not sufficient, for the realization of important social and political goals. Inappropriate energy sources could make attaining such goals impossible. Decisions made today about energy sources will, to a far greater extent than is commonly realized, determine how the world will look a few decades hence. Although the thinking of economists and scientists has dominated energy policy, the most important consequences may be political.

An Attractive Energy Source

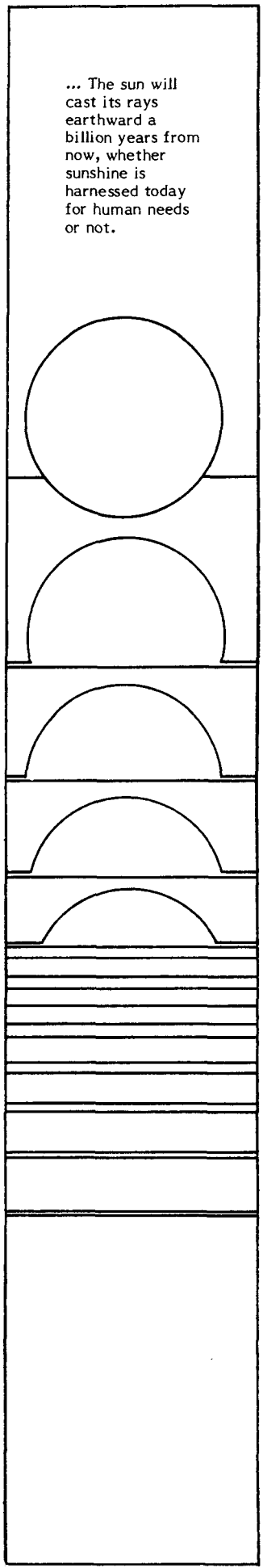
After examining the myriad constraints facing energy growth and the sweeping social consequences produced by energy choices, I believe that it will become apparent that our most attractive energy source is the sun. Solar energy can be tapped directly as sunlight, or indirectly as wind, water, hydro-, or plant power.

Past efforts to tap the solar flow have been thwarted by unreasonable economic biases. Environmental costs of conventional fuels, for example, have been largely ignored until recently. If reclamation were required of strip mining companies, if power plants were required to stifle their noxious fumes, if oil tankers were prohibited from fouling the oceans with their toxic discharges, if nuclear advocates were forced to find a safe way to dispose of long-lived radioactive wastes, conventional power sources would cost more and solar equipment would be more economically competitive. As such costs have been increasingly "internalized," conventional sources have grown more expensive and solar alternatives have consequently become more credible.

Unlike finite fuels, sunlight is a flow and not a stock. Once a gallon of oil is burned, it is gone forever; but the sun will cast its rays earthward a billion years from now, whether sunshine is harnessed today for human needs or not. Technical improvements in the use of sunlight could lower prices permanently; similar technical improvements in the use of finite fuels can only hasten their exhaustion.

A transition to an efficient, sustainable energy system is both technically possible and socially desirable. But 150 countries of widely different physical and social circumstances are unlikely to undergo such a transition smoothly and painlessly. Every potential energy source will be championed by vested interests and fought by diehard opponents. Bureaucratic inertia, political timidity, conflicting corporate designs, and the simple, understandable reluctance of people to face up to far-reaching change will all discourage a transition from taking place spontaneously. Even when clear goals are widely shared, they are not easily pursued. Politics tend to provoke opposition; unanticipated side effects almost always occur.

If the path is not easy, it is nonetheless the only road worth taking. For 20 years, global energy policy has been headed down a blind alley. It is not too late to retrace our steps before we collide with inevitable boundaries. But the longer we wait, the more tumultuous the eventual turnaround will be.



References

1. Hayes, D. *Rays of Hope: The Transition to a Post-Petroleum World.* New York: Norton, 1977.
2. Blumer, M. "Oil Contamination and the Living Resources of the Sea." Presented to the FAO Technical Conference on Marine Pollution and Its Effects on Living Resources and Fishing, Rome, Dec. 9-18, 1970.

Tinkering with Sunshine

Solar energy is a rapidly changing field. Discussions of "soft energy paths" were still fairly new when this article was written. Since its appearance ERDA has become DOE and "solar home" has become a familiar term. Nevertheless, this remains a provocative and fascinating review of some of the solar pioneers, their insights, and their inventions.

TINKERING WITH SUNSHINE

THE PROSPECTS FOR SOLAR ENERGY

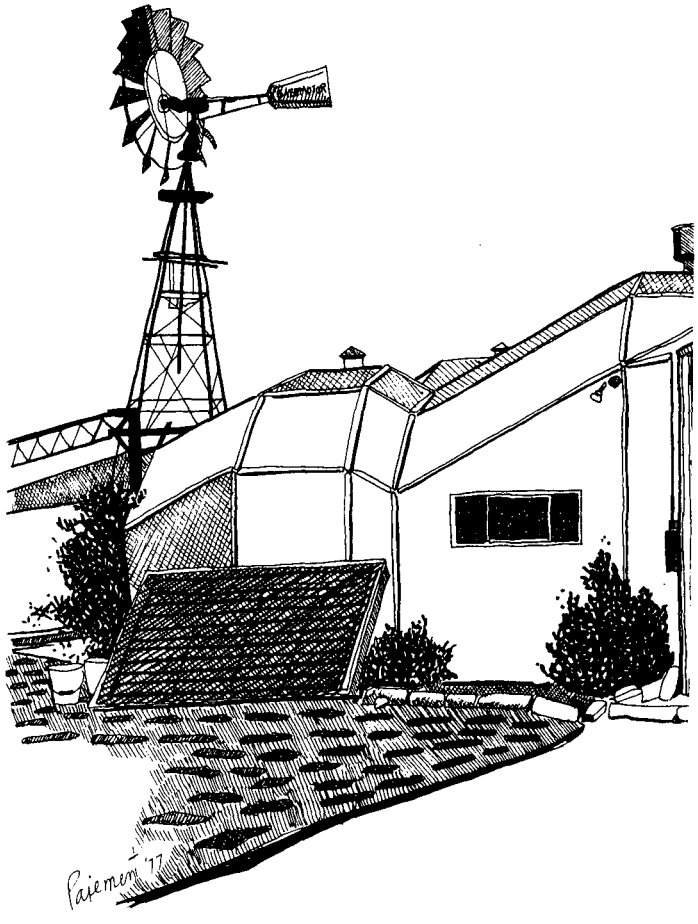
by Tracy Kidder

Oil grows scarcer and more expensive . . . nuclear power becomes increasingly controversial. But consider the sun. The world basks in an inexhaustible source of power, although the technology for using it hardly exists. At the moment solar energy is a field for visionary inventors and entrepreneurs hoping to build the Model T that will give birth to a new industry.

In October 1976, on the eve of the natural gas shortages, a twenty-nine-year-old physicist named Amory Lovins published in *Foreign Affairs* a treatise called "Energy Strategy: The Road Not Taken?" Since then, the Lovins article has become something of a focal point for the debate over national energy plans.

We can travel into the future on one of two paths, Lovins writes. The one generally favored by U.S. policy has the nation increasing energy production in all possible ways, but mainly through exploitation of fossil fuels and old-fashioned nuclear fission. Later, in "the era beyond oil and gas," come large-scale, "arcane" energy systems: breeder reactors, nuclear fusion devices yet to be fully imagined, huge space stations gathering electricity from the sun and beaming the juice to earth in the form of microwaves. Lovins calls this "the hard path." In Lovins's view, it is a road with dire social consequences: energy wars, repression at home, environmental degradation, and several kinds of catastrophes associated with uranium.

We can follow the other path, "the soft path," Lovins continues, by engaging in a new and "elegant frugality." The country maintains its standard of living, but Detroit and Con Edison and the average homeowner learn to conserve truly vast amounts of fossil fuels. In this way, time is bought. We use it to turn, not to new nuclear reactors, but to "benign," renewable sources of power and heat, and we end up, in about fifty years, living off our "energy income": chiefly sunshine and solar products like the winds. The technologies employed then are diverse, easy to understand, safe, relatively clean, and invulnerable to nation-crippling accidents and sabotage because, for the most part, they are deployed at the community level. As a consequence, democracy grows stronger.



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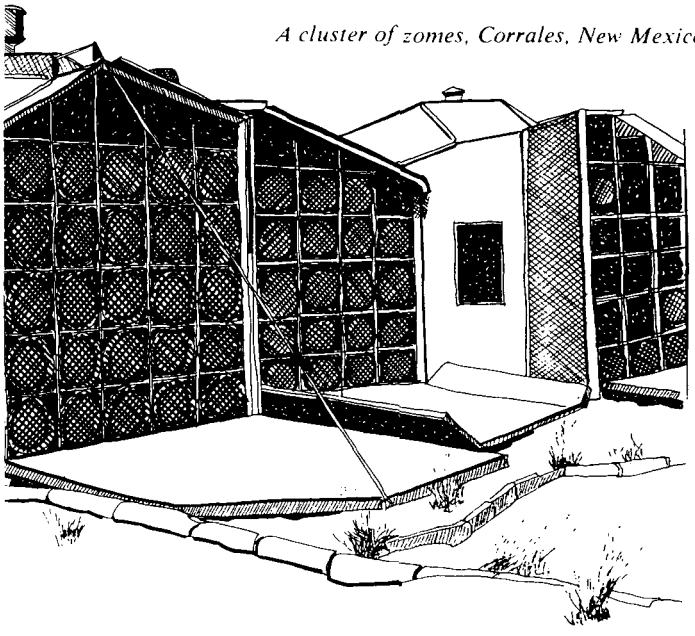
Our energy suppliers are no longer "alien and remote." Local autonomy prevails. Nuclear reactors are now antiques and at last there is a chance for peace among nations. Lovins argues that we must choose one path soon, because the country lacks the material and spiritual resources to follow both.

Lovins's scheme for a "soft" energy future rests largely on an optimistic view of solar technologies. It's a faith that many share. Surely sunshine is the most enticing of energy sources. It can be "mined" in ways that appear to be harmless, and there's more than enough to go around. Contemplation of the sun's power leads even respectable scientists to grandiose hypotheses; one physicist has calculated that if we could convert to mechanical power all of the solar radiation that strikes the United States in just a day, we could lift the entire Republic—and the 1000-meter-thick crust it sits on—about three and a half feet into the air. For those who feel that mankind must find a way around plutonium, who wince at news of each new oil spill, the sun is today's messiah. I pick up small-town newspapers and college alumni bulletins and again and again I read of people who have discovered the guiltless joys of using solar energy in the home. It's the self-reliant way. It's the way to harmonize with Mother Earth, while keeping the Arabs out of Fort Knox. But how much energy can we get from the "soft" solar technologies, from such things as windmills, solar ponds, solar space and hot-water heating systems, from rooftop arrays of those marvelous photocells that make electricity from sunshine? And how soon can we get it? What is the real market potential of these technologies?

The Office of Technology Assessment and the Stanford Research Institute, the Energy Research and Development Administration (ERDA), Mitre Corporation, Westinghouse, GE, Thompson Ramo Wooldridge, Inc. (TRW), and the National Science Foundation are some of the organizations that have looked into the future of solar energy. The House and the Senate have held hearings; the collected volumes of testimony on this subject generated by just one Senate committee have a total weight of about twenty-five pounds. A forty-one-year-old solar architect named Gordon Tully holds that solar technologies will have come of age when the thermal energy produced by all the solar collecting devices in the United States is equivalent to the thermal energy that would be produced by burning all the solar studies. Out of this forest of paper come many conflicting predictions.



A cluster of zomes, Corrales, New Mexico

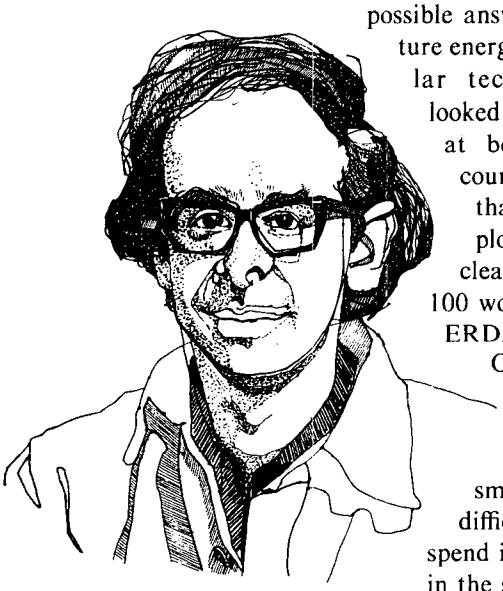
It isn't surprising to find that there is no consensus on what can be done with the sun, because there has been little hard research to go with the studies. In 1952, the Paley Commission prepared a report for President Truman called "Resources for Freedom." It was a prescient document. It warned of future oil shortages and of a growing dependence on the Middle East, and it recommended "aggressive research" into both the "peaceful atom" and solar technologies. But successive administrations and Congresses took only half that advice. From 1953 to 1973 the U.S. government spent some $5 *billion* on research and development in nuclear energy, but less than a million on solar technologies.

Government spending on solar research did not begin until 1974, after the Arab oil embargo and in the midst of growing protests against nuclear power. Since then, government financing has come on strong, thanks to a generally enthusiastic Congress and, more recently, to the Carter Administration. In fiscal year 1978 the government will spend a record $368 million on solar research, development, and demonstration, and the subsidy will be still larger if, as now seems certain, Congress goes along with the President's plan to allow tax credits for people investing in solar-heating equipment. Meanwhile, however, about $3 billion will go to R&D in nuclear technologies, and the lion's share of that will be spent on the breeder reactor and on fusion, which face futures at least as uncertain as those of most solar technologies.

The usual explanation for this apparent double standard is that solar technologies simply don't need as much money as nuclear ones. Energy bureaucrats also say that the infant solar industry isn't large enough to absorb more money than it's getting. But many disagree. Henry Kelly, a thirty-two-year-old staffer in Congress's Office of Technology Assessment, has helped to draw up a study of possible approaches to

solar energy. The list is huge. Kelly concludes, "Anybody who says more money can't be spent on solar technologies is just wrong."

In general, the strongest barriers to larger, useful investments in solar energy appear to lie within the government itself. Soon to be assimilated into the new Department of Energy, ERDA has been a true child of the old Atomic Energy Commission, which it replaced several years ago. The prevalent attitude within ERDA has been that nuclear power is the only possible answer to the country's future energy needs. Meanwhile, solar technologies have been looked on as small contributors at best, and at worst, as countercultural toys. More than 2000 of ERDA's employees are involved in nuclear programs, and a mere 100 work in the solar division. ERDA's hierarchy and the Office of Management and Budget, which control staffing, have kept the solar crew small, and this has made it difficult for the division to spend its money wisely. People in the solar division talk about working twenty-hour days. They admit that they aren't able to monitor properly even their existing programs.



Amory Lovins

Space and hot-water heating are the most readily practicable of all the solar technologies. Government projects, along with the Arabs and the brutal winter of 1977, have created a boom in the craft. In the early 1970s there were only about 100 solar-heated houses in America. Now there are several thousand and many more on the way, and it is certain that there are even more people working on solar heating than there are solar-heated houses. Professors at more than a dozen universities and something like 550 companies (some large and many small) have entered the competition. It seems the public has been aroused; the government-sponsored Solar Heating and Cooling Information Center has been receiving about 3000 phone calls a week from interested citizens.

About a quarter of all the energy used in America goes to heating buildings. So solar heating could be significant. But how significant? Is Lovins right when he says that this technology is "now available and economical"? With those questions in mind, I went out in the spring and summer of 1977, into a few regions of solar-heating land, to see what part of the future was there.

Two views from Olympus

An important moment in the history of modern solar-heating technology occurred in 1939, when a team of MIT engineers, led by a young assistant professor named Hoyt Hottel, built a small house outside of Boston and fitted it out with a rooftop "flat-plate" collector. Copper pipes were mounted on a copper surface and the whole thing was covered with three layers of glass. Water was pumped through the pipes on the roof, heated there by the sun, then sent to the basement into a large steel storage tank. The heat was transferred to air and finally circulated through the house by a blower system, as the need arose. This was the prototype for most of the "active" systems on the market and in houses today—systems, that is, in which air or water, moved by mechanical means, carries the heat around. (In a "passive" system, parts of the house itself collect the heat, which is distributed with little or no help from machines.)

The first MIT house was nothing more than a laboratory: Hottel used it to establish the basic engineering principles behind solar collector performance and was so meticulous that his calculations served to correct the Weather Bureau. That first house worked; Hottel was able to use summer sun to heat the building in the winter. But the storage system was huge, "an economic monstrosity," according to Hottel. So his team built another house, this time using a south-facing wall of water, a more or less passive system. But they weren't able to insulate the window well enough after dark to keep heat loss at a satisfactory level. So they went back to active systems and built two more houses, and in 1962, after twenty years of experiments, Hottel and his team "shelved" space heating. "We had gotten the data to know it was uneconomical at the time."

It is May 1977, somewhere near the end of the era of cheap oil and gas, and Hoyt Hottel—MIT professor emeritus, seventy-four and white-haired—sits in his office before a large plate-glass window, looking out on a corner of MIT's labyrinthine campus. He is justifiably proud of his work, but grows dour when he turns to the object of all those meticulous experiments. He says that over the years he has watched the costs of solar space heating continually hover above the rising costs of conventional heating, and although he allows that the solar approach may now be almost competitive with expensive, inefficient, electrical-resistance heating, he believes it is still much more costly than heating with oil or gas.

