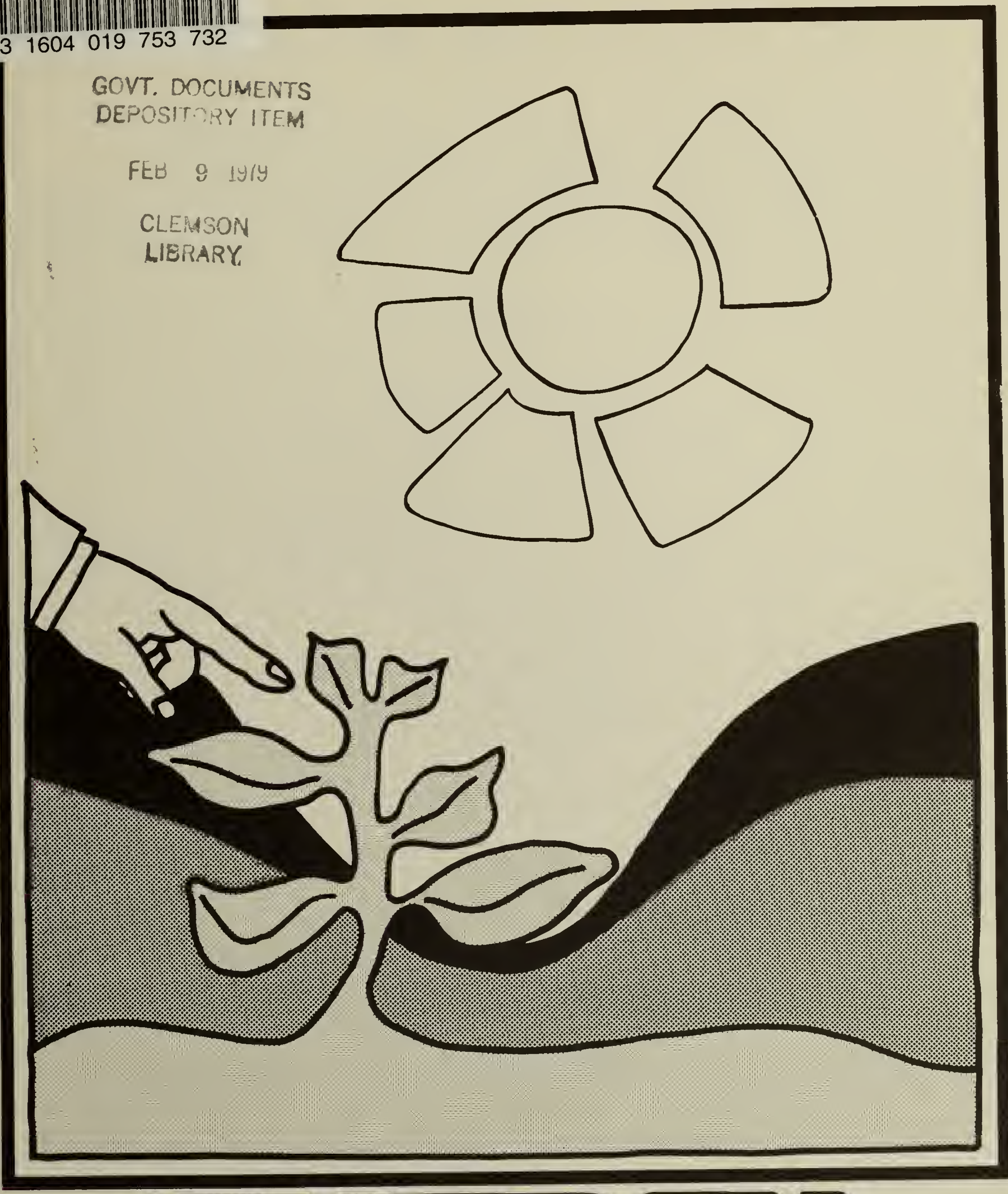

ENERGY
MANUAL FOR PARKS
A HANDBOOK FOR INTERPRETERS AND NATURALISTS

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by
Lee Stephenson

Project Coordination
Nancy Carson Shirk

Writing on ENERGY CONSERVATION
David Howell

Writing on ADAPTING
Jean Matthews and Loran Fraser

Editorial Production
Anita Finkelstein

Editorial Assistance
Catherine Lerza
Deborah Baldwin

Design
Attic & Cellar Studios

NATIONAL RECREATION AND PARK ASSOCIATION

April 1976

To the Park Interpreter and Naturalist:

The ENERGY MANUAL FOR PARKS has been prepared to give you the most up-to-date and accurate information available on energy use by nature and by people. It contains tools you can use to help park visitors gain a new understanding of energy, both in the park and at home. We have tried to tailor the MANUAL to your special needs; now we hope you will tell us it can be improved. We are eager for your opinions and questions. The last page in this book is a stamped evaluation and information request form for your convenience. Please tear it out and mail it to us.

Loran Fraser	**Kirk Marckwald**	**Becky Milliken**
Nancy Carson Shirk	**Lee Stephenson**	**Anne Townsend**

Acknowledgements

Thank you to the following people, who were of enormous help.

Wilson Clark	**G. Tyler Miller Jr.**	**Vivian Sande**
Roy Graybill	**Gary Mozel**	**Andy Sansom**
Charlie Knuth	**Tom Robertson**	**Lee Schipper**

The ENERGY MANUAL FOR PARKS was prepared by the National Recreation and Park Association (NRPA), 1601 N. Kent Street, Arlington, VA., 22209, (703) 525-0606. NRPA also conducts the Park Project on Energy Interpretation, funded by the Federal Energy Administration, which encourages the use of information on energy conservation in park interpretive programs. This project is now underway at approximately 100 sites in some 20 park systems across the country. The Project is described more fully in Appendix A. The views presented in the MANUAL are those of the authors. Additional copies are available from NRPA at $3.00 each.

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INTRODUCTION

"The places we manage are those places where the whole man -- physical, thoughtful, joyful -- can reach toward fulfillment."

-- William E. Brown

Parks are special places.

They represent many things to many people, and the reactions of visitors vary greatly, reflecting both their expectations and their experiences. The park experience ranges from quiet, isolated exploration and solitude to joyous coming together and the most human forms of sharing.

Park interpreters and naturalists are special people. They help a visiting public, increasingly cut-off from natural origins and connections, come to terms with a park -- an unfamiliar or perhaps new setting. They often serve as guides in search for something almost lost by modern society -- the ability to feel at home with nature.

A park, a natural system, provides an opportunity for a rediscovery of the laws which ultimately control our development. A park shows the way energy and matter are used in nature as opposed to the way we, apart from nature, use energy and matter. Parks also show the direct impact of our energy consumptive ways. Most park visitors come in cars and buses powered by gasoline; they consume food and desire shelter; they leave wastes of many forms; they occasionally overload existing natural ecosystems and in many ways change the park by their presence. Many parks are involved in controversy over the extraction or processing of energy resources nearby. So, in the park setting, millions of people each year have a unique opportunity to observe natural and man-made energy interactions, similarities and differences.