A consultant from Arthur D. Little would tell me

Tracy Kidder is a free-lance journalist who often writes about environmental topics.

later, "Hottel hasn't heard of the oil embargo." A prominent inventor of passive systems would say, "Hottel's a man who bought a ticket on a horse and threw it away before the race was over. Now he can't bear to think that his horse might come in." Hottel, for his part, has said that solar-heating enthusiasts base their case on emotion, not on natural law. He describes their reasoning as follows: "Solar energy has to be a good thing. . . . Out of the window with embarrassing negatives; I've made up my mind." Hottel doesn't say that solar heating won't become important sometime in the future, but he says that a future which includes it isn't one to anticipate with relish. "I think you have to say that when solar energy does become important, that will be a measure of the fact that we are not living as affluently as we do today," he told me. "Because by present standards, it is by no means the cheapest way to get energy."

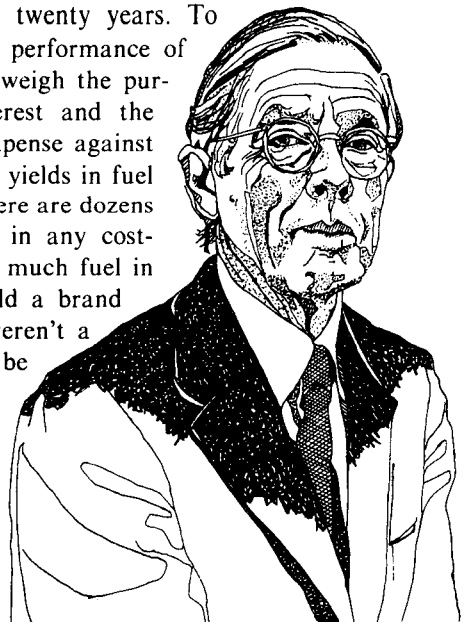
There is no disputing Hottel's central point. No source of energy, whether it's solar or nuclear or geothermal, will be as cheap and easy to grasp as the stuff we've been using these past 100 years. But it's because of this fact that solar heating now looks more practical than ever before. To some, in fact, this is the beginning of its exciting, even its romantic, age.

On the other side of Cambridge from MIT, near the now-defunct Harvard cyclotron, there is a little office crammed with books and articles on solar heating. In the filing cabinets lie hundreds of letters from well-known and anonymous solar inventors. Everything is in order. The size of the office and the complexity of the subject make order mandatory. William Shurcliff, a sixty-eight-year-old honorary Harvard research fellow, studies other people's inventions in here. He is the preeminent cataloguer of solar space-heating brainstorms, the author of *Solar Heated Homes: A Brief Survey,* which he has taken through thirteen editions in the last five and a half years. Shurcliff knows what is out there, if anyone does. Visiting him one day, I remarked that a friend who was building a solar-heated house had hit upon the idea of improving his collector's performance by dyeing the water inside it black. A novel idea, I had thought. Shurcliff said, "Hmmm. Black water." From the shelf over his desk he pulled down a thick looseleaf notebook, looked up "Black Water" in the index—"I think books without indexes should be banned, don't you?"—and proceeded to read off a list of about five companies and "lone wolf" inventors who'd tried it. And then there were several people with hot-air systems who had tried black dust. "So you see there's been quite a lot on that."

Shurcliff is tall and thin and he speaks in the accent one often hears on the seacoast north of Boston. He describes himself as "a tired old optics man." "The electromagnetic spectrum is one of the grandest things in the universe," he told me. "I've spent most of my life working in parts of it, so it was very easy for me to get into this field, and I did it eagerly." For about thirteen years he worked in optics and radiation at Polaroid. Then he came to Harvard and ran radiation security for the atom-smasher, and when his duties ended there some five and a half years ago, he took up solar heating, thinking at first that he would spend his time inventing. He still keeps his hand in, but he found that in general other people's ideas were more interesting than his own, and so he became a cataloguer, the first and, until recently, the only cataloguer of space-heating ideas.

At least once before, Shurcliff has devoted himself to a cause. He is generally credited with a large role in the successful campaign against the SST; mainly, he wrote courtly, threatening letters. These days he could be described as a solar advocate. "This world damn well needs solar heating," he says.

Shurcliff does believe that the solar-heating art can be practical, but he is aware of the problems. "Hurdles," Shurcliff calls them, disdaining the ordinary word. First among them stand the questions of cost, durability, and performance. In an industry so new, durability is hard to predict, but it is assumed that a good system will last twenty years. To measure the cost and performance of the system, one must weigh the purchase price with interest and the yearly maintenance expense against the savings the system yields in fuel or electric bills. But there are dozens of unknown variables in any cost-benefit equation. How much fuel in any given winter would a brand new house use if it weren't a solar house? What will be the rate of inflation, where will interest rates stand, what will maintenance cost, and, the crucial question, what will be the prices for gas, oil, and electricity? Will there be enough of those commodities to go around, come January 1985? Several studies have attempted to deal with the economic question and several have concluded that solar heating is practical today. But those conclusions are based on a plethora of averages, and there really is no such thing as an



William Shurcliff

average solar-heating system, an average house, or, in many places, an average winter. Shurcliff seems more reliable. He has studied particular systems. He thinks that at least 80, and maybe 97 percent of them aren't a bargain, not as they are measured beside today's gas and oil prices.

Hard enough, then, to make a solar-heating system pay when it's installed on a new house designed with the sun in mind. "How much more difficult it is," exclaims Shurcliff, "to 'retrofit' solar heating to an existing, badly insulated, imperfectly oriented house in a region crowded with tall trees or tall neighboring buildings!" Perhaps householders will be persuaded to undertake retrofits as home improvements or as security against some dark, cold, fuel-less winter. Maybe, as Shurcliff suggests, some will decide that it's fun, "like owning a yacht." But economics will weigh heavy, and retrofit will always be an expensive proposition, like any remodeling job.

Although sunshine is free, the nation would have to pay a price for widespread solar heating. Putting the systems in place would require large amounts of labor and natural resources such as copper. A great deal of energy would be expended; it takes about five years for a well-designed system to gather as much useful energy as it took to build it. A host of small problems must be dealt with, too. For example, experts agree that the most economical systems provide only part—somewhere between 30 and 60 percent—of the heating needs for an average house. So a back-up system is required, and an electrical one is usually the cheapest to install. But thousands of solar houses in a given area, using electricity only on cold, cloudy days, would force the local utility to invest in equipment that would be used just a few times a year. The result would be special high electric rates for solar-heated homes. A possible solution, now being investigated, is to have solar-home owners turn on the power only during the utility's off-peak hours, and use this electricity to heat up their storage systems.

Shurcliff seems a careful man. He approaches the future cautiously, by asking questions. But five and a half years of studying the designs that now fill his books and filing cabinets seem to have left him in a state of controlled excitement. "We deal, indeed, with a ferment," he writes. In his little office, it is 1905 and a new industry is stirring. There are hundreds, maybe thousands, of people banging metal in their back yards, trying to build automobiles. Just which of these curious contraptions is the ill-fated Hupmobile and which the Model T is hard to say. But Shurcliff has seen a great many small ideas, and also some complete systems—maybe 3 or 4 percent of the total—that show definite promise. They look cheap and they work, though some seem "crude" today. No single one seems perfect for all climates, but that is no real problem.

"I'm willing to go out on a limb," Shurcliff told me. "I think that there will be dozens of winning schemes."

Rhombic dodecahedra and other works of genius

In Corrales, New Mexico, near Albuquerque, there stands an amazing private residence, not a house in any ordinary sense, but a series of metal structures connected to each other, silvery and strange, standing in rugged, treeless terrain. Steve Baer, who created this place, who built it and lives in it, describes the structure as "ten exploded rhombic dodecahedra stretched and fused to form the different-sized rooms." He also describes his home as "a cluster of zomes."

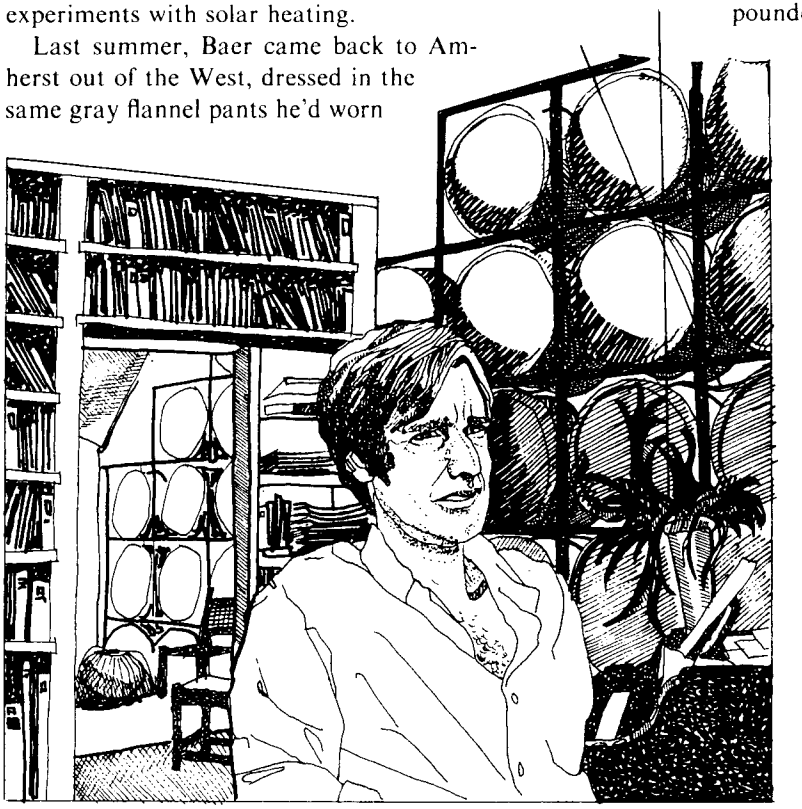
A closer look reveals that arrays of used, fifty-five-gallon oil drums, filled with water and laid horizontally behind single sheets of glass, make up the southern walls. These are the prototypes of the now famous (in solar heating circles) "drum wall." The walls are equipped with large insulating panels which Baer raises and lowers like drawbridges with a simple rope and pulley device. He drops the panels on winter days to let the sun heat the water drums, and raises them at night to keep the heat in. The walls were cheap to build—about $5 a square foot, which is roughly half the cost of conventional rooftop collectors. They do about 75 percent of the heating in the zomes, allowing, that is, for indoor temperatures that vary from about 55 to about 80 degrees. Baer, who has always been interested in weather, thinks it's fun to live in a house that reflects what's going on outside. Some people do not like the temperature fluctuations or the walls, of course. "He'll sell his stuff by word of mouth," one conventionally minded solar engineer told me. "Word of mouth is the only way to persuade people to put fifty-five-gallon drums in their living rooms." But Baer and his company, Zomeworks, have already been employed on some 200 solar-heating projects, and orders for Zomeworks devices come from all over the country these days.

Out of Zomeworks comes the Beadwall—plastic beads are blown into the space within a double-glazed window on cold winter nights and sucked out with a small vacuum-cleaner motor when the sun rises. Baer and his colleagues invented the Skylid, an insulated shutter especially good for skylights: the shutter opens and closes by itself, at the direction of two small thermostats. Baer has been a pioneer in Convective Air Loop Rock Storage (a way of using natural convection

rather than the usual mechanical blower to move heated air in and out of a storage system made up of stones), and he thought up something he calls the Double Bubble Wheel Driving Engine. Run by the effect of heat on bubbles in water, it can be solar-powered. There is no end to his inventions. He says he wants to be like Charlie Parker and never play the same tune twice.

Born and raised in California, Baer went to Amherst College and left before graduation. After a stint in the Army, he studied math and physics in Zurich, then came back to the United States. It was the 1960s. Baer wandered around a while, stopping in at some of the communes then flourishing. There he began his experiments with solar heating.

Last summer, Baer came back to Amherst out of the West, dressed in the same gray flannel pants he'd worn the first time he came to college, twenty years before. He is thirty-eight, slim, has sandy hair conventionally cut, piercing blue eyes, and was tanned when I met him. Someone told him that he looked like a representative from NASA, he was so clean-cut. I overheard someone else say that he looked like Gary Cooper.



Steve Baer and his drum wall

The occasion for Baer's return was the University of Massachusetts's "Toward Tomorrow Fair," a grand celebration for a dubious future, featuring music from Pete Seeger and speeches from Barry Commoner, Buckminster Fuller, Julian Bond, and Ralph Nader. Out on the fairgrounds, there were hundreds of displays. There were fine-looking wood stoves and pretty windmills, a wind-driven car, many kinds of waterless toilets, chain-saw sculpture, a teepee inside which foot massages were being administered, and lots of booths which bore such names as "Planetary Citizens" and "New England Institute of Appropriate Technology." Some very satisfactory-looking flat-plate collectors were on display as well.

Up from the fairgrounds, outside a U.Mass lecture hall, a huge sign, painted in a shaky hand by a rather hysterical woman, a solar energy buff whom I met later on, said, "WELCOME STEVE BAER!" The line for his lecture was several hundred yards long and many didn't get in. They missed something.

The first half of Baer's speech was a stew compounded of ideas familiar to disciples of Abbie Hoffman and to students of the nineteenth-century laissez-faire economists. It was a eulogy for the hippies and the communes of the sixties. It was a lament for something he called "the free economy." It was an angry diatribe against government involvement in solar heating. At one point Baer began to chastise Exxon for the ads it has been running in magazines and newspapers, cautionary ads about solar energy. The audience showed it was with him. But then Baer seemed to draw back and eye the crowd. Suddenly he was saying that the oil company executives were "just people." "If we were in their place we'd do the same thing they're doing." And a little later on: "Alternate energy! That's a bunch of junk. It doesn't have anything to do with good design." And to what was now a mainly silent house, though I heard some nervous-sounding laughter around me, Baer announced, laughing heartily himself: "I didn't believe in the alternate-energy future until I saw how dull it was gonna be and how stupid the slogans were gonna be and how much I wasn't gonna like it. Then I knew it would come."

Afterward, over drinks at the Student Union, I got Baer onto the subject of Hoyt Hottel. Baer said that after he had built the drum wall, he had read about Hottel's early experiment with the water-filled wall.

"He decided it didn't work," Baer said. "But that was because he didn't do it the right way. And he didn't keep on. If he'd been some crackpot, he might have.

"The crackpot is ready to explore new territory without government funding. There's gotta be room for crackpots in any society."

Who were some of the crackpots in solar heating? I asked.

"Well, like me," he said.

Many large companies leaped into solar heating after the oil embargo, picked up government grants, and started out trying to apply very sophisticated, expensive engineering to the problem of heating homes. GE went so far as to assign solar operations to its space division. But a number of companies that began this way have since changed their approach and are now working on conventional designs.

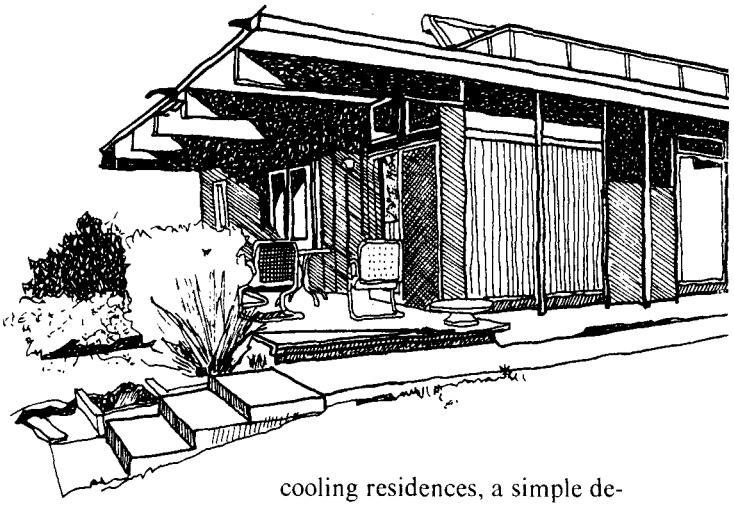
The so-called "high-tech" approach generally involves trying to increase the efficiency of a system by getting the maximum amount of heat out of each square foot of collector. Some gadgets that usually accompany this approach are "selective surfaces" (collector coatings which absorb more sunlight and emit less thermal radiation than ordinary black paints) and "evacuated vacuum tube collectors" (in which tubular absorbers are insulated by vacuums maintained around them). Such high-efficiency devices invariably cost a great deal. The rationale for using them is that high efficiency leads to reduced collector size and thus to reduced materials costs. Maybe someday the approach will yield economical systems, but it hasn't so far. Moreover, efficiency is a difficult concept to apply to solar heating. For instance, when it is cold outside, many efficient high-temperature collectors lose more heat than inefficient, low-temperature ones, in which case the low-efficiency collector is the more efficient.

One thing many promising solar-heating systems seem to have in common is that their inventors are not connected with big companies. For the most part, they are a gang of small entrepreneurs and lone wolves. They have worked with their own money; only a few have gotten support from ERDA. Perhaps that gave them a head start in the quest for economy.

Traveling around, talking to solar people on the phone, I kept hearing of wonderful systems, so many I could not examine all of them. But here is a sampler of possible Henry Fords and their solar-heating Model T's:

• Steve Baer and his zomes. Although his audience may be limited today, he is by no means finished with inventing.

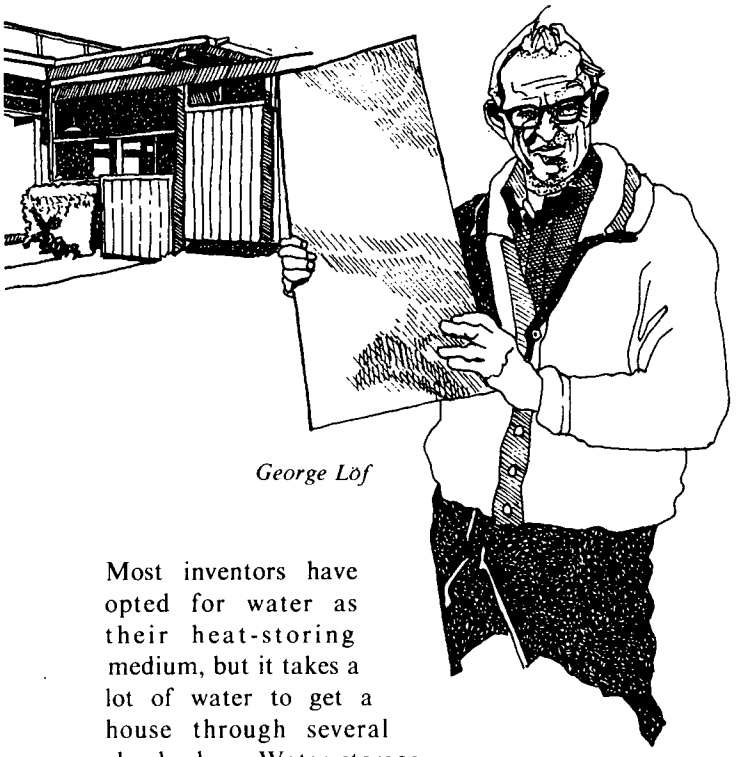
• Then there is the man who taught Baer some tricks: sixty-eight-year-old Harold Hay. Fifteen years ago, while working for the State Department as an adviser on building materials to the government of India, Hay hit upon an idea for both heating and



cooling residences, a simple design that would employ "a minimum of modern Western technology." Hay's flat-roofed Sky-Therm house has ponds beneath the roof, a virtual swimming pool contained in large plastic bags. Many little devices make the system work. Powered by a one-quarter-horsepower electric motor, the insulated roof panels open on winter days to catch the sun and close on winter nights to keep the heat in. Warmth flows down from the water bags through the metal ceiling of the house. The first home he built in the United States has 1140 square feet of living space. In the winter of 1973–1974 the house was 100 percent solar-heated, and it can get through four cold, sunless January days. Admittedly, it stands in California between San Francisco and Los Angeles, where the winter isn't harsh. On the other hand, the house is versatile. On summer days the roof stays closed and opens up at night. Thus heat from the house accumulates in the ponds all day and at night it passes out to the sky by convection and radiation. The result, according to the reports of tenants, is marvelous air-conditioning. The system is also cheap—$5000 for a 1000-square-foot house, and less if several are built simultaneously. Hay has also developed a Sky-Therm home for northern climes.

• Felix Trombe of France, another of the "solar pioneers," has approached space heating with a wall—the Trombe Thermosiphoning Wall. A black-painted concrete wall faces south, behind two layers of glass. There are openings at the top and bottom of the wall. Cold air comes from the house through the bottom opening, is heated in front of the wall, rises as hot air will, then passes through the top opening and back into the house. The system appears to be cheap, like Hay's, and in one house in France, it has delivered 60 to 70 percent of the necessary heat. The design suffers, though, from the ironic deficiency of too many solar houses. It doesn't let much sunlight in: there's a wall where one would like to have windows.

• Many of the hurdles solar heating has to surmount are related in one way or another to storage.



George Löf

Most inventors have opted for water as their heat-storing medium, but it takes a lot of water to get a house through several cloudy days. Water storage is expensive and it can fill up cherished basements. If there were something else that could do the job in a lot less space, the industry might be revolutionized. Maria Telkes, now in her seventies and working at the University of Delaware, has struggled for some thirty-five years with a thing called Glauber's Salt. In many ways, it's marvelous stuff, a nonflammable and nontoxic, cheap, and abundant crystal. (It is a by-product of several industrial processes). It also melts at a low temperature—120° F. When it melts, it stores an enormous amount of thermal energy, and when it changes from liquid back to solid form, it gives off eight times as much heat as an equivalent volume of water. Yet Glauber's Salt has not been a wholly reliable substance. Telkes, who is quite defensive on the subject—"You have probably heard that it doesn't work," was the first thing she said on the phone—claims that she has cured the ailments. ERDA is spending over $100 thousand to see if she's right. But the real question is whether, once you have improved Glauber's Salt, you have saved any money.

• Back, for the time being anyway, to plain old water storage. Consider the prosaic achievement of thirty-nine-year-old Spencer Dickinson. He is a builder in Jamestown, Rhode Island, and a state representative. Dickinson's solar houses are conventional, active types, and the one he has built in Jamestown isn't much to look at. It is small and short on windows. Some people say that it looks like a chicken coop. But it also looks like a lot of tract houses all across the country, so one can't say that its appearance disqualifies it from the market. What is interesting about this house? More or less by accident, it's 100 percent solar-heated. I say "by accident" because Dickinson outfitted the place with an expensive electrical heat pump, which turns out to be superfluous. Here, the secret is the storage, a shallow, concrete water tank beneath the floor, lined with plastic and covered by a huge concrete slab. The tank is as long and as wide as the little one-story house itself. Heated water from the rooftop collector flows down to the tank and warmth rises up into the house without any outside assistance.

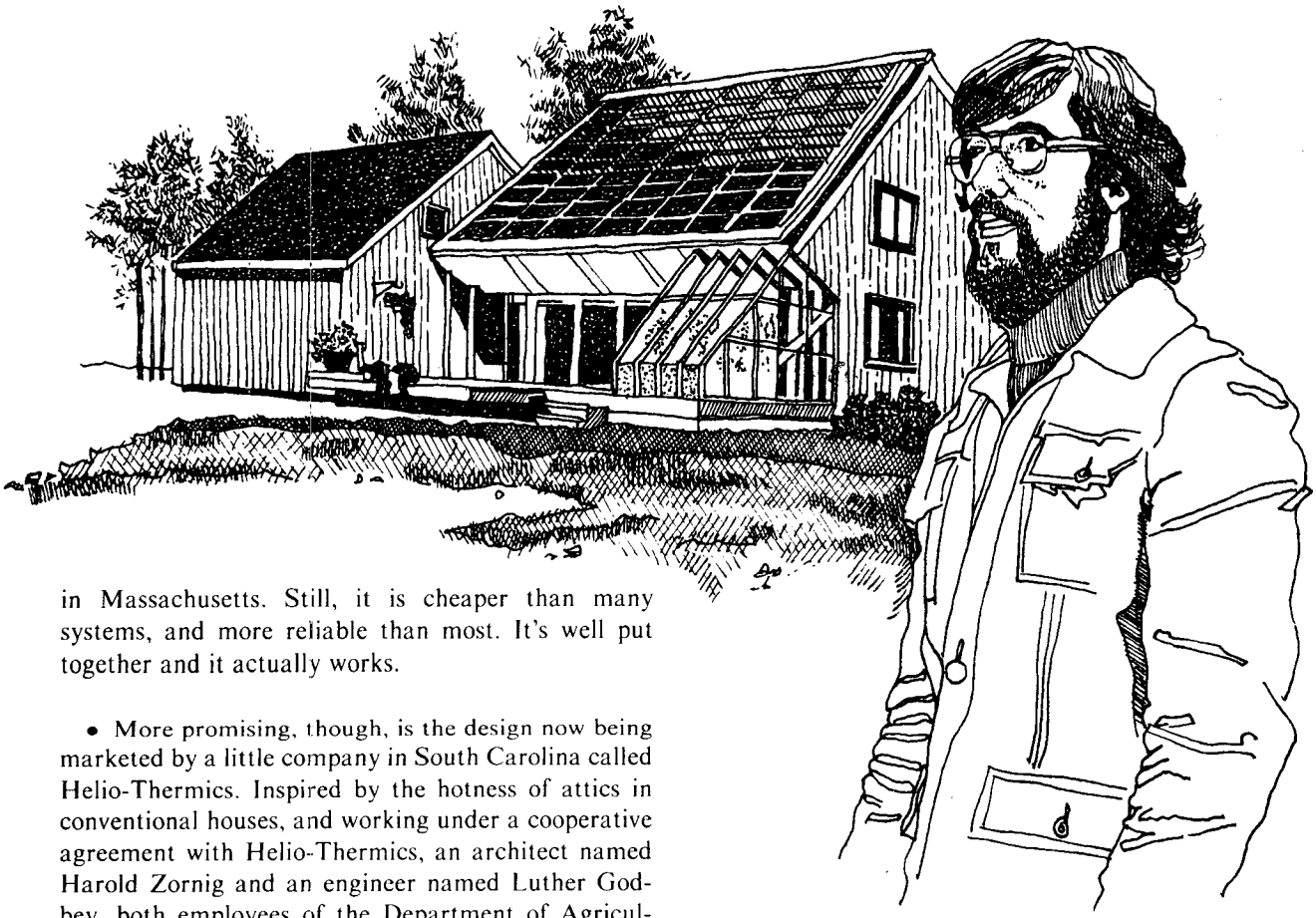
The tank cost about $2000, and it might have cost a great deal more. In fact, it almost wasn't possible to build it, because the huge slab that goes on top had to have structural supports and there was just no way to provide conventional ones. Then Dickinson thought of stones. He bought about $50 worth of stones and put them in the shallow tank. The stones support the slab.

Of course, there is no basement in the house, but the system could be cheap, since it requires only a collector and a store and the simplest of distribution apparatus. Dickinson says the whole system, now that he's gotten the hang of it, should go for about $5000 or $6000.

• There are, of course, exceptions to the rule that nothing interesting is coming from big companies or from the government. A few years ago a management group at Raytheon decided to dabble in sunshine. They built an active water system controlled by a fancy microcomputer. It hasn't functioned well and of course it is expensive. About this time a thirty-two-year-old Raytheon engineer named Will Hapgood was designing a solar-heating system that would be at least as simple as an oil burner and, as Hapgood puts it, "idiot proof."

Hapgood may be an anomaly among big company engineers. A rock musician now studying classical flute, he goes to work in sneakers, jeans, and a T-shirt. He does a great deal of work for Raytheon's Amana subsidiary in Iowa, but he does it near Boston. The last time he was at Amana headquarters he got expelled from the premises, on account of his long hair. Now the Amana people have come to Boston to see what Hapgood's up to.

Hapgood designed his system for John Bemis, the president of Acorn Structures—a firm that makes high-quality prefabricated houses in the $40,000 to $100,000 range. There is nothing novel about the Bemis–Hapgood system: it's a fairly ordinary, active water type. It isn't cheap—$7200 to provide about 55 percent of the heating needs of a three-bedroom house



Bruce Anderson and Goosebrook House

in Massachusetts. Still, it is cheaper than many systems, and more reliable than most. It's well put together and it actually works.

• More promising, though, is the design now being marketed by a little company in South Carolina called Helio-Thermics. Inspired by the hotness of attics in conventional houses, and working under a cooperative agreement with Helio-Thermics, an architect named Harold Zornig and an engineer named Luther Godbey, both employees of the Department of Agriculture's Rural Housing Research Unit in South Carolina, designed this hot-air system. *Mother Earth News* has gushed over it. Indeed, it looks like one of the cheapest of all the heating systems available today. Sunshine gets into the Godbey–Zornig house through a double-glazed, translucent, fiber-glass roof, and strikes sheets of black-painted plywood located in the attic, heating up the air. Some heat moves into the living space by itself. There is also a one-half-horsepower blower, hidden in a closet and activated by a device which Helio-Thermics likes to call "a computer" and which Godbey describes as "just a plain old solid-state control device." The blower drives air through the attic and down into the storage system, a bin containing forty tons of railroad ballast and located directly beneath the house's main floor. The system has worked well, delivering about 75 percent of the first Helio-Thermics house's necessary heat during an average 40° F winter in South Carolina. The "incremental" cost of this system in the little prototype house, which has 1000 square feet of floor space, was less than $3000. For a few hundred dollars more, the system can also provide 50 percent of the energy for a home's hot-water heating. These figures, which come from the USDA, probably make this system economical today. The trick to cutting incremental cost, Luther Godbey told me, is designing the system right into the house, using the solar collector to replace the roof, placing the store right in the foundation. He and Zornig also strove to minimize the use of expensive components such as ductwork.

The system is a testimonial to the low-technology approach. Luther Godbey drawls, "I think the best thing you can say for solar energy right now is simplicity." Interesting that the idea came from a rural branch of the USDA and was financed by a local builder, not from the public coffers. Interesting that nothing half so economical has come from the National Laboratories, which have received millions in ERDA solar-heating research grants.

• A list of solar-heating wizards and important plodders ought to include at least several dozen more names than the following: Shawn Buckley of MIT, whose "thermic diode" could solve a lot of problems for some active water systems; Malcom Wells in New Jersey, who may be the world's best designer of solar-heated houses located partially underground; George Löf of Solaron in Denver, one of the grand old men of the trade and a pioneer in active hot-air systems; David Wright, who has roamed the Southwest designing dozens of solar houses, including many strange and wonderful-looking passive ones. There is Norman Saunders of Weston, Massachusetts, who stands among the geniuses of the passive approach, eschew-

ing moving parts. His latest design is the Saunders Solar Staircase, which consists of a translucent plastic roof under which hangs a tier of steps, shiny on the tops and transparent on the vertical faces, and precisely sloped and spaced so that summer sun can't get through but winter sun can. There is also Bruce Anderson, more a synthesizer than a pure inventor. His new Goosebrook House in New Hampshire is quite expensive—it sold for $70,000 four days after it went on the market; the entire solar-heating system cost about $8000. But it's a spacious home, designed to be a showplace. It weaves several strands together: a greenhouse (for heat as well as growing things), an active water roof collector system, and unobtrusive passive features, such as a set of doors which slide on tracks out of the garage to insulate the southern windows after nightfall. It is the nicest, airiest solar house I've seen.

There is also Dr. Harry Thomason. (His doctorate is honorary, from Catawba University, where he got his undergraduate degree in physics and math; he says he learned his engineering in the Coast Guard.) No list can exclude Thomason. Quite literally, the man demands attention.

Thomason's career began serendipitously. "This is a true story," he told me. "It was in the *Reader's Digest*. The New York *Times* likened me to Sir Isaac Newton." It was 1956, as Thomason remembers it, back in the middle of North Carolina farm country, a land of sudden summer thunderstorms. "The old barn still stands there," he recalled. "It had a rusty roof—that made the difference." A hot day, sun beating down on the barn roof, Thomason out near the barn. Suddenly huge clouds rolled in. "Down came the rain. I ran under the overhang on the barn roof and I thought to myself, 'Gosh, that's nice warm water.' I looked up to see where it was comin' from. Right off the old barn roof. Instantly—of course, it's what we call a flash of genius—I realized what was goin' on. 'That's a solar collector there.' I just dashed under the overhang. Cold water had been fallin' on my head. Now here came warm water on my head off the barn roof. That was the original inspiration."

Like Norman Mailer and Browning's Caliban, Thomason often refers to himself in the third person. He writes in his newsletters: "Thomason SPEAKS OUT and writes about EXXON and government agencies who are discouraging solar heat." Or, "DR. THOMASON WILL CONTINUE HIS ONE-MAN (ONE FAMILY) CRUSADE TO FORCE HUD, FEA, ERDA AND THE BIG OIL COMPANIES TO STOP MISLEADING THE AMERICAN PUBLIC. THEY LEAD YOU TO BELIEVE THAT SOLAR HEATING AND AIR-CONDITIONING APPARATUS IS EXPENSIVE. THOMASON HAS THE PROOF; THOMASON'S 'SOLARIS' IS VERY LOW IN COST."

"He's his own worst enemy," many say. Steve Baer is one of the few people in the business who doesn't take strong exception to what is known as "Thomason's style." Baer feels he understands. Thomason has gotten a lot of good press lately, his disciples now include a number of private builders, and ERDA is spending $194,000 to test a Thomason home. But it wasn't always so. He has had a long hard time getting people to take him seriously.

Skepticism about Thomason's system persists, partly because of his style, but also because of the claims that he makes for his brainchild. He says that at a cost of about $3500 his "Solaris" design will provide 95 percent of the heat for a three- or four-bedroom home in a moderately warm climate. In what he calls "bitter cold Massachusetts" or "bitter cold Minnesota," he says he can get you 75 percent for $4500. This is about half the cost of most good active systems, and the performance he boasts of is 20 or 30 percent better than most.

His collector is essentially a corrugated aluminum barn roof, painted black and covered with a single

Dr. Harry Thomason

layer of glass, which is about as simple and cheap as an active solar collector can get. Water flows in a thin stream out of holes in a pipe that runs along the top of the collector. The water travels down the corrugated valleys into a gutter, then down to the basement into a 1600- or 2000-gallon water tank surrounded by stones. The water heats the stones, a blower takes the heat from them and sends it into the house. The U.S. Department of Agriculture and Professor J. Taylor Beard of the University of Virginia have tested the Thomason collector. "The results of those tests shocked the nation," Thomason told me. In fact, what they showed was that Thomason's collectors are quite efficient, when they're operated at low temperatures. And that is how they operate; that's the trick, according to people like Bruce Anderson, who is executive editor of *Solar Age*, author of the new book, *Solar Energy*, and a designer, and who installed a Thomason-style collector on the Goosebrook House. What's more, this collector seems to be virtually indestructible.

I heard allegations that high humidity and mold on northern interior walls afflict some Thomason houses. But a family in Minnesota told me that their Thomason home was fine and cozy. They said they used only $25 worth of gas for their back-up heating from February 25 to March 25, 1977, which was a particularly frigid month up north. The builder said the system cost about $6000, more than a Thomason unit should, according to Thomason. But the house and system are large, and the builder says he was a novice at solar heating and made some costly mistakes.