The United States is now in a period of uncertainty. One of our concerns is energy. After a brief but traumatic bout with gasoline scarcity, Americans are now faced with rising energy dollar costs, but availability of supply for those who can pay. Many conflicting and disparate messages about the reality of the "energy shortage" bombard the public; a natural skepticism results.

The Park Project on Energy Interpretation is an attempt to take advantage of the park setting, the park interpreter's knowledge and experience, and the park visitor's natural curiosity, to try and communicate some information about energy.

The Project reflects a belief that very real adjustments are going to be made in our society because of changing fossil fuel patterns. It also reflects an informed commitment to immediate conservation of energy throughout the economy, by everyone, as the most immediate, reliable, and universally available alternative for dealing with the situation, in both the short and long term. There are even benefits to be gained from conservation in addition to extending our energy supplies; these benefits include restraint on environmental degradation and increased sharing and human exchange.

We are adaptive creatures. In addition to drawing on natural inventiveness, we can learn from nature. Certain natural system models, such as the carrying capacity of ecosystems, the adaptive devices used by plants and animals to cope with changes of climate, the use of simple processes, and the reliance on diverse local communities, tell us much about how to survive and flourish on our planet.

Humans come into contact with natural systems in the park -- sometimes *only* there. The park interpreter therefore is able to touch people at a significant point, to share a significant experience.

This book is designed to supply information on energy which the park interpreters can add to their understanding of natural environments, and to suggest ways in which this and other Project materials can be integrated into on-going park interpretive programs. And since this book will also be used by those not so familiar with the way nature works, a review of some basic processes is included. Readers are certainly aware that many conflicting opinions and "facts" complicate judgments about our energy problems. We have used our best judgment and the advice of many experts to select the material presented in the Manual. However, so that you can make these judgments for yourself, we have frequently cited the sources for our facts. Books and articles noted in parenthesis are fully identified in the bibliography included in Appendix D.

Energy considerations facing our country raise many questions about the direction of our society and how our goals can be attained. Changes lie ahead for all of us.

1 LIFE FROM THE SUN

The sun is a primary source of all life on earth.

"Energy is the go of things." -- James Clerk Maxwell

The earth and its living things are sustained by a wondrous assortment of resources and natural processes now often taken for granted by humanity. Overlapping and supporting one another in infinitely complex systems of checks and balances, these processes provide the basis for life. The absence of any one of these resources or processes has wide-ranging impact on life, perhaps even eliminating it. Thus ecologists say that everything is connected to everything else. Although we still have much to learn about these processes on earth and know little of what exists beyond our atmosphere in the vast reaches of space, one thing is certain: this "web of life," to use Aldo Leopold's phrase, does not exist on any other known planet.

The most basic life-giving resource available to us is the sun, a star whose awesome power controls the movements of the earth, its eight sister planets, and the host of moons and asteroids in our solar system. Scientists do not know exactly how such stars are created, but most agree that stars are born when great masses of gas and dust come together in space. Our sun is only one of billions of stars in our galaxy -- the Milky Way -- and not a particularly large one at that. Our solar system revolves around the center of the Milky Way at a fantastic speed -- roughly 500,000 miles per hour. Even so, it takes 250 million years to complete one revolution around the galaxy, which is only one of billions of galaxies extending into space beyond the reach of our most powerful telescopes.

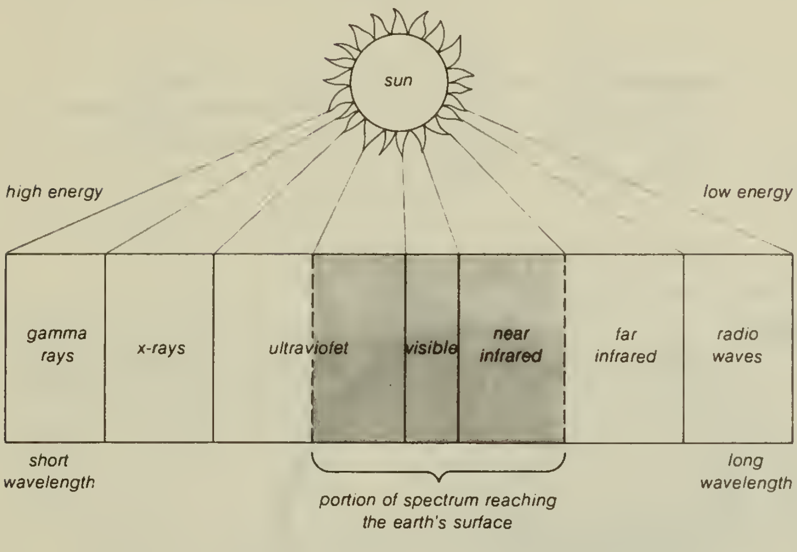
But insignificant as our sun may be in the great expanse of the universe, it works miracles here on earth. Its fiery mass releases an enormous quantity of energy which provides virtually all of the power to run the "great engine of earth." It heats the atmosphere, melts ice, evaporates water, generates winds, waves, and currents, and even tears down and rebuilds the landscape as wind and water erode existing land features while shifts in the earth's crust create new features. Most spectacular of all, our sun, in cooperation with plants, stores on the earth's surface the energy from which all life springs.

Our sun is composed primarily of hydrogen and is constantly undergoing a nuclear chain reaction which consumes 4.2 million tons of its mass every second. The chain reaction results when the intense heat in the sun's core, estimated at 36 million degrees Fahrenheit, causes light molecules of hydrogen to fuse together, creating heavier elements and releasing vast amounts of energy.

This energy emanates from the sun in all directions in the form of electromagnetic waves. The waves radiating on a path toward earth, less than one-billionth of the sun's released energy, travel the 93 million miles to our atmosphere in eight minutes. The result is a continuous daytime supply of electromagnetic energy, equivalent to an estimated 2.5 *billion billion* horsepower.

Even though the sun consumes an enormous quantity of its mass every minute, there is no immediate danger that it will burn up. Estimated to be 10 billion years old, the sun has enough hydrogen to perpetuate its energy-producing reaction for eight billion more years. It is just entering middle age.

The electromagnetic energies emanating from the sun have a variety of wavelengths, only some of which are the visible energy we call sunlight (Figure 1-1). About one-third of the energy, including most of the harmful, short-wavelength ultraviolet rays (which can cause skin cancer), are deflected or temporarily stored by the earth's atmosphere and radiated back into space. A tiny portion of the energy reaching our atmosphere (estimated to be four one-hundredths of one percent) drives all of the processes which support life. Without this energy from the sun the earth would become a lifeless, cold planet, covered with snow and ice



(Figure 1-1)

The electromagnetic spectrum The sun radiates a spectrum of electromagnetic waves over a wide range of wavelengths and energies, but because of the earth's atmosphere only a small fraction of these actually reaches the earth's surface. (A minor amount of high energy waves also penetrates the atmosphere.)