Rhett Turnipseed, an official in ERDA's solar division, checked out this Minnesota house. "I keep waiting for the other shoe to drop," he told me. "Thomason's system makes real good engineers climb the walls. It's a Pinto, not a Cadillac. It's like a Model A, it'll rattle around some, but the data coming in looks good. He's a little guy with a widget that works."

Referring to the now well-known story of the old barn roof, and to the article which likened Thomason to Sir Isaac Newton, Steve Baer said, "Well, it took Newton a whole heavy apple. With Harry, it was just a few raindrops."

An astonishing gizmo

Most people who are taking part in the refinement of solar heating do not anticipate a new piece of hardware that will at once solve problems of retrofit, cost, performance, and durability. If there is an astonishing gizmo coming, it probably belongs to another solar technology: photovoltaics.

It is impossible to explain the conversion of solar radiation to power without recourse to specialized language, and the specialized language itself is sometimes a disguise for a highly mysterious process. As one science writer has put it, "Photovoltaics is basically an incomprehensible drama." It is perhaps enough to say that when sunlight strikes the crystalline forms of certain elements—silicon, for instance—it frees electrons from their places in the atomic structure and thus generates a small electric current.

The potential applications of photocells appear to be vast, ranging from central power stations to neighborhood photovoltaic plants, perhaps even to individual energy systems for single-family dwellings. Many who dream of local or personal self-sufficiency in energy—a dream which is generally described as "pulling the plug on the utilities"—look toward photocells with interest and anticipation, and so do many solar-heating architects and engineers. "Hybrid" systems gathering both electricity and heat for houses are being tested. They work. The problem is that energy systems employing photovoltaic cells always end up costing a great deal more than the houses they're attached to. So far, the only practical uses for photovoltaics have been on spaceships and buoys located in remote archipelagoes. Though photocells proved themselves to be reliable and durable in those applications, power from a photovoltaic system today would cost twenty, thirty, or maybe even forty times as much as electricity from a conventional nuclear system.

Photo-electric cells produce direct current, and since American homes now run almost exclusively on alternating current, a converter must be used. Storage is a more severe impediment; the absence of a cheap way to store electrical energy afflicts the entire power industry, and a great deal of research is now under way. The space station approach to photovoltaic systems is in essence a plan to get around the storage dilemma by putting the cells in a place where the sun always shines, but that may be the most expensive of all possible solutions. Some researchers throw up their hands over storage and say that photovoltaics can never be more than a supplement to conventional and nuclear central power station energy. Some look to flywheels and to such ideas as storing electric power in underground caverns, in the form of compressed air. Some feel the answer lies with the good old lead-acid battery, or maybe with the sodium-sulphur high-temperature battery, which is being developed for electric cars. Today, the wiring and packaging of cells accounts for about half of their cost. At the one plant I visited, assembly and packaging were being done laboriously, by hand. Cheaper techniques must be applied. Inexpensive ways of installing arrays of cells must also be found, and ultimately backyard inventors such as Thomason and Baer might be enlisted in that effort.

Looming over all other impediments today, however, is the cost of the photo-electric devices themselves, a problem for solid-state physicists, not for solar-heating wizards. The material used most often for the absorber plate, which is the cell's main component, has been silicon, the second most abundant element on earth, after oxygen. But producing single-crystal silicon hasn't been cheap. In the past, a high-purity, cylindrical ingot of crystal silicon was drawn from a crucible and then cut like a bologna, in sheets a few thousandths of an inch thick. It was slow work. A lot of hand labor was required. Up to 75 percent of the silicon was lost in the form of expensive sawdust. Then, several years ago, Tyco Labs in Waltham, Massachusetts came across a way of "growing" the silicon crystal in a very thin continuous sheet, which could be scribed and cut with relative ease and little waste. The process is now being refined by Tyco Labs Solar Energy Corporation, 80 percent of which is owned by Mobil Corporation. Mobil-Tyco's work is considered to be among the most promising approaches in the photovoltaic field, but there are many others. Backed partly by federal money, about fifty organizations have joined the search for a cheap photocell. Investigators include universities, national laboratories, small companies, and large concerns such as Motorola, RCA, Shell, Exxon, Texas Instruments, and Rockwell International.

I talked to representatives from Mobil-Tyco, from ERDA's solar division, from Solar Power Corporation (an Exxon subsidiary), from Lincoln Laboratory. Optimism was general. The cost of photo-electric cells has already come down from about $50 per watt to about $15, and some researchers claim that they'll have the price down to $2 a watt within the next two years. ERDA has decreed that the cells will cost fifty cents a watt by the mid-1980s and something like thirty cents in the 1990s. Even at $2 a watt, large new markets should open up. Opinion divides on the question, but some researchers feel that at thirty cents a watt photovoltaic cells could grab a sizable chunk of the residential market.

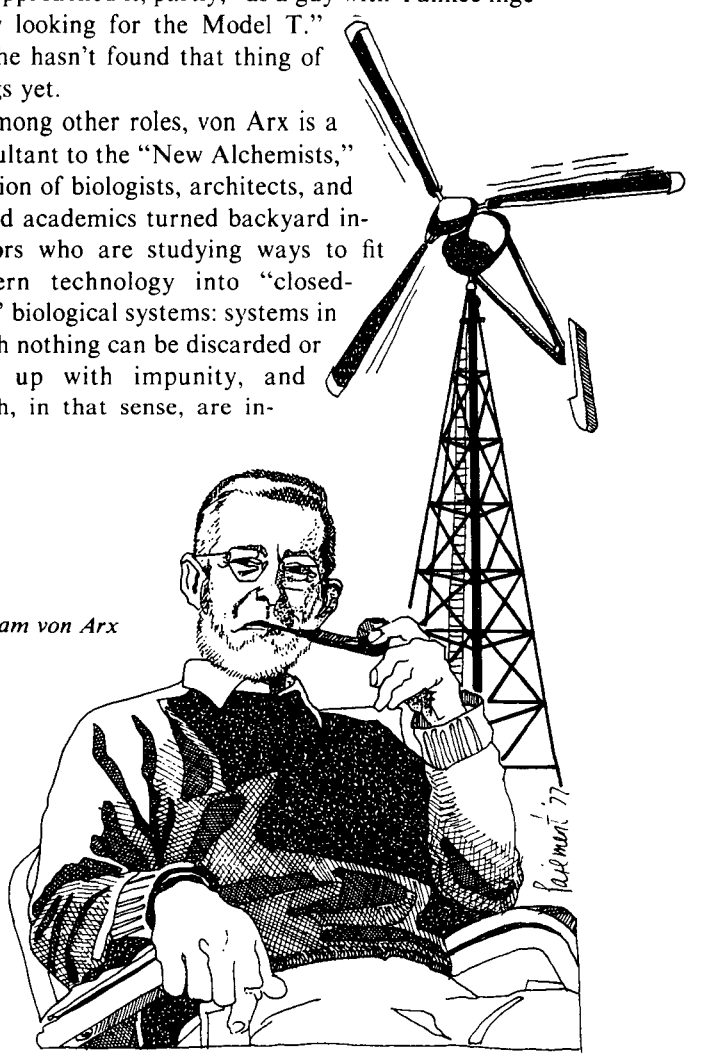
The economics of the breeder reactor are fully as uncertain as those of the photocell, and compared to nuclear fusion, which has yet to be proven feasible, even in a laboratory, the photo-electric art is far advanced. Nevertheless, in fiscal 1978 the government will spend six times more money on fusion and twelve times more on the breeder than on photocells. And if the $60 million allocated to photovoltaics in 1978 is too little, as some researchers say, ERDA will still have trouble handing out the loot. ERDA has only four people working in photovoltaics. Given the rules of the Washington funding process, four is a pitifully small number to go with $60 million.

A solar philosophy

In a favorite vision, the scientist William von Arx foresees a change in the hardware hanging from the electrical transmission towers that stride in all directions across the United States. These tall backbones of the central-power-station approach to heat and light are stripped of their high-tension wires. Von Arx imagines windmills attached to them instead.

A senior scientist at the Woods Hole Oceanographic Institute, von Arx has been a professor at MIT and a consultant to a wide variety of scientific agencies such as the National Science Foundation, NASA, and the National Academy of Sciences. Changing the direction of his research every ten years or so, "to avoid going stale," he has worked "in and between" the fields of astronomy, meteorology, geology, and oceanography. "I've wanted to understand the physical environment of man," he explains. This inquiry has led him finally to the all-embracing field of energy. He has approached it, partly, "as a guy with Yankee ingenuity looking for the Model T." But he hasn't found that thing of things yet.

Among other roles, von Arx is a consultant to the "New Alchemists," a legion of biologists, architects, and lapsed academics turned backyard inventors who are studying ways to fit modern technology into "closed-loop" biological systems: systems in which nothing can be discarded or used up with impunity, and which, in that sense, are in-



William von Arx

tended as metaphors for the earth itself. At a cost of about $1000, von Arx has built a solar pond on the field behind New Alchemy East headquarters, near Falmouth on Cape Cod. This shallow concrete pool, which is filled with water, brine, and particles of coal, is about fifteen feet in diameter and produces some four kilowatts of thermal energy by just sitting in the sun—enough heat, von Arx maintains, to warm about a third of a typical Cape Cod house. But the pond idea is old and already well-investigated, principally by Dr. Henry Tabor of Israel, and its possible applications appear to be severely limited. Von Arx has also drawn up plans for a community heating system, suitable for suburbia, which employs underground aquifers to store summer heat for winter use. A group in Texas is working on this, too. It is a promising idea, yet untested. Today, von Arx remains primarily a theorist.

He lives a few miles from his pond, in an airy modern house surrounded by vegetable gardens, on a hilltop overlooking Buzzards Bay. An eleven-inch telescope is set up on the grounds. The morning of the first day of last summer found the windmill near his front door chattering away in a gentle southwester and von Arx inside listening to a public radio broadcast of the Latvian celebration of the summer solstice—an ancient solar rite. He is a man of medium height, vigorous and muscular though a prodigious smoker of Pall Malls. He will not name his age—"Let's say I'm over sixty." He was wearing shorts and sandals, a crew cut, and a close-cropped white beard. Von Arx has a way of making his eyes appear to grin. He uses this gesture and other more conventional smiles to qualify statements like these: "I'm worried about the long-term future, *if* there is to be a long-term future." Or, "The threat of plutonium is far mightier than the media has led us to believe." Or, applying the nautical phrase to energy, "It's time to order a change of course. We got weather ahead."

Amory Lovins, who has spent many hours on the phone with von Arx, writes of "a substantial social movement" which has begun "a re-examination of the industrial ethic." In a phrase which his adversaries love to mock, Lovins describes this movement as "camouflaged by its very pervasiveness." Indeed, it is hard to know just how pervasive such a movement might be. But its existence is obvious, especially at gatherings like the "Toward Tomorrow Fair." Uninterested in working hard to convince the already convinced, von Arx stays away from such events, but he is one of this amorphous "movement's" eloquent and credible spokesmen. He says he is looking at energy "from a global point of view." His sinuous argument reproduces the Lovins and the E. F. Schumacher small-is-beautiful line, but from a naturalist's and space explorer's perspective. Ever since the Crusades, von Arx believes, mankind has treated the planet as if it were "an open ecosystem." To him, nuclear energy is merely another attempt to perpetuate this dangerous violation of "the limits to natural abundance." We must use less energy absolutely, he feels, and much more of what we use must be of the renewable kind. This would be the ideal: "To live by the natural regimen of the sun."

Even if the short-term contributions of solar crafts are small, technologies such as solar heating aren't likely to be insignificant. Bruce Anderson contends, "Out of solar heating comes energy conservation." The effort to warm living rooms with sunshine does seem to have given solar-heating engineers and people who live in solar houses a new awareness of energy, how hard it is to gather and contain, and how precious. "In*sul*ate before you in*sol*ate," has become the first principle of the trade.

Revelations come from solar heating. I have in mind the sort of thing which the sixty-five-year-old entrepreneur John Bemis told me, while we were admiring one of his elegant, expensive, solar-heated Acorn Structures. "It's fantastic what volumes of energy we're used to having in a house," mused Bemis. "You know, having a two-gallon-an-hour oil furnace in your basement is like having a bulldozer down there. And that's a pretty powerful piece of machinery, a bulldozer."

But it is difficult to foretell the ultimate practical significance of solar heating and of the other solar arts. Their philosophical importance is easier to see. Many well-informed participants in the energy debate, such as the ardently pro-nuclear Representative Mike McCormack, hold that solar and nuclear technologies are not mutually exclusive. We must look to both in the future, they say, and maybe they are right in practical terms. But to solar theorists, the approaches to nature which these two technologies represent are not compatible.

On August 6, 1945, President Truman stirred the nation with this description of the bomb that had been dropped on Hiroshima: "It is a harnessing of the basic power of the universe. The force from which the sun draws its power has been loosed against those who brought war to the Far East." That was the beginning of the age of nuclear power. The idea of using this source of destruction for peaceful purposes had been made terribly alluring. Nuclear power would be an atonement, a way of forgetting Hiroshima. But now the solar advocates have redefined the issues. In their rhetoric, solar technologies seek only to collect the energy which nature has provided, while nuclear explorations have sought to penetrate the secrets of the

sun and have set about recreating versions of the solar furnace on earth by smashing atoms. To the solar advocates, nuclear energy stands for an arrogant, aggressive attempt to master nature, while the solar approach is a humble, passive effort to make peace with the planet.

Outside Bill von Arx's front door the little windmill is whirling in the freshening breeze off Buzzards Bay. Von Arx stands contemplating this piece of machinery, which looks like the skeleton of an airplane with the propeller still intact, mounted on a tripod some ten feet tall. "I think it's beautiful," he says. And then he points up toward the morning sun, which supplies the force that drives his windmill, and grinning, he explains, "That's a safe distance for a nuclear reactor. And it runs unattended, you see." □

A City Changes Its Energy Future

Davis, California has become a quiet, independent example of what can be done at the local level to improve our energy future. By a thorough study of local climate and needs, the city has been able to devise a building code which offers energy savings, choices for builders, a better environment for residents, and a model for other localities.

Davis, California Amended Its Building Code and Decreased Its Use of Energy

A City Changes Its Energy Future

KATHERINE ALVORD and MICHAEL R. EATON

POWER PLANTS are a hot political issue in California, second only to taxes. But while debate about coal and nuclear energy boils in the political cauldrons, a medium-size Northern California city has begun a program that, if copied widely, could spare us the hazards of either energy source. And while the Pacific Gas and Electric Company, Northern California's giant utility, mounts an expensive ad campaign to convince consumers that solar energy is not practical, that same city boasts a fully "solarized" PG&E office. The city is Davis, where energy use has actually dropped off in recent years—the average customer today uses 15% less electricity and gas than three years ago. Even more encouraging, these savings have been accomplished with remarkably little dissension; builders, planners, consumers and the business community all profess to be advocates of conservation.

Davis developed an energy conservation building code about five years ago to assure that new homes built there perform their basic tasks efficiently. The code is based on research that confirmed the correlation between a house's compass orientation and its indoor temperature. The researchers found that east/west-oriented houses and apartments are poor energy performers; dwellings aligned north/south, on the other hand, not only require drastically less summer air conditioning, but with proper shading, south-facing windows can capture heat from the winter sun and still keep out summer heat. In addition, houses oriented to take advantage of cooling breezes maintain comfortable indoor temperatures with less electricity.

Initially, public reaction to the new code was supportive—memories of the energy crisis were fresh. But the local construction industry was far from pleased by the prospect of new government controls; many builders feared the code would add substantially to building

Several weeks before President Carter unveiled his new energy plan, Rosalynn Carter toured Davis, California. Aboard the most popular form of local transportation, she inspected the energy-efficient Village Homes development.

Bill Brooks—Davis Daily Democrat

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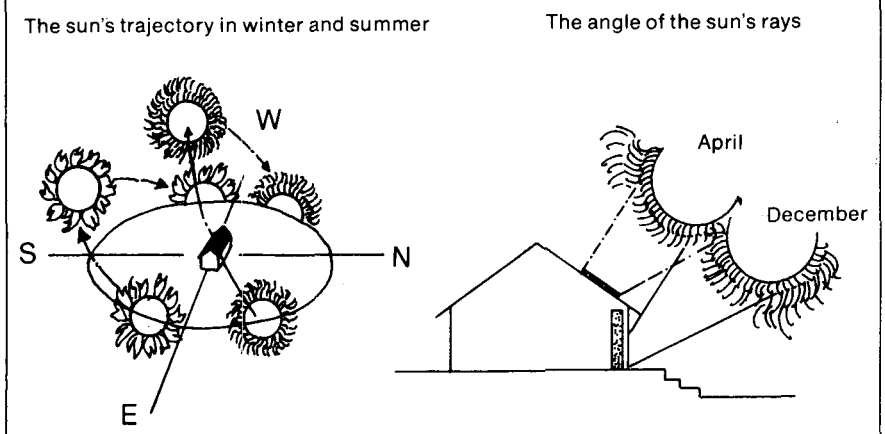
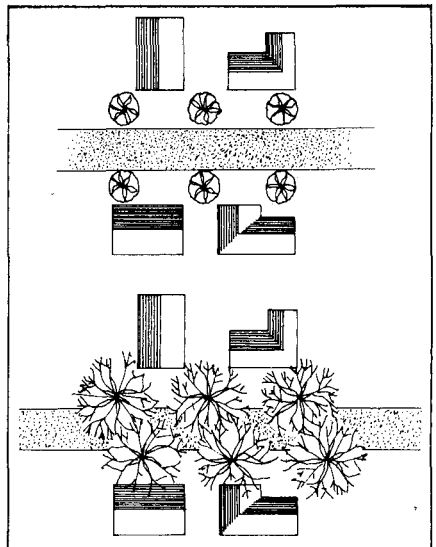
Drawings adapted from The First Passive Solar Catalog—*David Bainbridge*



A house built to face north and south allows maximum use of the sun for indoor temperature control. In summer, when the sun's path is higher relative to the horizon, south-facing windows can be shaded, for example, by an overhang. In winter, when the sun's path is lower, its rays are low enough to reach the windows below the overhang. Such window placement allows generous lighting with minimum indoor temperature variation.



Trees that shade pavement can reduce neighborhood temperatures at least 10°.

costs, and some doubted the code could achieve the savings projected. Following a series of community meetings and city council hearings, the building code was adopted. Many of its specific building standards, which have been in effect since January 1976, are stricter than state standards. Davis' code, like the state's, gives builders a choice of how to meet those standards. Builders can meet prescribed structural standards or they can meet a more flexible performance standard. Someone who chooses to meet performance standards need not meet each of the specific structural requirements of the code but must still attain the same level of energy efficiency.

In the few years since passage of the Davis code, local builders have lost their skepticism. In fact, a number have become enthusiastic boosters of the program. A builder who didn't believe the code would be effective hung thermometers in the first homes he built to comply with the code, to prove the city wrong. He changed his opinion when the houses maintained a 75-degree indoor temperature through 100-degree summer days; now he speaks out for the energy ordinance.

Aware of possible energy savings, several builders routinely erect houses that far exceed the code's performance goals. In one solar home development, 70% of the houses have no need for air conditioners. Another builder constructed moderately priced homes that use solar energy for 90% of the space and water heating and 100% of the air conditioning needed.

The code has also endeared itself—via the pocketbook to home-buyers. The costs of meeting the code have proven to be minimal ($50 for tract homes and up to $700 for custom-built homes—less than 1% of the purchase price). Since annual utility savings average about $150, the investment is returned in a few years. The city estimates that houses built under the new code require only 50% of the space heating and cooling required by houses built before 1976.

Seeing the results of its present regulations, Davis has adopted or is considering a number of further steps. Some of these steps clarify pre-1976 regulations; for example, the code encourages the use of south-facing windows for winter heating, so those windows must not be shaded. An old regulation that high fences must be twenty feet from sidewalks (and thus sometimes within a few feet of windows) constrained design of unshaded windows, so the setback rule was relaxed.

Other steps create new opportunities for conservation; the city council will soon vote on whether to require that new homes have plumbing connections for solar heaters, which would reduce costs for future homeowners who might decide

Provisions of the Davis Building Code

Home-builders in Davis may choose either the performance or the prescriptive standards of the building code. To satisfy the performance standards, a finished house must conserve energy at specified levels. Most builders prefer to meet the prescriptive standards, which have been proven effective at keeping homes comfortable and efficient. These standards include the following provisions:

- Unshaded roofs and walls must be light-colored. Light colors reflect the sun's heat and keep interiors cooler during the hot Davis summer.
- Prevailing breezes in Davis are from the south on summer nights. If homes are not built to take advantage of this natural ventilation, mechanical ventilation must be provided.
- All south-facing glass must be shaded during the summer months. Shade-screens, overhangs and landscaping are often used to give shade.
- Most building codes do not specify the maximum percentage of total area that windows may occupy, but the Davis code does. Basically, windows, skylights and other such glazing are limited to 12.5% of a house's floor area, but additional glazing may be added if double-pane or south-facing glass is used and/or if extra thermal mass (material that helps stabilize temperature by absorbing heat during the day and giving it off at night) is built into the home.
- Insulation in Davis residences must be rated R-11 in exterior wood-frame walls and R-19 in roofs and ceilings (the higher the number, the more effective the insulation). Suspended floors must also be insulated with a minimum of R-19 insulation.

to retrofit houses with solar water heaters. Noting another logical use of solar energy, Davis has obliged builders of all new multi-family developments to install clotheslines. Subdivision restrictions against "solar clothes dryers," as they have been affectionately called, are now illegal.

One of the major causes of energy consumption in Davis is unshaded streets and parking lots. Such areas collect and radiate a great deal of heat; the outside temperature on hot days can be ten degrees higher in unshaded neighborhoods. To remedy this condition, the city passed an ordinance requiring that trees shade at least 50% of paved parking lots, and city planners also encourage narrower streets in new subdivisions to minimize heat-absorbing surfaces and to conserve land.

The city council intends to vote soon on an ordinance requiring homes when sold to be retrofitted with energy-saving equipment. Depending on the house, the ordinance would call for insulation, weatherstripping, window-shading, solar heating, or other conservation devices.

Some city officials would like to see ordinances passed for commercial structures similar to those instituted for homes. Even without ordinances, the city currently ensures through a rigorous design-review process that conservation measures, including appropriate shading and building orientation, are applied to new commercial structures.

Public education has played an important role in the development and implementation of the city's energy plan. After the community meetings were held and the code enacted, and before cutbacks due to Proposition 13, the city systematically informed residents through a periodic newsletter of the latest additions to the city's energy program. It also offered more suggestions for energy conservation.

The Davis program has been emulated by many communities and, fine-tuned for climatic differences, could be implemented in every city in the country. If it were, the question, "coal or nuclear power?" that seems to dominate discussion at both the state and federal levels, could be answered, "neither, for now." And instead, political leaders could devote themselves to the task of ensuring that our energy future is compatible with our environment. ◻

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The Sun: Who Owns It?

"In the present state of affairs, American case law is clear . . . there is no right to the sun." In view of this situation, the authors suggest precedents and methods by which a code of solar rights and easements could be developed in American law.

The Appraisal Docket

Rulings and precedents on matters affecting real property valuation

The Sun: Who Owns It?

by Earl A. Talbot and Dawn Walter

With the current interest in alternative energy sources and "reusable" energy forms, the advocates of the antifossil fuel movement, as well as the President of the United States, constantly promote the sun as the hope for tomorrow. To them it is the ultimate "clean" and inexhaustible source of energy. However, solar energy is not without its problems. The weather, which is as unpredictable as the judicial process, and the technological development of solar collectors are not the only vagaries involved in the use of solar power. Who has the right to sunshine is an open question in American jurisprudence; the present position is the law of the jungle. Unfortunately, solar proponents seem not to recognize this problem.

If Mr. Smith builds a solar collector on his property and Mr. Jones builds a structure (in all respects conforming to building codes and zoning ordinances) that happens to shade Mr. Smith's collector, Mr. Smith is then the owner of a solar collector without sunlight and, under present law, there is little that he can do about it.

Sunlight, like the rain, falls from the heavens on us all. But unlike the rain, our law never has attempted to appropriate sunlight among its potential users. On the other hand, American water law is an extensive body of doctrine, theory, and rights, not to mention numerous judicial decisions. Those from the western states are familiar with the importance and value of water rights. It may be, if the solar proponents are right in their predictions, that the right to ownership will become important for solar energy as well.

In the present state of affairs, American case law is clear in its approach to the question: there is no right to the sun. A prime example of this judicial

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attitude is found in the leading case of the *Fountainbleau Hotel Corporation* vs. *Forty-Five Twenty-Five, Incorporated.*[1] The owners of the Eden Roc Hotel attempted to enjoin construction of the Fountainbleau Hotel, which, when completed, would substantially block the sunlight from the Eden Roc's beach. Only interference with lawful property rights can be enjoined, the court decided. Because there is no legal right to the unobstructed flow of light across adjacent land, no injunction could issue. The Eden Roc's long access to uninterrupted light brought it no prescriptive rights (i.e., rights gained through long-term use) to continue such use. To overcome this attitude, 12 states have enacted legislation classifying the right to use solar energy as a property right and encouraging the use of this right.[2]

DOCTRINE OF ANCIENT LIGHTS

The American attitude toward the common law right to sunlight is not universal among the common law nations. England, the motherland of the common law, has the Doctrine of Ancient Lights. This concept was developed originally to ensure availability of interior lighting for homes. In England today, after a 27-year period of unobstructed sunlight has run, a landowner's access to sufficient light to read a book in the middle of a room in his(her) house is protected by the doctrine.[3]

It has been suggested that the Doctrine of Ancient Lights could be adopted by statute in this country and modified to ensure access to solar energy.[4] Under this theory, whenever a solar collector is installed, a presumption that the use of the sunlight has continued for the prescriptive period would arise, and a challenger would be forced to rebut the presumption and prove rights superior to those of the first user. Such a presumption, however, may not be a sufficient guarantee as a basis for investment in expensive solar heating and cooling equipment, and enforcement of a homeowner's rights could involve an expensive legal battle.

NEGATIVE EASEMENTS OR COVENANTS

The general category of property rights in which the Doctrine of Ancient Lights falls is that of negative easements or covenants, which authorize the dominant estate owner to prevent some activity on the servient estate, such as a covenant to use property for residential purposes only. Negative easements are created today by express grant or reservation in a document or, in some instances, by implication. However, they could be created for solar rights under proper statutory authorization.

Even with today's law, it is possible that a solar easement by implication would arise when a grantor who originally owned two adjoining lots sells

1. 114 So. 2d 357, 181 Fla. Supp. 74 (1959).
2. *Legal Briefs for Architects, Engineers, and Contractors*, Volume 4, Number 16, August 28, 1978, p. 1.
3. "The Dawning of Solar Law," 29 *Baylor Law Review* 1013 (1977).
4. *Supra*.

one but retains the other over which sunlight flowed to reach his collector. Circumstances would indicate that the grantor intended to retain an easement for solar energy over the lot previously conveyed. Hence, an easement to protect the grantor's access to the sun would have been established by implication.

Even today, cautious individuals wishing to construct solar collectors first should purchase or lease the necessary easements or covenants from their neighbors. In such a voluntary arrangement, however, one neighbor, by refusing to sell or by holding out for an exorbitant price, could block another from obtaining the prerequisite rights to building a solar collector. It has been suggested that privately negotiated express easements would be more responsive to the needs of individuals than special interest groups.[5] However, the bother of obtaining these rights makes this approach impractical in most situations.

In a new subdivision, solar energy rights can be created easily by the developer through the use of restrictive covenants in deeds to purchasers. Each purchaser would obtain the right to receive the unobstructed flow of sunlight across property to the south but would be restricted from obstructing southern neighbors' access to the sun.

ZONING

Of course, zoning long has been used as a land-planning device. By controlling lot size, height requirements, and setback lines, the use of solar energy can be encouraged greatly. To be within the bounds of constitutionality, however, the zoning regulation cannot be arbitrary or unreasonable and must be substantially related to public health, safety, morals, or general welfare.[6] Because zoning is a well-established concept that courts tend to favor with a strong presumption of constitutionality, it may be a promising vehicle for solar rights allocation. Under today's typical zoning ordinances, however, access to sunlight is not necessarily recognized.

NUISANCE LAW

Preventing interference with solar rights also can be approached from the standpoint of nuisance law, but the private nuisance theory has not been very successful in American courts. Casting shadows on neighboring land has not been considered a private nuisance.[7]

A public nuisance theory may be a more practical legal device for establishing solar energy rights. Statutes or ordinances could be enacted making interference with solar energy a public nuisance. This approach, however, could create a "standing" problem for an individual challenger. Courts require that a private individual seeking to enjoin a public nuisance

5. *Supra.*
6. *Village of Euclid* vs. *Ambler Realty Co.*, 272 U.S. at 387.
7. *Fountainbleau, supra.*

must prove injury different in kind, not simply in degree, from the injury to the public at large.[8]

ANALOGY OF SOLAR AND WATER RIGHTS

Some theoreticians believe the easiest way to allocate solar rights is through analogy to the existing body of law dealing with allocation of water rights.[9] Both water and sunlight are used, not captured and sold. The only real difference (for legal purposes) is that sunlight cannot be possessed. Due to these similarities, the analogy to water allocation law makes sense.

There are two theories in water allocation law: riparian and prior appropriation. In riparian states (usually states with ample water resources), all owners adjacent to a stream have equal rights to use the water as an incident to land ownership. In prior appropriation states (generally the western states where water is scarce), the one who first puts the water to a beneficial use gets the user rights. Requirements for appropriation are summarized as follows:

> "(i) Intent to appropriate; (ii) notice of appropriation; (iii) compliance with law; and (iv) a diversion of water from a natural stream and its application with reasonable diligence and within a reasonable time to a beneficial use."[10]

Constructive notice is achieved either by application for a permit before an administrative agency in permit states or initiation of a judicial proceeding in mandate states. Use of the race-notice system of recording laws also has been suggested as a method of giving constructive notice for solar energy users. With this system, recording an intent to install a solar collector would vest the right to use energy in the first purchaser over any unrecorded purchasers. Notice would be effective against all structures for which building permits had not been issued. A requirement of filing notice on all land to be affected would be required.[11]

The concepts of abandonment, forfeiture, and adverse possession could be applied to allocation of solar energy to ensure that parties will not sit on their rights. Presumptions could be established to determine the period in which solar energy must be put to beneficial use. Permits could be transferred among users and/or forfeited due to nonuse.

The water-use permit process before an administrative agency seems well suited to allocation of solar energy rights. A conditional permit might be granted that could ripen into a full permit when the solar collector is completed and approved.

Homeowners, and for that matter, all property owners willing to make the investment in solar heating, cooling, and electrical generation, are

8. W. Prosser, *The Law of Torts* (4th Ed., 1971), p. 88.
9. "The Allocation of Sunlight: Solar Rights and the Prior Appreciation Doctrine," 47 *University of Colorado Law Review*, 421 (1976).
10. F. Trelease, *Cases and Materials on Water Law* (2d Ed., 1974), pp. 36-37.
11. "The Allocation of Sunlight," *supra*.

entitled to protection of their investments. The enabling legislation and mechanics for protection of rights are beginning to emerge. A permit system based on analogy to water-allocation law of prior appropriation overseen by an administrative agency probably would be the most comprehensive system for securing and protecting solar rights.

Although the sun may not provide America with the quantities of energy its proponents envision, there is no question that solar collectors will be with us in increasing numbers. By legislative action, the states ought to provide a framework of rights to allocate the resources of the sun. Until then, investment in a solar collector should be undertaken cautiously to ensure that, as a practical matter, it cannot be cut off from the sunlight; otherwise the solar collector owner may have a white elephant enjoying the cool shade of his back yard.

What Role Will the Utilities Play in Harnessing the Sun's Energy?

As the use of alternative energy grew in the late 1970's, one of the major questions raised was: How should energy systems of the future be administered -- in a centralized or a decentralized way? While many feel strongly that "the sun belongs to everyone," others urge that energy utilities may have something to contribute to the broad acceptance of new technologies.

ENERGY REPORT

What Role Will the Utilities Play in Harnessing the Sun's Energy?

Utilities and their customers will have to forge new relationships if solar power is to provide one-fifth of the nation's energy by the year 2000.

BY DICK KIRSCHTEN

President Carter's goal of using the sun to provide one-fifth of the nation's energy by the year 2000 poses a fundamental challenge to the customary relationships between utilities and their customers.

If that objective is reached, conventional energy practices will be turned topsy-turvy. Consumers will be part-time producers. And utilities, which once beat the drums to increase their power sales, will be "service agents," assisting their customers in reducing their purchases.

The President set forth his solar goal on June 20 at the dedication of a solar water heating system atop the west wing of the White House. From that vantage point, Carter projected a future of rising utility rates and consumers who will find that it pays to make more efficient use of energy, particularly from the sun.

Accordingly, the President's solar scenario for the turn of the century is based on a low estimate of over-all energy demand—about 95 quadrillion British thermal units (quads)—that represents an increase of no more than 20 per cent above current consumption.

That goal can be met if various "solar" technologies—defined broadly enough to include hydroelectric power—contribute 19 quads, or 20 per cent of the total. That would be a four-fold increase over their present output, most of which comes from hydropower.

Quite a different perspective comes from the utility industry. Despite its scaling back of earlier projections, the industry still expects generous increases in energy output—with a demand level in the year 2000 of anywhere from 130 to 140 quads. But of that total, it expects solar—as defined by the Administration—to provide less than 10 quads.

Electric utilities, which face immediate competition from solar heating devices, take a very dark view of Carter's "low growth" energy future through rapid adoption of solar technologies and aggressive energy conservation.

The utility-supported Electric Power Research Institute, in contrast to Carter, is still betting on a high-growth future made possible by the breeder reactor. Just a month before Carter's solar proclamation, the *EPRI Journal* forecast that solar and other new energy sources, not including hydropower, "will provide only about 5 per cent of domestic energy supplies" during the remainder of this century.

In the next century, the institute predicted, "the United States, . . . faced with looming power shortages and loss of leadership in the nuclear field, will finally relent and take the breeder off the shelf." After that, it said, "U.S. electricity generation . . . can continue to grow without resource constraints."

The disparity between these views—sharpened by Carter's opposition to rapid development of the breeder reactor—reflects the highly polarized national debate that has cast a shadow over the immediate future of solar, as well as nuclear, energy.

There is widespread sentiment among solar advocates that the utility industry should be bypassed in favor of individually owned or decentralized solar power installations. But the utility industry has made large financial commitments to present and future central-station generating plants designed to produce huge blocks of electricity for transmission over far-flung grid systems.

In the middle are a growing number of energy analysts who are convinced that solar energy, coupled with many meaningful conservation measures, will go nowhere unless the utilities become actively involved in financing the high initial costs and in adjusting their load management practices to provide backup power at reasonable cost during periods when the sun's energy is inadequate to meet consumers' needs.