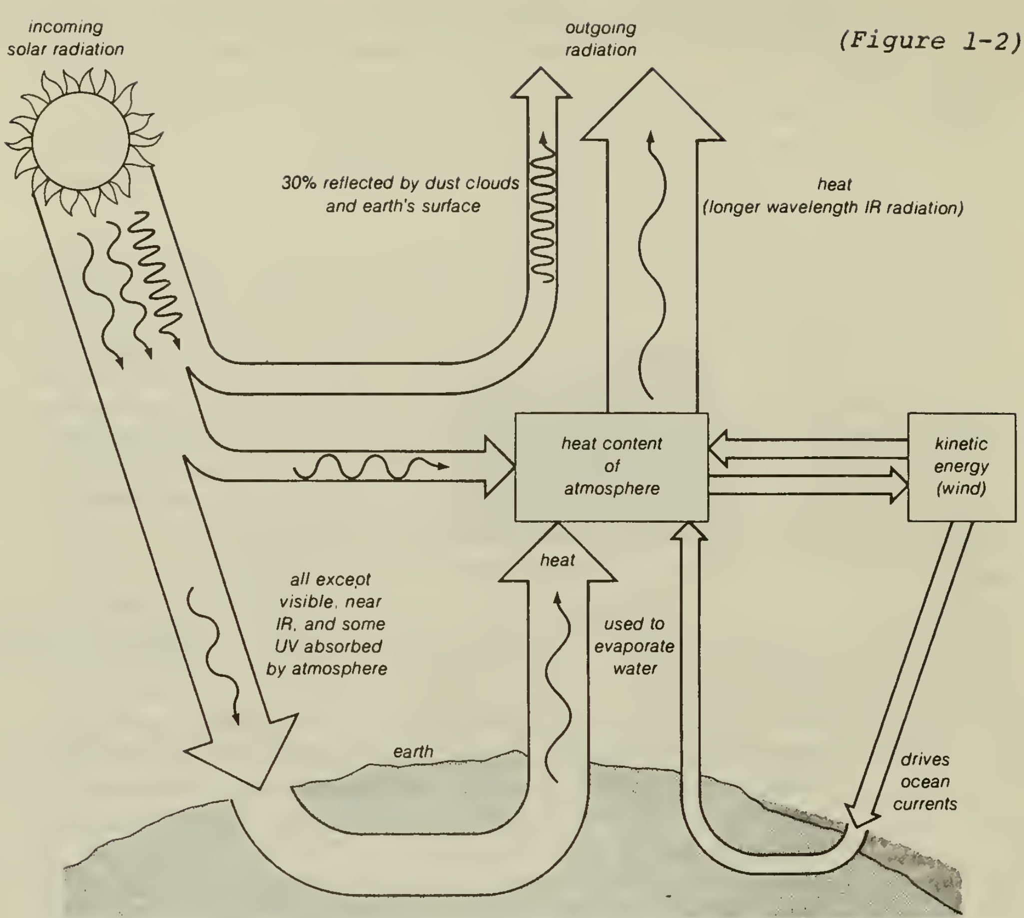
(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

The multitude of physical and life-giving processes of the earth generated by the sun's energy cannot be fully covered here. But consider, for example, the processes of weather-making. The sun's energy warms the earth's surface, which in turn warms the atmosphere (Figure 1-2). But the temperature of the earth and atmosphere is constantly changing from day to night, from season to season, and from the influence of other factors. This creates masses of air at different temperatures and pressures, expanding and contracting, rising and falling and moving laterally as one mass fills the space vacated by another. The landforms of the earth also affect these movements, which we call wind.

At the same time, the sun's warmth causes water on earth to evaporate and be raised into the atmosphere. As this water vapor rises, contact with cooler air converts it to droplets of water which make clouds. The moisture then may be moved over great distances by wind before the water falls as rain. The rain feeds lakes and rivers, which eventually flow into oceans. At any point along this path the water may be evaporated once more and begin the cycle again (Figure 1-3).

The movements of "weather" are not entirely random. In fact, a definite pattern exists. The earth's orientation to the sun causes it to be warmest at its equator; since reflected heat from the earth warms the atmosphere, it is also warmer here. This creates pathways of air movement as warm air rises from areas near the equator and is replaced by cooler air from the north and south. What would otherwise be a

(Figure 1-2)



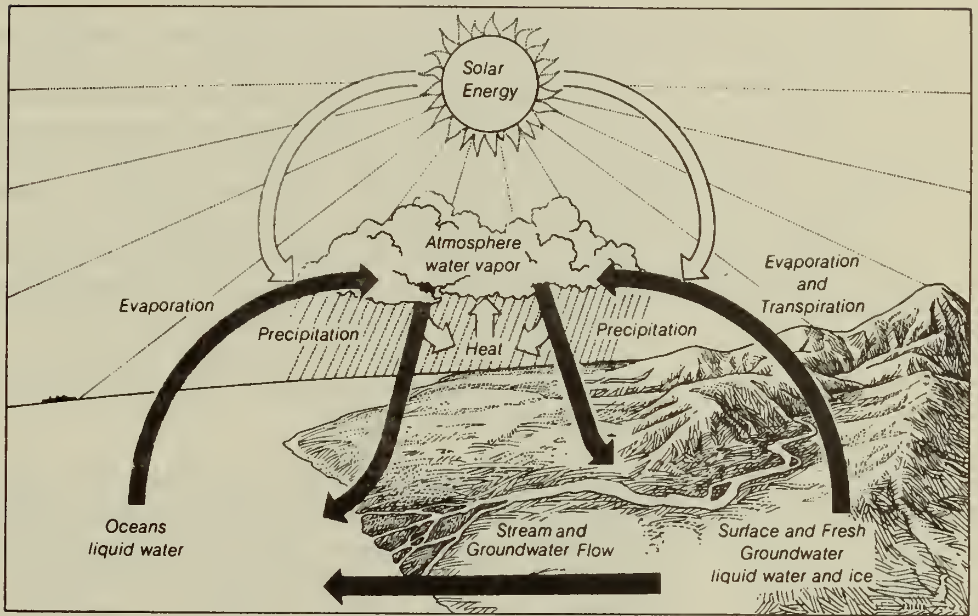
The atmospheric heat balance. In accordance with the first law of thermodynamics, energy in must equal energy out, but in accordance with the second law the energy leaving is degraded to longer wavelength infrared radiation (heat).

(G. Tyler Miller, Jr.,
<u>Living in the Environment</u>,
Wadsworth Publishing Co.)

very orderly exchange of air masses is complicated by the earth's rotation. The planet makes one west to east revolution on its axis every 24 hours. But the earth's surface at the equator is spinning faster (due to its larger diameter) than the surface nearer the poles. As the shifting air masses change location, the direction of their movement is modified by the earth's rotation. In the Northern Hemisphere air currents are generally pushed to the right of the direction they are moving and in the Southern Hemisphere are generally pushed to the left.