The authors of a six-year energy study conducted at the Harvard Business School concluded recently that conservation and solar power are the nation's best bets for resolving the present energy crisis. But they issued this grave warning:

"Some proponents of solar power are making a serious error in trying to keep utilities out of solar energy instead of encouraging them to enter the business of 'delivering' solar energy by taking responsibility for installing and financing (perhaps owning) solar units.

"Wide diffusion of solar heating will have a major impact on the utilities, and if they feel threatened and so oppose it, then large-scale implementation of solar could be delayed for a long time."

METERS ON THE SUN?

During its domestic policy review of solar energy this year and last, the Carter Administration held 10 regional meetings to solicit public views. "The dominant theme of every hearing was strong support for the decentralizing and self-reliant characteristics of solar energy," the official summary of the meetings said. "A substantial number of witnesses premised their entire solar advocacy on opposition to centralized power generation in general and nuclear power generation in particular."

Allan R. Hoffman, the Energy Department official who supervised the policy review on a day-to-day basis, said in an interview that witnesses at the hearings were polarized over the issue of utility involvement.

"Many feel the utilities have a strong role to play in financing solar in-

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stallations, maintaining them and generally helping to overcome the initial cost barriers," he said. "But others were adamant that the utilities should be kept out. One of the most frequent comments heard from this group was that 'nobody wants a meter on the sun.'"

Hoffman said some witnesses objected to the extension of utility monopolies into the newly developing solar field, warning that competition would diminish and equipment prices would rise. Opponents of the utilities also stressed a desire for greater "individual control" over the power derived from the sun, Hoffman said.

Richard Munson, the coordinator of the Solar Lobby, a consumer advocacy group that believes 36 quads of energy—almost twice Carter's goal—could be supplied by the sun by the year 2000, agreed in an interview that the utility question is a difficult one for the solar movement.

"We represent a wide spectrum of views, including people who hate utilities and see solar as an opportunity to cut the utilities off altogether," Munson said. "As a middle-of-the-roader, though, I recognize that you can't ignore the utilities. Mechanically, they are the system. They have the capability for marketing, billing, metering and providing the backup power needed to supplement the solar contribution."

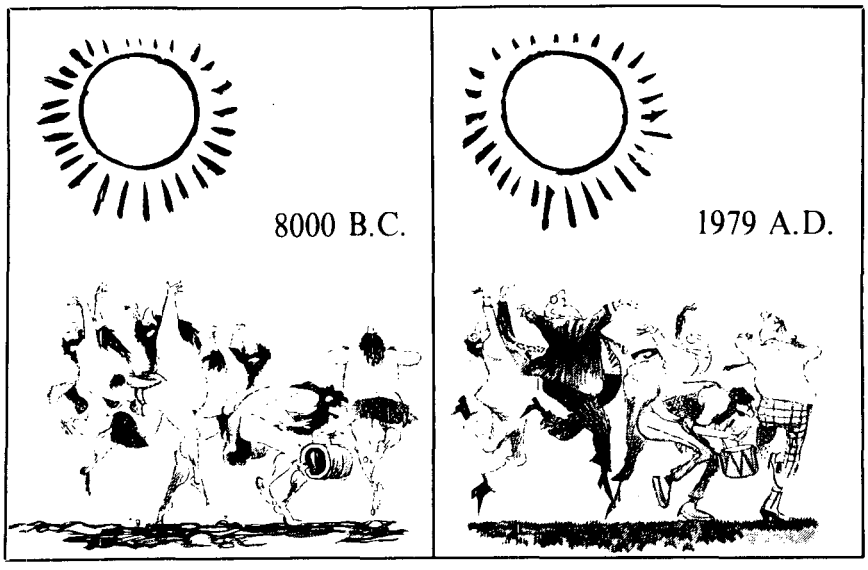
The problem, as Munson sees it, is, "How do we use the electrical grid to aid the transition to solar but still guarantee that there will be competition and innovation and ensure that solar will not be suppressed?" He added, however, that "a surprising number of solar advocates are turning toward utility financing as an attractive proposition. The question is, do the utilities favor it?"

The solar lobbyist added that there have been some disenchanting experiences with utility-sponsored solar experiments. He cited a California project in which an electric company installed solar hot water heaters and installed meters so that it could bill for the energy provided. "The killer was that when OPEC [the Organization of Petroleum Exporting Countries] oil prices went up, the utility increased its solar rate also."

SOLAR UTILITIES

In *Energy Future* (Random House, 1979), a report of the energy project at the Harvard Business School, editors Robert Stobaugh and Daniel Yergin are as tough on the utility industry as they are on the solar advocates who oppose utility involvement.

The utilities, according to the authors, feel threatened by solar heating, which they see as "competing with their own role as producer and converter of energy. . . . Like conservation, solar can be perceived as a threat to the utilities' self-defined growth program." As a result, many of the utilities are indifferent or hostile to solar energy and conservation. Their rate structures, Stobaugh and Yergin said, can discourage conversion to solar power.



The utility industry, of course, is by no means a monolith. There are private, investor-owned utilities, rural electric cooperatives, municipally owned utilities and federal power administrations such as the Tennessee Valley Authority (TVA) *(see box, p. 1638)* and the large hydropower distributors in the West. There are electrical utilities and natural gas utilities and some that supply both. All are subject to varying degrees of state and federal regulation and can therefore argue that their rates and behavior are not entirely their own doing.

The natural gas utilities appear to be both less threatened by—and more interested in—solar power than the electrical utilities. This is largely because today's solar heating systems are economically competitive with electric resistance heating but not with natural gas heating. Also, the gas utilities have historically had more experience in providing direct consumer services, such as appliance hookups and certain types of maintenance procedures.

A new study commissioned by the natural gas utility trade organization, the American Gas Association, notes that "solar heating systems in the residential gas market will have minimal impact on gas utilities through 1990." The September report, compiled by the Mitre Corp., also explores ways that the gas utilities can further the use of solar energy. It reports that "utilities could significantly accelerate the acceptance of residential solar space heating and hot water systems by leasing solar systems and thereby lowering the initial cost to the customer."

Paul C. Greiner, vice president of the Edison Electric Institute, the lobbying arm of the investor-owned electrical utilities, said in an interview that decentralized solar power units, if not correctly designed and controlled, may do very little to reduce the maximum power demand that a utility must be prepared to meet.

This is a matter of critical importance to an industry concerned about the high capital costs of generating equipment that stands idle except for periods of peak demand. Because of the intermittent nature of sunshine, Greiner noted, the demand for power to back up solar systems is likely to come in large surges.

The solution to the problem, he said, is to ensure that solar equipment is designed to include sufficient storage capacity that can be drawn upon during periods when the sun is not shining. With the development of sophisticated load management techniques, utilities also should be able to assure that backup power is provided only during off-peak periods—when it is most economical for both the producer and the consumer. Greiner noted that it will probably be necessary to anticipate cold snaps or prolonged periods of cloud cover so that extra power can be provided in advance to the storage systems of solar users.

A variety of storage techniques have been advanced, but for most solar heating applications, energy storage capacity most likely will be provided by a large-volume, well-insulated, hot water tank. In some areas, swimming pools—if properly covered—may be used as heat storage reservoirs.

Saving Money By Losing Sales

It's not easy to lose something as big and conspicuous as a 1,000 megawatt power plant, but S. David Freeman is trying.

Freeman, who forcefully advocated the emphasis on energy conservation in President Carter's first national energy plan in 1977, is now the board chairman of the nation's largest utility system.

And Carter has chosen that system—the federally owned Tennessee Valley Authority—to become the nation's "solar showcase." Freeman, in turn, has chosen to prove that it will be cheaper for TVA to assist its customers in displacing 1,000 megawatts of capacity using the sun's energy than to build a 1,000 megawatt power plant to provide precisely the same services. He has given himself until 1990 to achieve that goal.

For a system customarily armed with massive hydroelectric dams, huge coal-fired plants and the nation's most ambitious nuclear construction program, Freeman has shifted to an unfamiliar arsenal—wood stoves, water heaters and weatherstripping.

Robert F. Hemphill Jr., a former Washington energy policy maker, has been recruited by Freeman to join TVA's Knoxville headquarters to spearhead the system's solar and conservation programs. In an interview, Hemphill noted that TVA already has adopted rates for purchasing power from private companies in their service area that save energy by running waste industrial heat through turbines to generate electricity.

During peak generating periods, when it costs TVA the most to generate power, the authority will pay 135 per cent of its wholesale rate for power sold by private "co-generators." During off-peak hours, when TVA's need for extra power is minimal, the rate is 85 per cent of the wholesale rate. "These are the most generous rates that we can set and still show a profit for the system," Hemphill said.

While TVA's co-generation rates have nothing directly to do with solar energy, Hemphill views them as a forerunner of rates that eventually will be made available to individual generators of solar energy whose production exceeds their needs. Hand in hand with TVA's agreement to buy excess power is a commitment to charge reasonable backup rates for the electricity that decentralized power producers will need from time to time when their own production falls short.

In a recent speech, Freeman urged utility executives across the nation to "rethink the role of their systems." They must "envision their organizations as providing electrical energy services to customers, not generating electricity. No one uses electricity for its own sake; it is used for lighting, heating, cooling, shaft power and numerous other functions," Freeman said.

S. David Freeman

If power company executives could "cross the mental hurdle" and start thinking of themselves as more than just producers, he said, they would see for themselves that "decentralized energy systems offer utilities a potentially cost-effective option to increasingly expensive centralized generating plants."

Since arriving in Knoxville, Hemphill has taken charge of TVA programs aimed at installing 1,000 residential solar water heaters in Memphis and 10,000 in Nashville. In each case, the solar device would replace a water heater that had been running on TVA electricity.

With firewood readily available in the TVA service area, Freeman and Hemphill are pushing a program to help finance the installation of 5,000 airtight wood stoves—again helping to heat homes that were formerly warmed by TVA electricity.

The giant regional authority also has launched active programs to promote solar heating and cooling of homes and is providing technical assistance to architects to encourage them to incorporate construction features that make optimal use of the sun's heat.

By 1990, David Freeman devoutly hopes that he will have lost 1,000 megawatts worth of business for TVA—and that the utility will come out ahead economically in the process.

The Edison Electric Institute is urgently pursuing research into load management techniques and has formed a working alliance with the Solar Energy Industries Association, which represents manufacturers of solar equipment, Greiner said. He insisted that such efforts, in addition to a large number of solar demonstration projects involving electric utilities across the nation, prove that the utilities are supporters of solar energy development, not obstructors.

"The utilities are the second-largest promoters and installers of solar energy," Greiner declared. "Only the Department of Energy, with all the federal funds available to it, is doing more."

ENERGY ACT "BLUNDER"

To most energy analysts, conservation and solar power initiatives go hand in hand: both reduce the amount of non-renewable energy sources that must be tapped.

But an early effort to involve the utilities as suppliers of energy services rather than simply as suppliers of energy was shot down in Congress last year. As part of the 1978 National Energy Act, Carter had proposed that utilities be required to provide long-term financing for conservation investments.

Henry Kelly, who directed a major solar energy study by the congressional Office of Technology Assessment, noted in an interview that "a coalition of unlikely allies" came together to knock utility financing out of the bill. Kelly, now on the staff of the federal government's Solar Energy Research Institute at Boulder, Colo., said forces opposed to any extension of the utilities' "monopolistic control" teamed up with "utilities that did not want to get into the business of insulation and weatherization improvements."

Kelly suggested that "the use of the utility infrastructure—a billing system all ready to go and a contract with every homeowner in the country—would be very useful for encouraging solar investments." Ideally, he noted, repayment for solar equipment would be offset in each month's bill by the savings from reduced purchases of energy from the utility.

Stobaugh and Yergin, in their energy analysis, place a similar priority on making the utilities "partners in the promotion of conservation and solar. The exclusion of the utilities from the conservation business in the 1978 National Energy Act was, in this connection, not some minor mistake but a major blunder," they wrote.

Because of "grandfather" provisions in the act, utilities in Oregon as well as TVA have been allowed to go forward

with diversified "energy service" programs that are being closely watched throughout the utility industry.

At a conference for energy leaders, including top utility executives, sponsored by the Aspen Institute last July, strong sentiment was expressed for a revision of the act that would permit utilities to become involved in development of decentralized technologies.

The dilemma for the utilities, as seen by participants in the Aspen conference, was summarized as follows:

"If they choose to participate in expanding the use of decentralized energy technologies, they risk directly causing under-utilization of their existing energy production capacity. If they do not participate, they face competition from suppliers of co-generation equipment, insulation, solar devices and others which may lead to the same result.

"To benefit from this situation, utilities must redefine their objectives and begin to think of themselves as providing electric end-use services at the least possible cost. Consumer confidence in the technical abilities of utilities, as well as their permanence, make them an ideal institution for selling and installing substitution [such as solar] and conservation technologies."

SOLAR POLICY DEBATE

In his "Sun Day" speech on May 3, 1978, Carter ordered an Administration-wide review of solar policy options, with the Energy Department as the lead agency. Many participants in the ensuing debate, including then deputy Energy secretary John F. O'Leary, openly made known their skepticism about solar's near-term prospects while the review was in process.

In a speech last November, O'Leary splashed cold water on solar technologies in general, predicting that they will "not apply significantly during this century." He said breakthroughs are unlikely in the economics of photovoltaic cells, which convert the sun's light, rather than its heat, directly into electricity. "If you look at the great white hope of just a year ago," said O'Leary, "it begins to wash out if you put a pencil to it hard."

O'Leary even put down his own agency's research commitment to a central-station solar generating project designed to feed the utility grid. "The 'power tower' concept that we are now spending a great deal of money on in the Southwest is similarly something that I think has very, very limited application," O'Leary said.

Solar advocates within the Administration, such as Council on Environmental Quality chairman Gus Speth, thus feel they won a major bureaucratic victory when Carter endorsed the goal of 20 per cent reliance on the sun's energy by the year 2000.

Although Speth's own agency had argued a year earlier that 25 per cent of the nation's energy could be solar by the end of the century, he said in a recent interview that the goal chosen by Carter "is an ambitious one, one that a number of people feel we would be very lucky to achieve."

To translate Carter's solar policy from a bureaucratic victory to a matter of reality, Speth conceded, a great many things must happen, not all of them directly subject to federal initiatives.

"There will have to be a major voluntary response to the incentives we have proposed—provided we succeed in getting them enacted," he said. "Next, there will have to be state and local actions in such areas as zoning laws and building codes that encourage or require the incorporation of 'passive' solar design features in new construction."

Even at that, Speth said, the program initiatives set forth thus far by the Administration might fall several quads short of its 19-quad goal. "Additional federal support for solar programs may be needed. We didn't say this was all that ever would be done. There are 20 more years, and lots of things will happen," Speth said, adding that the legislative agenda of the Solar Caucus on Capitol Hill includes many proposals that go beyond Carter's. "We will look at all of those, and I hope the Administration will be able to support many of them."

Piet B. Bos, director of the Electric Power Research Institute's department of new energy resources, acknowledged in an interview that his organization's prediction of roughly 9 quads from solar energy, 4 of them from hydropower, might well turn out to be low in the face of an aggressive program of federal subsidies and incentives.

But even by "stretching things as optimistically as I can," Bos said, "I cannot foresee more than 13.5 quads at the outside." A much more conservative estimate was offered by an analyst at the Edison Electric Institute, who pegged the solar production level in the year 2000 at 9.3 to 9.9 quads.

The Carter Administration is counting most heavily on solar heating advances in the residential and commercial areas and—with some pushing—in various agricultural and industrial processes. It hopes that solar applications in these areas can displace six quads of conventional energy.

Gus Speth, chairman of the Council on Environmental Quality, said the solar energy goal chosen by President Carter "is an ambitious one, one that a number of people feel we would be very lucky to achieve."

Another 5.4 quads is expected from biomass—plant life in various forms, from wood chips that can be burned to grain that can be fermented into alcohol and blended with gasoline to form gasohol. There are many schemes to channel biomass production into areas that don't compete directly with food production. One of them involves a plant that grows in arid areas that would not be amenable to normal farming. A relative of the rubber tree, it yields a substance that can be converted into oil. It is delightfully named euphorbia.

Encouraging experiments with newly designed wind machines—the modern equivalent of the old-fashioned windmill—have led the Administration to predict 1.7 quads from that source, along with another quad from photovoltaic cells and 0.1 quads from

ocean thermal conversion. Conventional hydropower, much of it already in place, accounts for another 4.3 quads, and the final half-quad apparently remains to be pinned down.

Critics contend that the Administration is placing far too much faith in the more exotic technologies that are yet to be proven and is much too sanguine about the speed with which new devices and practices can work their way into the marketplace and have an appreciable impact.

TOUGHER MEASURES

Carter's implementation strategy includes a solar bank to provide low-interest loans for solar purchases and additional tax credits to encourage passive solar design techniques, industrial solar heating applications and the use of energy-efficient wood-burning stoves in primary residences. There also are a series of directives to various federal agencies calling for administrative actions designed to encourage solar power development. (*See NJ, 8/4/79, p. 1289.*)

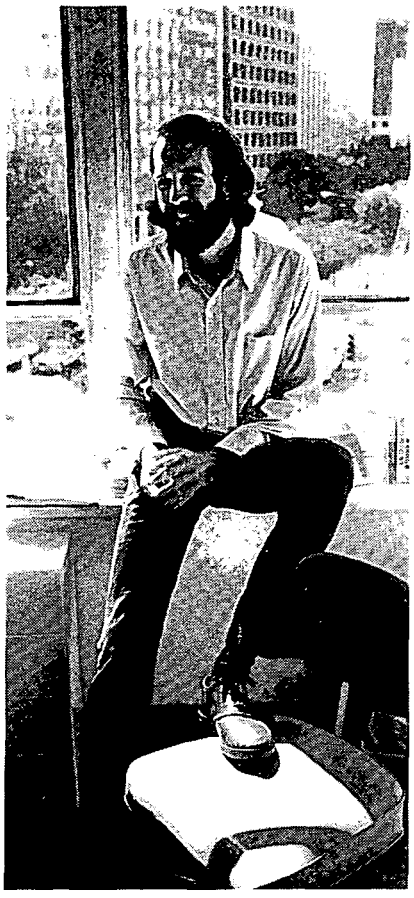
The Solar Lobby has denounced these measures as overly conservative, especially when compared with Carter's bold proposal to authorize up to $88 billion for a crash synthetic fuels development program. (*See NJ, 8/25/79, p. 1410.*)

Some of that money, however, could be used to develop fuels from biomass, which would help add to the solar energy total. The lobbying group also has charged that the Administration has been lax in providing funds and manpower for solar and conservation programs that already have been enacted into law.

Another point of contention is Carter's linking of his solar bank and new solar tax credit proposals to the uncertain enactment of a "windfall profits" tax on the oil industry. "Instead of a long-range plan for reaching the 'Solar 2000' goal, the President's plan came out looking like a tactical gambit to line up support for his battle to win passage of his windfall profits tax," remarked a congressional aide who has followed solar policy issues closely.

Although TVA launched an aggressive solar program during Carter's tenure, an environmental group recently took issue with the Administration for failing to use its leverage to promote conservation practices and solar energy development within the sprawling system of rural electric cooperatives that benefit from federally subsidized loan programs and tax exemptions.

In a recent analysis of the rural cooperatives published by the Washington-based Environmental Policy Institute, the Rural Electrification Administration and the National Rural Electric Cooperative Association were accused of giving only lip service to conservation and alternative energy programs while steadfastly promoting large, centralized power developments.



Richard Munson is coordinator of the Solar Lobby, a consumer advocacy group that believes 36 quads of energy—almost twice Carter's goal—could be supplied by the sun by the year 2000.

The report quoted Senate testimony last year by association spokesman Morgan D. Dubrow, who expressed concern about "the unrealistic impressions being given to the public that solar and other so-called appropriate technologies can be put in place quickly and economically and will soon make a major contribution to the nation's power needs."

As a result, Dubrow complained, "people are beginning to rebel against construction of additional power plants and other facilities needed to provide future electrical requirements of a demanding public."

Carter's critics also point out that he chose the middle of three options proposed in the final report of his domestic policy review. The most stringent set of policy options envisioned mandatory federal actions to promote solar development if the response to solar incentives appeared to be insufficient. Some solar advocates would like to see federal building standards, which include solar design features, made mandatory for new housing projects that benefit from federal mortgage guarantee programs.

OUTLOOK

Solar energy appears to benefit as well as suffer from the localized applications of solar energy—rooftop collectors, windmills, small hydro projects—that are so attractive to the resource's most ardent supporters.

These relatively small-scale technologies that must be individually—and sometimes ingeniously—tailored to specific geographic and climatic conditions are broadly appealing to a generation of young Americans who express little faith in large institutions. But the very diversity of the basket of solar resources, along with the regional variations in sun, wind and water resources, makes it difficult to construct a uniform national policy for fostering solar power development.

One national trend working in solar's favor, however, is the rapid population growth in the Sunbelt states of the South and Southwest. That is where sunshine is most dependable and most housing construction activity is taking place—two conditions that should enable solar technologies to flourish.

But many local decisions and accommodations will have to be worked out along the way. And, as stressed by the energy executives who met last summer at Aspen, a great many understandings will have to be reached between large institutions and those who seek independence from them.

"The centralized versus decentralized debate is far more complex than a simple debate of big versus small, solar versus nuclear, or soft versus hard technologies," the conferees concluded.

Power companies, they said, will have to adapt to competition from new energy sources. "Considerable evidence indicates that future electric systems will incorporate a broad mix of technologies and institutional arrangements."

To accomplish such a marriage will require a considerable degree of accommodation on all sides. The Harvard Business School energy team concluded its argument for a solar future with a somewhat fervent plea for such improved relations:

"We wish to stress the need for greater understanding among normally warring parties. For instance, public interest groups must understand the substantial and complex difficulties faced by utilities as they try to adapt to the new energy era." □

To Teachers

WHO PLAN TO USE THE READER WITH STUDENTS

Whether you are teaching young people or adults, whether you use this reader for classroom reading or for student assignments, there are a few facts that you should be aware of.

1. You have certain rights to and restrictions on your use of the material in this reader under the copyright law.

2. The statements and opinions contained in this material should be weighed and evaluated carefully.

3. In using readings with students, preparation and follow-up are as important as the reading itself.

Let's look at each of these points more closely.

Your Right to Use the Reader

The articles included in this reader are reprinted here by the generosity of a number of writers, artists, editors, and publishers. Where the material is copyrighted (and most of it is), the copyright appears with the article, poem, or story. The copyright law does allow teachers to reproduce such material; however, there are limitations on that right. To make your rights as an educator clear, and to encourage you to use the reader, we have included the Congressional Guidelines for Classroom Copying. These guidelines appear on pages 53-5.

Point of View

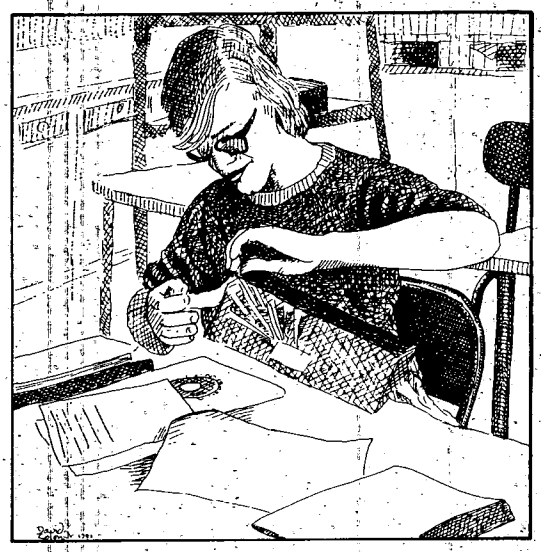
No magazine article can give you the full energy story; writers and publishers, like everyone else, have points of view. We can't guarantee that the articles included here are completely objective or all-inclusive. What this reader does attempt to do is to give a broad sampling. For suggestions on how to read thoughtfully and how to help students do the same, read on.

Reading: Preparation and Follow-Up

To profit from a reading, the person doing the reading must begin with

motivation,
background,
reading ability and vocabulary, and
critical skills

How can you be sure that you and your students get the most from your energy reading? Below are some suggestions for preparation and follow-up on reading assignments.



Motivation

Students today know that their future literally depends on energy. It's not hard to motivate them to read about energy, if you remind them that energy knowledge gives them more control over that future. To motivate,

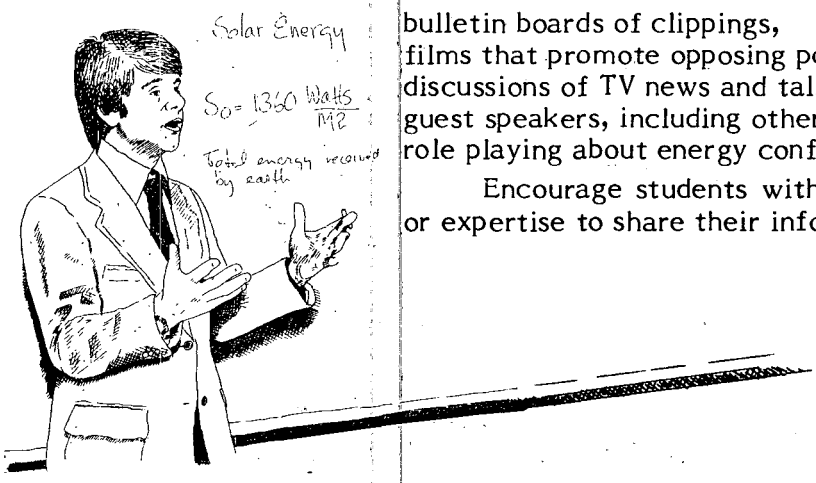
discuss sources of anxiety for them and their families, such as:
- rising costs,
- blackouts and shortages,
- political and strategic barriers to energy supply, and
- daily necessities and comforts that depend on energy;

use questions to encourage imagining and sharing, like:
- "Have you ever been in a greenhouse? What was it like?"
- "What would happen to utility companies if everyone used solar energy?"
- "Do you remember how you felt when you first became aware of an energy crisis?"
- "How do you think a person in a developing country might feel about energy use in the United States?"
- "How would you design a completely self-sufficient house?"

or do a pre-reading activity, for example:
- try a simple experiment or demonstration related to the article's subject,
- take a poll or survey,
- plan a debate or writing assignment based on the article's information, or
- consider various energy futures and raise questions about the probable outcomes.

Background

Students care about the energy future, but they often lack specific information. They tend to get their opinions by hearsay, and talk in generalities and slogans. They need more context for their reading. You can break through oversimplified thinking with



bulletin boards of clippings,
films that promote opposing points of view,
discussions of TV news and talk shows,
guest speakers, including other faculty members, or
role playing about energy conflicts.

Encourage students with special knowledge or expertise to share their information.

Reading Ability and Vocabulary

Not every reading is intended for every student. In fact, some of the articles in the reader are only appropriate for teachers and advanced students. Stack the deck for reading success:

1. Select articles at the appropriate reading level. (They are keyed in the table of contents with color tabs; one for easy, two for intermediate, and three for difficult.)

2. Introduce new words before beginning the reading. Students can use the glossary (page 57) or they can try to figure out the meanings of the words from their context.

3. Attack the reading at the easiest (informational) level first, and then lead students to the more difficult levels:
   First, search for and recall facts.
   Second, consider what the writer is trying to communicate.
   Third, apply what the writer says to one's own experience.
   Fourth, analyze how the writer presents his/her ideas.
   Fifth, suggest new ways of presenting or adding to these ideas.
   Last, evaluate and express opinions on the material.

Critical Skills

Students like magazine readings because they perceive magazines as "adult" reading. But reading like an adult requires 1) desire for objectivity and 2) tolerance for ambiguity.

Desire for Objectivity

Help students to generate questions about the reading that encourage objectivity:

Who is the author?
Is he/she associated with some special interest group?
What are his/her claims to expertise?
Where does he/she use facts and where, opinions?
What is the quality of the evidence?
How can the assertions be verified or compared with opposing views?
Is the information up-to-date?
Is the style objective and balanced?
Does the author use propaganda techniques and emotional appeals?
Does the article leave out or gloss over certain points?

Tolerance for Ambiguity

Encourage students to be aware of ambiguities in their reading and discuss them:

Are there things the author has left out (intentionally or unintentionally)?
Are there other possible points of view on the subject?
May time and events alter the validity of what the author says?
Is the real situation more complex than the author suggests?
Does the author admit to uncertainty on some points?

With this kind of thoughtful preparation and follow-up, a reading becomes more than just another assignment. It becomes an opportunity to expand vocabulary, sharpen thinking, and develop more mature skills in evaluating ideas.

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Agreement on Guidelines for Classroom Copying

in Not-for-Profit Educational Institutions with Respect to Books and Periodicals

The purpose of the following guidelines is to state the minimum and not the maximum standards of educational fair use under Section 107 of H.R. 2223. The parties agree that the conditions determining the extent of permissible copying for educational purposes may change in the future; that certain types of copying permitted under these guidelines may not be permissible in the future; and conversely that in the future other types of copying not permitted under these guidelines may be permissible under revised guidelines.

Moreover, the following statement of guidelines is not intended to limit the types of copying permitted under the standards of fair use under judicial decision and which are stated in Section 107 of the Copyright Revision Bill. There may be instances in which copying which does not fall within the guidelines stated below may nonetheless be permitted under the criteria of fair use.

Guidelines

I. Single Copying for Teachers

A single copy may be made of any of the following by or for a teacher at his or her individual request for his or her scholarly research or use in teaching or preparation to teach a class:

A. A chapter from a book;
B. An article from a periodical or newspaper;
C. A short story, short essay or short poem, whether or not from a collective work;
D. A chart, graph, diagram, drawing, cartoon or picture from a book, periodical, or newspaper.

II. Multiple Copies for Classroom Use

Multiple copies (not to exceed in any event more than one copy per pupil in a course) may be made by or for the teacher giving the course for classroom use or discussion; provided that:

A. The copying meets the tests of brevity and spontaneity as defined below; and,
B. Meets the cumulative effect test as defined below; and,
C. Each copy includes a notice of copyright.

Definitions

Brevity

(i) Poetry: (a) A complete poem if less than 250 words and if printed on not more than two pages or, (b) from a longer poem, an excerpt of not more than 250 words.

(ii) Prose: (a) Either a complete article, story or essay of less than 2,500 words, or (b) an excerpt from any prose work of not more than 1,000 words or 10% of the work, whichever is less, but in any event a minimum of 500 words.

Each of the numerical limits stated in "i" and "ii" above may be expanded to permit the completion of an unfinished line of a poem or of an unfinished prose paragraph.

(iii) Illustration: One chart, graph, diagram, drawing, cartoon or picture per book or per periodical issue.

(iv) "Special" works: Certain works in poetry, prose or in "poetic prose" which often combine language with illustrations and which are intended sometimes for children and at other times for a more general audience fall short of 2,500 words in their entirety. Paragraph "ii" above notwithstanding such "special works" may not be reproduced in their entirety; however, an excerpt comprising not more than two of the published pages of such special work and containing not more than 10% of the words found in the text thereof, may be reproduced.

Spontaneity

(i) The copying is at the instance and inspiration of the individual teacher, and,

(ii) The inspiration and decision to use the work and the moment of its use for maximum teaching effectiveness are so close in time that it would be unreasonable to expect a timely reply to a request for permission.

Cumulative Effect

(i) The copying of the material is for only one course in the school in which the copies are made.

(ii) Not more than one short poem, article, story, essay or two excerpts may be copied from the same author, nor more than three from the same collective work or periodical volume during one class term.

(iii) There shall not be more than nine instances of such multiple copying for one course during one class term.

The limitations stated in "ii" and "iii" above shall not apply to current news periodicals and newspapers and current news sections of other periodicals.

III. Prohibitions as to I and II Above

Notwithstanding any of the above, the following shall be prohibited:

A. Copying shall not be used to create or to replace or substitute for anthologies, compilations or collective works. Such replacement or substitution may occur whether copies of various works or excerpts therefrom are accumulated or reproduced and used separately.

B. There shall be no copying of or from works intended to be "consumable" in the course of study or of teaching. These include workbooks, exercises, standardized tests and test booklets and answer sheets and like consumable material.

C. Copying shall not:

(a) substitute for the purchase of books, publishers' reprints or periodicals;
(b) be directed by higher authority;
(c) be repeated with respect to the same item by the same teacher from term to term.

D. No charge shall be made to the student beyond the actual cost of the photocopying.

Publications Address List

THE APPRAISAL JOURNAL
American Institute of Real Estate Appraisers
430 North Michigan Avenue
Chicago, Illinois 60611

THE ATLANTIC MONTHLY
8 Arlington Street
Boston, Massachusetts 02116

JOURNAL OF HOME ECONOMICS
American Home Economics Association
2010 Massachusetts Avenue, N.W.
Washington, D.C. 20036

NATIONAL JOURNAL
Government Research Corporation
1730 M Street, N.W.
Washington, D.C. 20036

SATURDAY REVIEW
150 East 58th Street
New York, New York 10155

SIERRA
530 Bush Street
San Francisco, California 94108

Glossary

a

active solar energy system
a system which requires external mechanical power (motors, pumps, valves, etc.) to operate the system and to transfer the collected solar energy from the collector to storage or to distribute it throughout the living units. Active systems can provide space heating and cooling, domestic hot water, and/or steam for industrial use.

b

backup energy system
an energy system using conventional fuels to supply all the heating and domestic hot water during any period when the solar energy system is not operating.

biomass
a volume or amount of plant material in any form: algae, wood, plants, crop residue, animal manure, etc.

breeder reactor
a more complex nuclear reactor than ones now in commercial use, a breeder converts non-fissionable uranium or thorium to nuclear fuel. Conventional nuclear reactors depend on fission of an uncommon form of uranium, U_{235}, which comprises less than 1% of uranium ore. To extend the use of uranium, breeder reactors may be able to change more abundant forms of uranium into fissionable elements. Higher operating risks, engineering problems, and waste disposal considerations have been factors in slow development of breeder technology.

c

capital intensive
requiring heavy capital investment. The energy industry, for example, is said to be capital intensive rather than labor intensive because it employs relatively more dollars and relatively fewer people compared to some other industries.

coal
solid fuel formed by the decomposition of plants buried deep under the earth's surface. A group of naturally occurring, carbon and hydrogen-rich substances are called "coal". Various types are ranked by the percentage of carbon in dried samples or by the caloric value of moist ones. From least to most carbon-rich, the coal group includes peat, lignite, sub-bituminous and bituminous coals, and anthracite.

conservation
making the best use of natural resources by reducing waste, improving efficiency, and slowing the rate of consumption.

d

e

energy transition
a time in history when there is a significant change in the mix of energy resources on which people depend. An example is the transition in the U.S. from use of coal and wood primarily (as in 1900) to widespread use of gas and petroleum, in addition to coal, by 1950. Another example is the entry of nuclear power generation on the commercial scene and its increased contribution to total energy needs, up from 1% in 1973 to 4% in 1979. If the future brings greater reliance on renewable resources and less dependency on fossil fuels, OR if fission/fusion processes generate the major share of commercial electricity, either of these scenarios would be another "energy transition".