This complex system of weathermaking (greatly simplified here) is driven entirely by the sun's energy. It operates largely independently of infinitely more complex life systems on earth, although neither would exist without the sun's energy. (We will delve further into the subject of living things in Chapter Two.) But from what did these intricate processes build? How was the earth born? How did life here begin?

Figure 1-3



The natural water or hydrologic cycle showing chemical cycling (solid arrows) and energy flow (open arrows).

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

George M. Woodwell, an ecologist, has written of how these systems probably evolved on earth:

> Solar energy has been fixed in one form or another on the earth throughout much of the earth's 4.5 billion year history. The modern biosphere probably had its beginning about two billion years ago with the evolution of marine organisms that not only could fix solar energy in organic compounds but also did it by splitting the water molecule and releasing free oxygen.
>
> The beginning was slow. Molecular oxygen released by marine plant cells accumulated for hundreds of millions of years, gradually building an atmosphere that screened out the most destructive of the sun's rays and opened the land to exploitation by living systems. The colonization of the land began perhaps 400 million years ago. New species

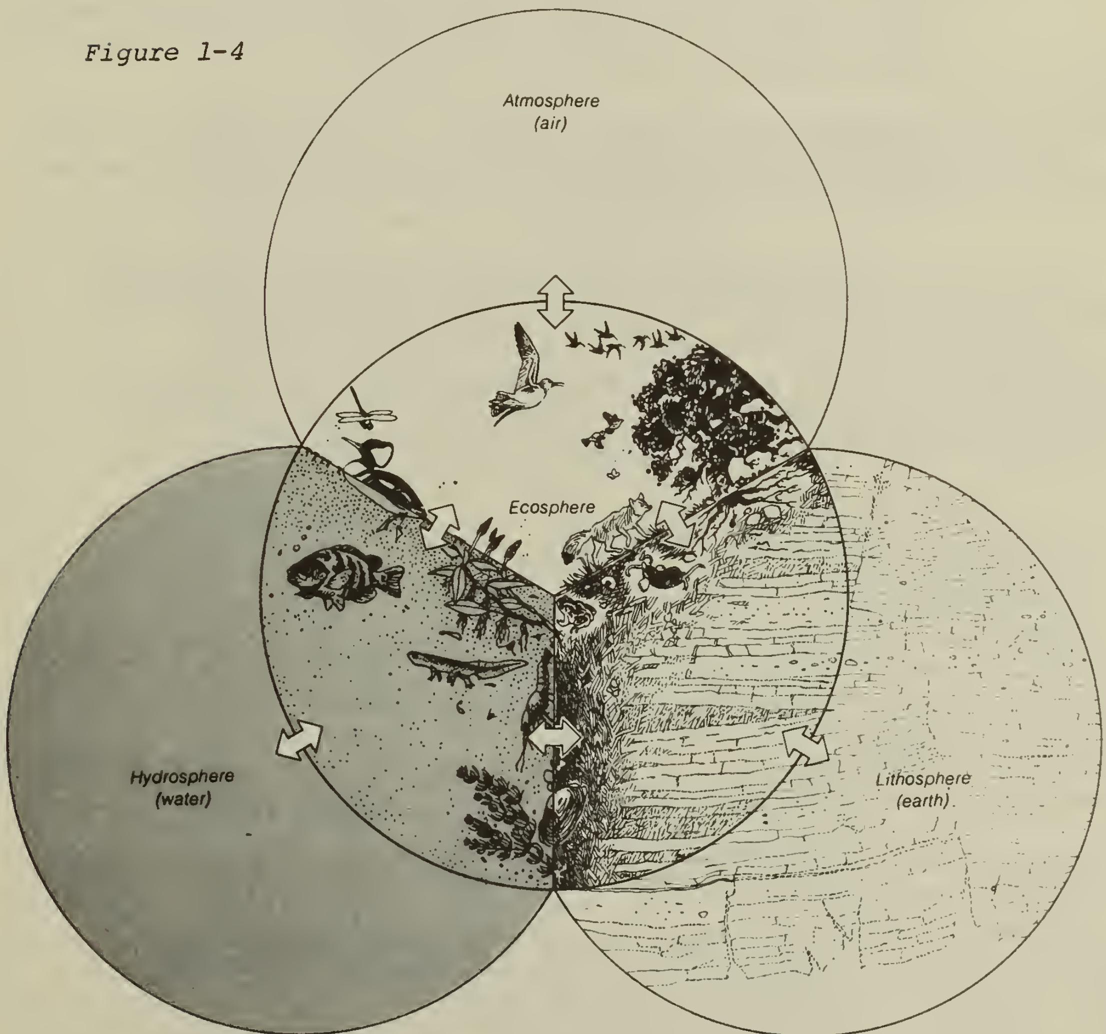
> evolved that derived more energy from a more efficient respiration in air, accelerating the trend.
>
> Evolution fitted the new species together in ways that not only conserved energy and the mineral nutrients utilized in life processes but also conserved the nutrients by recycling them, releasing more oxygen and making possible the fixation of more energy and the support of still more life. Gradually each landscape developed a flora and fauna particularly adapted to that place. These new arrays of plants and animals used solar energy, mineral nutrients, water, and the resources of other living things to stabilize the environment, building the biosphere we know today...
>
> The arrangement of these species in today's ecosystems is a comparatively recent event, and the ecosystems continue to be developed by migration and continuing evolution. Changes accrue slowly through a conjoint evolution that is not only biological but also chemical and physical. The entire process appears to be open-ended, continuous, self-augmenting, and endlessly versatile. It builds on itself, not merely preserving life but increasing the capacity of a site to support life. In so doing it stabilizes the site and the biota...Interactions among ecosystems are exploited and stabilized by living systems adapted to the purpose.... (*The Biosphere,* W. H. Freeman and Company)

The concept of "systems" is important to an understanding of the planet's functions and its place in the universe. A system is any group of regularly interacting and interdependent components forming a unified whole. The universe is a system. The earth is a system, and also a sub-system of the universe. All things on earth, including the human race, are systems -- as well as sub-systems of the earth and universe.

Systems grow until the available supply of an essential resource -- energy, water, oxygen, or hundreds of others -- is being fully utilized. This modifies further growth, resulting in a state of equilibrium unless the system evolves some manner of overcoming this limiting factor. Life on earth has evolved within a complex set of limiting factors. Living things are not found everywhere on earth, but only in those areas where all of the necessary resources exist in sufficient quantity to support life. For example, no life is found in the upper atmosphere or the core of the earth.

The planet is composed of three primary physical systems: the atmosphere above, surface and underground water (the hydrosphere), and the surface and sub-surface land mass (the lithosphere). Life does not exist very far into any of these layers and, in fact, is "limited" to a thin shell only about nine miles thick where the three layers meet. Scientists call this shell the biosphere or ecosphere (Figure 1-4). It includes about seven miles of life-supporting atmosphere and a thin crust of soil, minerals, and rocks extending only a few thousand feet beneath the earth's surface.