environment
the sum of all external conditions and influences affecting the life, development, and ultimately the survival of an organism.

f

fission
a nuclear reaction in which large atoms are split in two with the release of large amounts of energy. Heat produced by fission of a particular kind of uranium, U_{235}, is used to generate electricity in Western Europe, the U.S., and Japan.

flat-plate collector
an enclosed, glazed panel containing a dark absorbing surface that converts sunlight to heat without the aid of a reflecting surface to concentrate the rays. The collector transfers its heat to a circulating fluid.

fossil fuels
coal, petroleum, and natural gas; this term applies to any fuels formed from the fossil remains of organic materials (plants and animals) that have been buried for millions of years. The ultimate source of energy for those plants and animals was the sun.

fusion (nuclear)
a nuclear reaction involving combinations of small atomic nuclei into larger ones with a tremendous release of energy. Experimental fusion reactors are being developed in Europe and the U.S. The fuel for fusion is deuterium, a form of hydrogen which occurs naturally in sea water in a ratio of one atom to 6,500 atoms of normal hydrogen. Deuterium fuel is abundant, but technical and economic feasibility of fusion processes as the bases for electrical power is problematic.

g

generating capacity
the top capacity of a power plant to generate electricity. Usually measured in megawatts.

geothermal energy
heat trapped in the interior of the earth is called geothermal energy. Boreholes into the crust show an average temperature increase of 1° C for every 30 meters of depth, or about 100° F per mile. Geothermal heat is believed to come from the decay of radioactive materials deep in the earth as well as from friction of rock movements, tidal forces, and perhaps other sources. This heat keeps great quantities of buried rock molten and hot. Some of this energy escapes at the surface as hot water. Geothermal energy is available in four forms: dry steam, wet steam, hot rocks, and hot water.

greenhouse effect
a phenomenon which converts solar radiation to heat. Sunlight penetrates glazing quite easily but, when absorbed by objects behind the glazing, is reradiated as heat which does not penetrate the glazing as easily. Heat is thereby trapped and can be used. Also: the warming effect of carbon dioxide and water in the atmosphere acting as a "lid" to slow the escape of heat from the earth's surface. Molecules of water and carbon dioxide absorb and reradiate back to earth much of the heat radiated from it.

h

heat
energy that flows between a system and its surroundings because of a temperature difference between them. Heat results from the motion of molecules of matter. Also, the word heat is often used to refer to the energy contained in a sample of matter (for example, kilocalories per unit of food).

hydroelectric plant
an electric power plant in which the energy of falling water is converted into electrical energy by a turbine generator.

i

insolation
the energy received by earth from the sun, a contraction of the three words: incoming solar radiation. The total daily insolation is the equivalent of about 4.2 quadrillion kilowatt hours. Local insolation depends on the position of the earth in its orbit, the thickness and transparency of the atmosphere, the inclination of the intercepting surface to the sun's rays, and the solar constant. Weather bureaus now keep insolation data or "sunshine statistics".

insulation
material with high resistance (R-value) to heat flow. Some commonly used materials for home insulation are fiberglass, cellulose, rock wool, and styrofoam.

j k l

m

megawatt
a unit of power equal to 1,000 kilowatts or one million watts.

n

natural gas
a mixture of gaseous hydrocarbons occurring naturally in certain rocks. There are several kinds of gas trapped in porous rocks underground. One of these "natural gases" is methane, used as a commercial fuel. Petroleum deposits always include some methane, but natural gas deposits are not always accompanied by petroleum. Natural gas is commonly sold to individuals in hundreds of cubic feet (CCF), the unit appearing on household utility bills. One CCF of commercial methane has about 25,000 kilocalories, the equivalent of 8 pounds of coal or 0.7 gallons of crude oil.

nonrenewable resources
energy resources that are not being replaced during the time span of human history. Examples are coal, oil, natural gas, and uranium.

nuclear power plant
a generating station where heat for creating steam comes from nuclear fission instead of from combustion of fossil fuels.

nuclear reactor
a device in which a fission chain reaction can be initiated, maintained, and controlled.

o

ocean-thermal energy conversion (OTEC)
an energy technology in which the temperature difference (between cold deep water and the warm surface water 2,000 feet above it) in tropical oceans is used to generate electricity.

p

passive solar energy system
an assembly of natural and architectural components which converts solar energy into usable or storable thermal energy (heat) without mechanical power. Current passive solar energy systems often include fans, however.

petroleum
an oily, flammable liquid that may vary from almost colorless to black and that occurs in many places in the upper strata of the earth. It is a complex mixture of hydrocarbons and is the raw material for many products including gasoline, kerosene, lubricants, and waxes.

photovoltaic cell
a device which converts solar energy directly into electricity. Sunlight striking certain materials (silicon is most common) causes the release of electrons. The migration of these released electrons produces an electrical current. The conversion process is called the photovoltaic effect.

power
the rate at which work is performed. It is measured as units of energy per unit of time, for example: calories per second, watts (joules per second), or horsepower (foot-pounds per second).

q

quad
a gigantic energy unit (often used to state how much energy entire countries buy each year). It represents a quadrillion Btu or the amount of heat energy in 172 million barrels of oil. U.S. citizens used more than 78 quads of commercially-supplied energy in 1979.

r

radiation
the method by which heat is transferred through open space. About 60% of the heat transferred to a room from a wood stove is by radiation. Sunlight travels to us by radiation through space at "the speed of light", 299,728 kilometers per second.

reclamation
the process of replacing the soil, clay, and rocks removed earlier to expose coal or oil shale for strip mining; compacting and contouring the site; and replanting it to restore its appearance and reduce erosion and drainage of waste materials. (See strip mining.)

renewable resources
materials that are recycled by natural processes within a relatively brief span of time (a human lifetime). Fresh water, wind, sunshine, and trees are some examples of resources that replace or recycle themselves within human time frames.

retrofit
to modify an existing building by adding a solar heating or cooling system or insulation to improve its energy efficiency.

s

solar access or solar rights
the right to receive direct sunlight without interference. The protection of solar access is a legal issue.

solar energy
the electromagnetic radiation emitted by the sun. The earth receives about 4,200 x 10^{15} kilowatt-hours of solar radiation per day.

storage
the device or medium that absorbs collected heat and stores it for later use.

strip mining
mining for coal or useful ores by removing the soil and rock found above them, rather than by tunneling underground.

synthetic fuel
liquid, solid, or gaseous fuels produced from carbon-rich materials by human technology. Examples are coal gasification, coal liquefaction, oil shale extraction, and trash-to-energy conversions.

t

temperature
a measure of the energy of motion of the atoms and molecules of a substance. Thermometers and thermistors are used to measure an object's temperature. Temperature is not the same as heat. The tip of a burning match has a high temperature, but the object as a whole might contain very little heat due to its size.

thermonuclear reaction
a fusion reaction which is initiated by intense heat. The sun's energy production and hydrogen bombs are examples of thermonuclear reactions.

u v

w

wastes, radioactive
by-products of producing power by splitting atoms in a nuclear power plant; some of these materials are highly radioactive and remain radioactive for long periods of time.

work
energy transferred from one object to another, that is, a force acting against resistance to produce motion in a body; measured by the product of the force acting and the distance moved through, against the resistance.

x y z

Bibliography

Solar Overviews

"Solar Energy: Where It Is and Where It's Going" by Pam Hait, ARIZONA HIGHWAYS, May 1980, pp. 6-11, 35, 43-44.

"Soft and Hard Energy" by Nicholas Wade, THE NEW REPUBLIC, February 25, 1978, pp. 25-29.

"Solar Energy: Wave of the Future?" by Daniel I. Levy, JOURNAL OF PROPERTY MANAGEMENT, July/August 1976, pp. 151-154.

"Kilowatts from the Sky" by Peter Britton, THE LAMP, Summer 1976, pp. 16-21.

"Something New Under the Sun" by John W. Moore and Elizabeth A. Moore, THE SCIENCE TEACHER, January 1976, pp. 34-35.

"The Sun in a Drawer" by Bruce Anderson, ENVIRONMENT, October 1975, pp. 36-41.

"The Energy Resources of the Earth" by M. King Hubbert, SCIENTIFIC AMERICAN, September 1971, pp. 60-70.

Life-Style and Energy Use

"Solar Peasants" by Peg Boyles, BLAIR & KETCHUM'S COUNTRY JOURNAL, January 1981, pp. 37-43.

"Living Without Electricity" by David Bear, BLAIR & KETCHUM'S COUNTRY JOURNAL, August 1980, pp. 68-71.

"Energy from Muscles" by John J. Pullen, BLAIR & KETCHUM'S COUNTRY JOURNAL, March 1980, pp. 36-41.

"Changing Family Lifestyles: Adapting to the Energy Crisis" by Thomas A. Cornille, Karol S. Oransky, and Ruth Pestle, JOURNAL OF HOME ECONOMICS, Winter 1979, pp. 36-37.

"Human Equivalent Power" by Everett Hafner, ENVIRONMENT, July/August 1979, pp. 34-37.

"Energy and Families: The Crisis and the Response" by Bonnie Maas Morrison et al, JOURNAL OF HOME ECONOMICS, Winter 1978, pp. 18-21.

"Energy Decisions and Quality Living" by Beatrice Paolucci, JOURNAL OF HOME ECONOMICS, Winter 1978, pp. 22-26.

"Strategies for Energy Conservation" by Nancy M. Rudd and Molly Longstreth, JOURNAL OF HOME ECONOMICS, May 1978, pp. 40-43.

"Textiles and Energy" by Sara L. Butler, JOURNAL OF HOME ECONOMICS, May 1978, pp. 44-45.

"Energy and the Family", JOURNAL OF HOME ECONOMICS, January 1976, pp. 5-14.

"A 'No-Growth' Economy by the 1980's? Implications for the American Family" by Edward J. Metzen, JOURNAL OF HOME ECONOMICS, November 1975, pp. 12-15.

"Growing Backyard Textiles" by Eleanor Hall Nelson, JOURNAL OF HOME ECONOMICS, May 1975, pp. 16-18.

"Pedal Cars: The Gasless Way to Go" by Sheldon M. Gallager, POPULAR MECHANICS, May 1974, pp. 98-100, 167.

"Housing Technology: How Does It Affect the Energy Crisis?" by James E. Montgomery, JOURNAL OF HOME ECONOMICS, December 1973, pp. 16-22.

"Now It's Pedal Power to Fight Pollution!" by Bruce Wennerstrom, MECHANIX ILLUSTRATED, February 1973, pp. 79-81, 128.

The Energy Future

"The Food Connection" by Peter Farb and George Armelagos, NATURAL HISTORY, September 1980, pp. 26-30.

"Global 2000 Report: Vision of a Gloomy World", by Luther J. Carter, SCIENCE, Vol. 209, 1 August 1980, pp. 575-576.

"Solar Energy Poses Some Elemental Questions" by William C. Hayes, ELECTRICAL WORLD, November 1, 1978, p. 3.

"The Solar Timetable" by Denis Hayes, ENVIRONMENT, July/August 1978, pp. 6-13, 38.

"U.S. Energy Demand: Some Low Energy Futures" by the Demand and Conservation Panel of the Committee on Nuclear and Alternative Energy Systems, SCIENCE, Vol. 200, 14 April 1978, pp. 142-152.

"The Year the Oil Ran Out" by Donald E. Carr, BLAIR & KETCHUM'S COUNTRY JOURNAL, October 1977, pp. 46-49.

"Energy Strategy: Soft vs. Hard Technologies" by Amory B. Lovins, RENAISSANCE UNIVERSAL JOURNAL, Spring 1977, Vol. 2, No. 1, pp. 13-21.

The Government, Industry, and Energy

"Institutional Barriers to Solar Energy: Early HUD Demonstration Experiences" by Gerald Mara and David Engel, SOLAR LAW REPORTER, Vol. 1, No. 6, March/April 1980, pp. 1094-1117.

"Insurers Face Coverage Needs of Solar Systems" by Ken Bossong, SOLAR ENGINEERING MAGAZINE, March 1980, pp. 11,13.

"The Federal Government Must Do Much More to Push Solar for Homes", CIVIL ENGINEERING-ASCE, February 1980, p. 42.

"Ripping Off the Sun" by Richard Munson, THE PROGRESSIVE, September 1979, pp. 12-15.

"Solar Comes Out of the Shadows" by Charles G. Burck, FORTUNE, September 24, 1979, pp. 67-75.

"Energy Economics", THE NEW REPUBLIC, July 7 & 14, 1979, p. 5.

"The Role of the Government in Subsidizing Solar Energy" by Michael D. Yokell, AMERICAN ECONOMIC REVIEW, Vol. 69, No. 2, May 1979, pp. 357-361.

"Solar and Utilities/Utility Involvement: A Roundtable Discussion" by Bruce Anderson, SOLAR AGE, December 1978, pp. 12-17.

"The Coming Boom in Solar Energy", Special Report, BUSINESS WEEK, October 9, 1978.

"Letting the Sun Shine" by Ralph Nader, SOLAR AGE, January 1978, pp. 12-13.

"Solar Energy Research: Making Solar After the Nuclear Model?" by Allen L. Hammond and William D. Metz, SCIENCE, Vol. 197, 15 July 1977, pp. 241-244.

"The Link Between Energy Policy and Unemployment" by Barry Commoner, NATION'S CITIES, February 1977, pp. 13-15.

Solar and the Law

"The Solar Envelope" by Ralph L. Knowles, SOLAR LAW REPORTER, Vol. 2, No. 2, July/August 1980, pp. 263-297.

"Describing the Solar Space in a Solar Easement" by Eugene J. Riordan and Robert L. Hiller, SOLAR LAW REPORTER, Vol. 2, No. 2, July/August 1980, pp. 299-319.

"Simplified Solar Easements" by Kenneth H. Burke and Bruce N. Lemons, SOLAR LAW REPORTER, Vol.2, No. 2, July/August 1980, pp. 321-340.

"Drafting a Simple Solar Easement" by Gregory Franta, SOLAR LAW REPORTER, Vol. 2, No.2, July/August 1980, pp. 341-346.

"Siting ≠ Protection: A Note on Solar Access" by Dale D. Goble, SOLAR LAW REPORTER, Vol. 2, No. 1, May/June 1980, pp. 25-55.

"Who Owns the Sun?" by Barbara J. Grady, TITLE NEWS, October 1979, pp. 7-15, 25.

"The Solar Surveyor: Scanning a New Horizon" by Gunther Greulich, TITLE NEWS, October 1979, pp. 16-20.

"The Solar Lending Quandary" by Forrest F. Leigh, TITLE NEWS, October 1979, pp. 21-22.

"Legal Obstacles to Decentralized Solar Energy Technologies" by Alan S. Miller, SOLAR LAW REPORTER, Vol. 1, No. 3, September/October 1979, pp. 595-612.

"Legal Aspects of Solar Energy Development" by Donald N. Zillman and Raymond Deeny, ARIZONA STATE LAW JOURNAL, 1976:25, pp. 25-57.

"Legal Access to Light: the Solar Energy Imperative" by Daniel P. Moskowitz, NATURAL RESOURCES LAWYER, Vol. IX, No. 2, 1976, pp. 177-208.

Solar Consumerism

"Solarizing? Here Are Guidelines for Getting a Square Deal" by David Dvorkin, SCIENCE DIGEST, January 1980, pp. 73-75.

"Selecting a Solar Contractor" by the Southern California Solar Energy Association, SOLAR AGE, February 1979, p. 15.

"New Danger: Solar Ripoffs" by Frank K. Coffee, MECHANIX ILLUSTRATED, February 1978, pp. 70, 132.

Local and Regional Responses

"How Tennessee Homeowners Get a Solar Assist" by Travis Price, POPULAR SCIENCE, March 1981, pp. 76-77.

"The More-Conserving-Than-Thou Northwest" by Cassandra Tate, BLAIR & KETCHUM'S COUNTRY JOURNAL, January 1981, pp. 74-87.

"Energizing America: Project SUEDE and the Solar Retrofit" by David Holzman, SOLAR AGE, September 1980, pp. 12-14.

"Nature's Energy" by Chris Carpenter, ADIRONDACK LIFE, September/October 1980, pp. 18-21, 52-55.

"Planning for a Sunny Future" by Twila de Vries and John Yellott, ARIZONA HIGHWAYS, May 1980, pp. 2-5.

"Minnesota Is Tops in Underground Space", SOLAR AGE, October 1979, pp. 40-43.

"Energy Conservation in Davis, California" by Desmond A. Jolly and Kangethe Gitu, JOURNAL OF HOME ECONOMICS, May 1978, pp. 37-39.

International Solar

"The Japanese Photovoltaic Threat" by Douglas L. Finch, SOLAR AGE, February 1981, pp. 34-37.

"China Updates Ancient Energy - with Emphasis on Solar" by Kevin Fountain, SCIENCE DIGEST, April 1980, pp. 26-29.

"The Future of Solar Power" by Anil Agarwal, ATLAS WORLD PRESS REVIEW, October 1979, pp. 27-29.

"Some European Solar Thermal Power Systems" by Clifford S. Selvage, SOLAR AGE, July 1979, pp. 9-11.

"Appropriate Technology in Africa" by Mona Anderson, SOLAR AGE, May 1979, pp. 42-45.

"Prince Edward Island Explores Energy Self-Sufficiency" by George Ellis, SOLAR AGE, December 1978, pp. 26-27.

"Solar Energy: the Third World First?" by Denis Hayes, AGENDA, January 1978, pp. 1-8.

"Energy Conservation Abroad" by George G. Wynne, NATION'S CITIES, February 1977, pp. 7-8.