Figure 1-4



Our life-support system—the ecosphere.

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

Except for occasional human forays deep into the earth or up beyond the atmosphere, life on earth is limited to the nine-mile-thick overlapping zone.

Because it is an essential ingredient to life, energy is a universal limiting factor. But, unlike other elements essential to life, energy is not cycled through the earth's systems. Only a tiny portion of the energy flowing in every direction from the sun strikes earth. An even smaller portion is captured and temporarily used on earth. Eventually this energy leaves the earth and re-enters space as heat, never to be used again on earth. Distinctly different from energy, matter remains in the biosphere; nothing ever leaves or enters this realm, except in occurrences such as incoming meteors or outgoing space flights. Within the biosphere, matter continually changes forms (plants die and become part of the soil, for example). This movement within the earth's closed system is called matter cycling.

An essay called "Odyssey" by the American naturalist Aldo Leopold provides a description of some of the ways matter cycles in the biosphere:

> X had marked time in the limestone ledge since the Paleozoic seas covered the land. Time, to an atom locked in a rock, does not pass.
>
> The break came when a bur-oak root nosed down a crack and began prying and sucking. In the flash of a century the rock decayed, and X was pulled out and up into the world of living things. He helped build a flower, which became an acorn, which fattened a deer, which fed an Indian, all in a single year.
>
> From his berth in the Indian's bones, X joined again in chase and flight, feast and famine, hope and fear ...
>
> Next he entered a tuft of side-oats grama, a buffalo, a buffalo chip, and again the soil. Next a spiderwort, a rabbit, and an owl. Thence a tuft of sporobolus ...
>
> Between each of his excursions through the biota, X lay in the soil and was carried by the rains, inch by inch, downhill. Living plants retarded the wash by impounding atoms; dead plants by locking them to their decayed tissues. Animals ate the plants and carried them briefly uphill or downhill, depending

> on whether they died or defecated higher or lower than they fed ...
>
> One year, while X lay in a cottonwood by the river, he was eaten by a beaver, an animal that always feeds higher than he dies. The beaver starved when his pond dried up during a bitter frost. X rode the carcass down the spring freshet, losing more altitude each hour than heretofore in a century. He ended up in the silt of a backwater bayou, where he fed a crayfish, a coon, and then an Indian, who laid him down to his last sleep in a mound on the riverbank. One spring an oxbow caved the bank, and after one short week of freshet X lay again in his ancient prison, the sea. (*A Sand County Almanac,* Ballantine Books)

Energy flow and matter cycling are the two processes essential to life. Scientists have been attempting to understand the intricate workings of these processes for centuries. The basis of what they have learned about energy is summed up in two "laws of thermodynamics."

The First Law of Thermodynamics, also known as the Law of Conservation of Energy, tells us that energy can be neither created nor destroyed, although it can be transmitted to another place or changed to another form. This means that when a plant, or an animal, or a human being, or a machine uses energy for food or to do work, the energy is not consumed or destroyed.

Energy can be stored for a time, for example in the structure of a plant or the body of an animal. Its form can change repeatedly -- such as from sunlight, to plant structure, to animal tissue. But if any system loses or gains energy in some process, the total amount of energy in the system *and* its surroundings must remain constant. For example, a piece of wood can be burned only once. But the ashes of the wood, plus the heat and smoke in the surrounding environment, have the same amount of energy as did the original piece of wood.

This suggests that there is a qualitative as well as quantitative aspect to energy. In our wood example, the energy dispersed in the wood's ashes and dissipated as heat and smoke into the surrounding environment is probably less useful to us than the original piece of wood. There are exceptions, such as smokehouses and production of charcoal. These two qualitative states of energy are called available and unavailable energy. The products of the wood's combustion, once dispersed, are low grade energy and not available to us to do more work. We could gather up some of the wood's now dispersed energy again but this would require the expense of much more energy than we could gather. Once energy is used it no longer has the same value.

This brings us to the Second Law of Thermodynamics, which describes what happens when energy is used. It notes that any process in which energy is changed from one form to another results in a degradation of energy, or an increase in disorder in the universe. All processes on earth, even the reflection of some sunlight by clouds before it reaches the earth's surface, results in degradation of the energy received from the sun. Each time energy changes form on earth, its quality is further degraded and it all eventually escapes into space, largely as low-grade, dispersed heat. Science knows of no exception to this rule. The available energy of a piece of wood will ultimately be degraded into unavailable, useless energy even if, instead of using it, we leave it in the form of a tree until the tree dies and rots.

Another way to look at the process is to think of available and unavailable energy in terms of order and disorder. Energy capable of doing work connotes order, and unavailable, low-grade energy connotes disorder; thus the flow of energy through the earth's systems is a process of increasing disorder. Local increases in order can be achieved by concentrating energy in fossil fuels, food, or human bodies, but the energy used to make this possible means there is always a net increase in disorder in these systems *plus* their surrounding environments.

Scientists use the term entropy to describe the degree of quality or order in a system. An orderly system has low entropy and a disorderly system has high entropy. Thus the ashes, dispersed heat, and smoke given off when a piece of wood is burned, have high entropy. Your body has low entropy.

The Second Law of Thermodynamics is often called the Law of Entropy. Scientists have learned that this principle applies not only to energy but to all known processes in the universe. They have found that all spontaneous occurrences involve a net increase in disorder. Consider the things around you: your room or office, your automobile, the clothing you wear, the chair you're sitting on, your food, a hot cup of coffee. All required an investment of energy to be transformed into their current state for your use; all will spontaneously become more disorderly unless you invest energy to maintain their order. Your room will become dusty and cluttered, your automobile, clothing, and chair will eventually reach a state of disrepair, your food will spoil, your hot coffee will cool to room temperature. And, if you accidentally drop your coffee cup, breaking it on the floor, under no conditions would you expect its pieces to spontaneously reform into a cup.

At first glance the process of life may seem to be an exception to this law. After all, the earth's incredibly complex life forms do regenerate, grow, and maintain their structure. However, this order is only possible with the constant influx of energy for food, warmth, shelter, and so forth. If you stop eating, the highly ordered system of your body will quickly fall into a state of disorder. The amount of energy needed to sustain life means that a net increase in disorder in the environment must result. In simpler terms, what the second law tells us is that we not only can't get something for nothing, but we can't even break even.

These two basic thermodynamic laws are essential to an understanding of how nature and humanity use energy. The two laws point out the very real and unyielding limits on what we are able to do with the energy nature has made available to us. Of course no scientific law is immune to revision due to new discoveries. However, Albert Einstein, who gave us the formula for the transformation of energy and matter -- $E=mc^2$ -- called the laws of thermodynamics "the only physical theory of universal content which I am convinced...will never be overthrown."

Many human efforts to harness energy or conquer nature are doomed to failure because we have tried to ignore these thermodynamic limits. Natural systems, on the other hand, remain in dynamic balance with the laws. As will be seen in the next chapter, humanity can learn much from nature's efficient operations.

2 NATURAL SYSTEMS

Natural systems are powered directly by the sun or the sun's recently-stored energy, food.

"The energy that sustains all living systems is solar energy, fixed in photosynthesis and held briefly in the biosphere before it is reradiated into space as heat. It is solar energy that moves the rabbit, the deer, the whale, the child on the bicycle, and the human eye as it reads these words."
-- George M. Woodwell

We know that without the sun, the earth would be a cold, dead planet -- nothing living, growing, or moving, no winds, no light. So what happens when the sun's rays strike earth? A large portion of the sunlight which reaches the earth's surface falls on vegetation. These plants have an incredible diversity in habitat and appearance, ranging from microscopic phytoplankton in the oceans to giant redwood trees. But they have in common the unique ability to convert the sun's radiant energy to food. No other thing on earth can transform the sun's energy to support life.

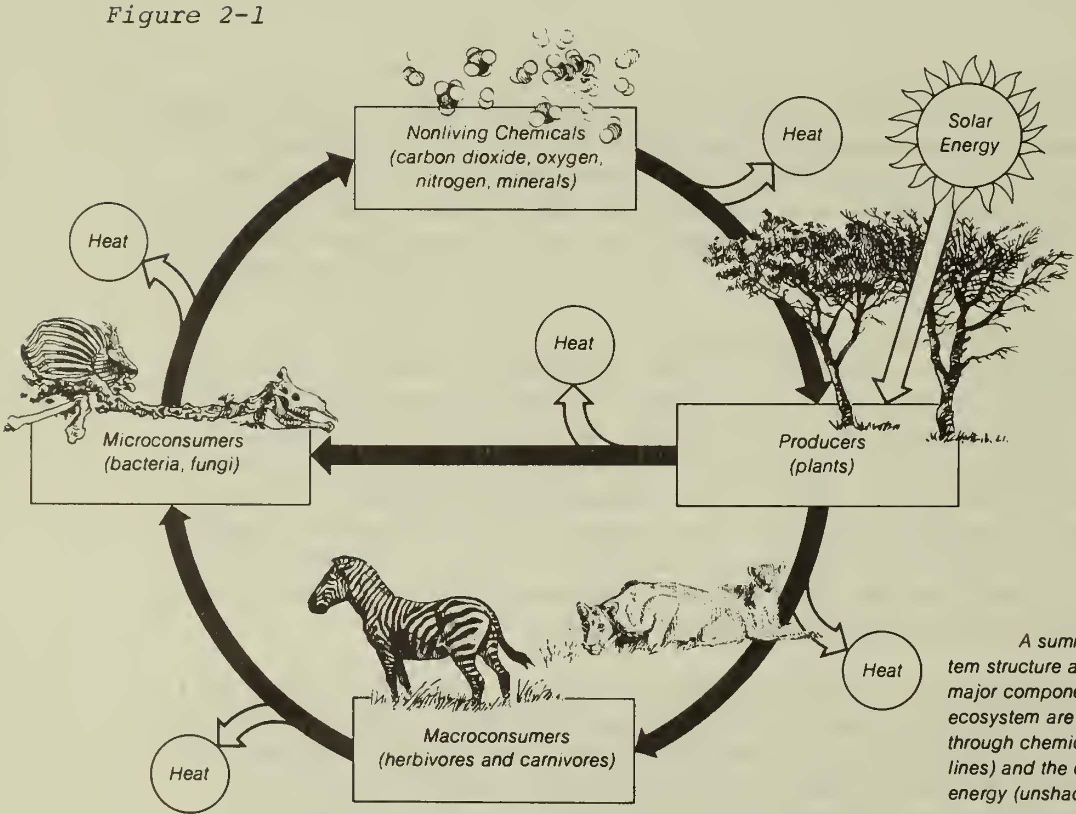
This process is called photosynthesis. The conversion is made by a substance in the leaves of plants called chlorophyll. Combining the sun's radiant energy with carbon (from carbon dioxide in air), hydrogen (from water) plus small quantities of minerals from the soil, plants convert the sun's rays to feed themselves. But they require only about one-sixth of the energy they capture for this purpose.

(Some energy escapes in the process; remember, no energy process is 100 percent efficient.) The remaining five-sixths is stored in the plant's structure in the form of sugar and starch, which is chemical energy. Other living things get their food by eating plants, or by eating other insects or animals which have consumed plants.

To study the way food and other resources move through living systems, ecologists divide the biosphere into units which have some unifying physical feature (such as a meadow, forest, or even a human body) through which the flows of energy and materials can be measured. These units are called ecosystems. The biosphere is an ecosystem, as are the multitude of smaller, overlapping systems (including you and me) which comprise it. Each ecosystem is connected to many others and, in a sense, is connected to all other ecosystems.

The functioning of many ecosystems is equally or more complex than the most sophisticated of human technologies. All ecosystems have both living and non-living components (Figure 2-1). The non-living things include energy, heat, wind,

Figure 2-1

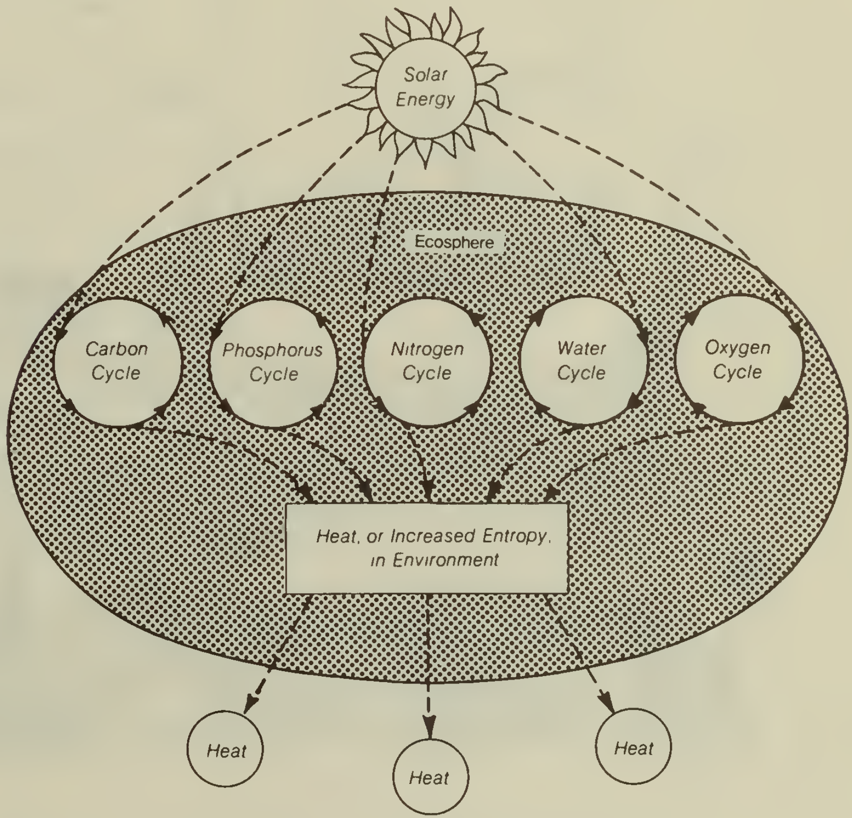


A summary of ecosystem structure and function. The major components of an ecosystem are interconnected through chemical cycling (solid lines) and the one-way flow of energy (unshaded lines).

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

light, humidity, rainfall, and chemicals. Six chemical elements -- carbon, oxygen, hydrogen, nitrogen, phosphorus, and sulfur -- make up more than 95 percent of the mass of all living things. They combine with the rest of the approximately 40 elements which are needed for life and cycle continuously through the soil, air, water, and other physical media (Figure 2-2). The carbon cycle is shown in more detail in Figure 2-3.

Figure 2-2

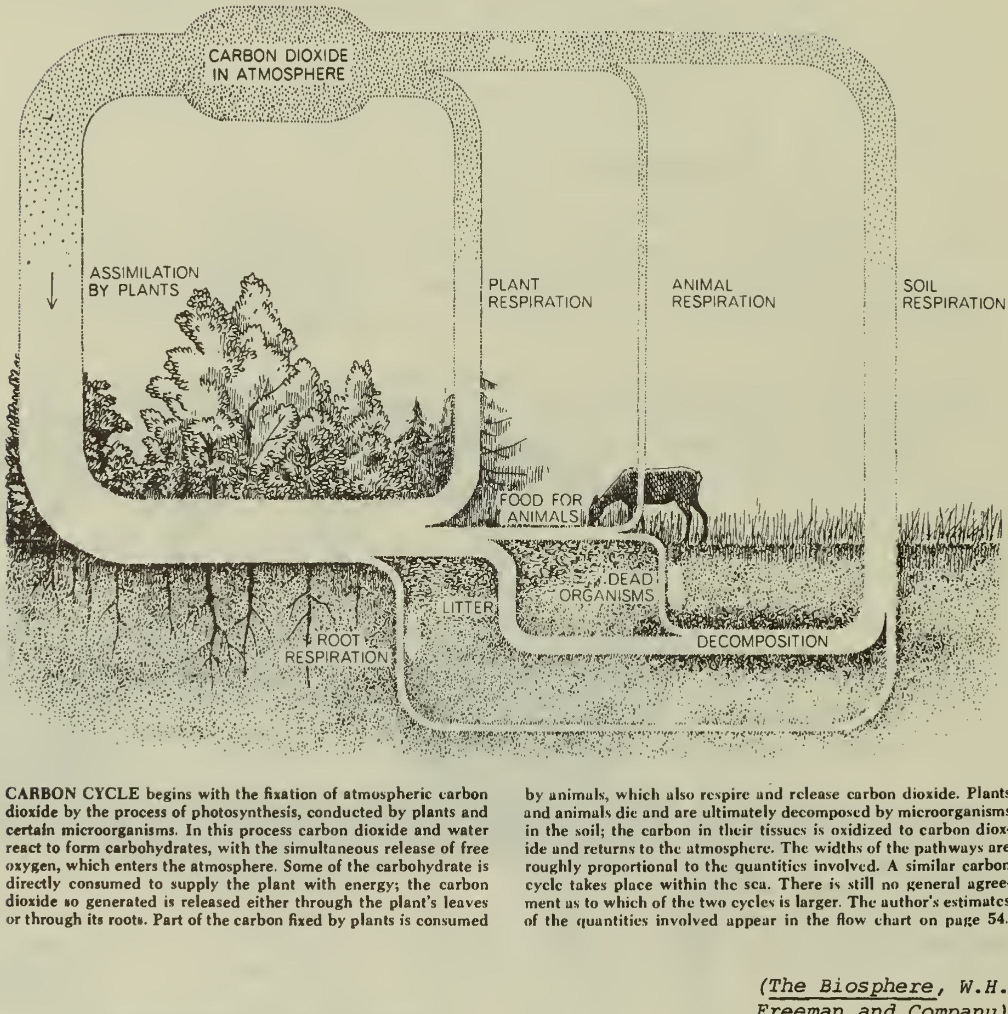


Life on earth depends on the cycling of critical chemicals and the one-way flow of energy through the ecosphere Dotted lines represent energy and solid lines represent chemicals.

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

Living things are also essential to the proper functioning of ecosystems. Included are a vast array of insects, plants, animals, and microscopic life, which pass chemicals through their bodies by respiration and food processing. When they die, chemicals stored in their body tissue return to the earth. Living things also transfer energy as they consume plants and feed on each other. Such energy relationships between organisms are called food chains.

Figure 2-3



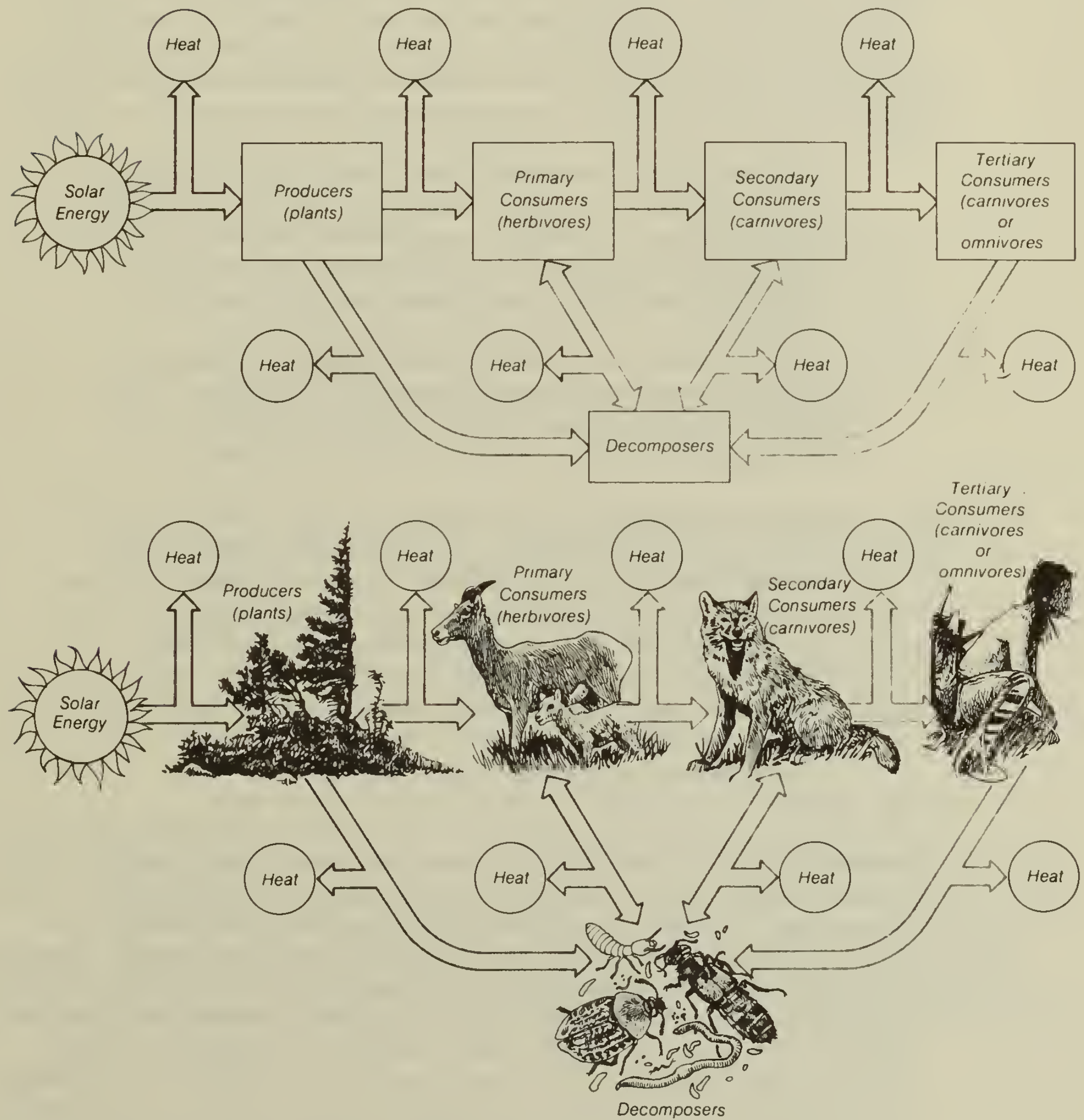
CARBON CYCLE begins with the fixation of atmospheric carbon dioxide by the process of photosynthesis, conducted by plants and certain microorganisms. In this process carbon dioxide and water react to form carbohydrates, with the simultaneous release of free oxygen, which enters the atmosphere. Some of the carbohydrate is directly consumed to supply the plant with energy; the carbon dioxide so generated is released either through the plant's leaves or through its roots. Part of the carbon fixed by plants is consumed by animals, which also respire and release carbon dioxide. Plants and animals die and are ultimately decomposed by microorganisms in the soil; the carbon in their tissues is oxidized to carbon dioxide and returns to the atmosphere. The widths of the pathways are roughly proportional to the quantities involved. A similar carbon cycle takes place within the sea. There is still no general agreement as to which of the two cycles is larger. The author's estimates of the quantities involved appear in the flow chart on page 54.

(The Biosphere, W.H. Freeman and Company)

Two major food chains function in ecosystems: grazing food chains and detritus, or decomposer, food chains. Grazing chains begin when plants, the producers, convert the sun's energy to sugar and starch. Then the consumers take over. Plant-eating animals (herbivores) receive the stored, chemical energy when they feed, using some to fuel their bodies and storing some in tissue. Meat-eating animals (carnivores) get their energy rations when they consume the flesh of the herbivores, again using some and storing some. Other carnivores prey on those carnivores. Omnivores, including humans, eat both plants and animals.

Detritus or decomposer food chains include insects and microscopic forms of life which break down matter. This chain completes a cycle (Figure 2-4) by reclaiming the elements

Figure 2-4



A simple food chain showing how energy flows through various trophic levels

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

stored in living tissue and returning them to the soil, where they again nourish plants. Without the decomposers all of the nutrients necessary for life would eventually be uselessly stored in dead bodies. No single species of decomposers accomplishes this solid waste disposal and recycling job; rather, the combined action of many species gradually breaks down these "wastes."

Plants, the producers, do their job very efficiently, using only a small fraction of the energy they receive from the sun and making the rest available to others. But the consumers of this energy are not so efficient. Usually 80 to 90 percent of the available energy is lost at each step (trophic level) in the food chain. Based on figures from Lamont C. Cole, Don Fabun describes these energy transfers:

> In earth's ecologic system, the first consumers are herbivores -- they reap the radiant harvest of the green plants. They harvest about half of the five-sixths of one percent of radiation reaching earth which is absorbed by the plants.
>
> When animals eat plants, only about 20 percent of what is consumed is turned into tissue; the rest is used up as heat to keep them going, or discarded as waste.
>
> When one animal eats another, the conversion efficiency is again about 20 percent. As a meat-eater, man is at the end of the chow line, living on 20 percent of 20 percent, of five-sixths of 50 percent, of four-hundredths of one percent. However, since man is an omnivore he can eat plants directly, and thus short-circuit the system.
> (*Dimensions of Change*, Glencoe Press)

Nature has a finely tuned set of checks and balances which, under normal circumstances, prevents any single life form from overrunning others, or destroying natural cycles. Most creatures (humans and a few other species excluded) have natural predators which control their numbers. The strongest and quickest of the species survive to procreate since sick, deformed, or aged members are the first targets of predators. When the number of predators exceeds the supply of prey, starvation, disease, or other predators check their numbers. As an additional safeguard against extinction, all species multiply faster than their normal death rate. This allows a few remnants of a species to reestablish a healthy population.

Thus nature has a complex community organization to maintain a balance of life forms, each member of which has some function in the ecosphere. John Storer, an ecologist, has described an example of the complicated web of controls which prevent one species from overrunning the earth:

> ... in this small community we are watching, the larvae of many insects spend parts of their lives in the upper soil. Shrews hunt them under the leaf mold. Other insects and some of the molds and bacteria also feed on them. On the surface many ground-nesting birds, such as the towhee, turn up the leaves to find them. The brown thrasher hunts here too, and continues the search among the bushes where it makes its nest. It is joined by the warblers and vireos, which extend their search up to the tree tops.
>
> As the trees grow larger and their lower branches die, the fungi may decompose and soften the wood in the knotholes, offering favorable nesting sites for woodpeckers and nuthatches, whose feet are adapted for hunting on the bark of tree trunks. The woodpeckers go one step further, drilling holes through the bark to catch the insects hidden within.
>
> Some of the insect pupae that survive this search emerge to fly over the tree tops, but here they are met by the swifts and swallows by day, by the nighthawks at dusk, and later by the bats that are equipped with nature's radar systems to hunt in the darkness. Each one of these controlling predators must in turn hold its own place against others that are larger or stronger or more active -- hawks, owls, foxes, weasels.
> (*The Web of Life*, The New American Library, Inc.)

The human race has shown its ingenuity by circumventing most of nature's checks and balances -- at least temporarily. Our intelligence has enabled us to prolong lifespans with advanced health care and to feed our ever-growing population (currently roughly four billion). But as will be seen in the coming chapters, these advances have exacted their costs.

3 HUMAN SYSTEMS

Systems constructed by people are also powered by the sun, but have recently been subsidized by fossil fuels—the sun's energy stored in the earth over hundreds of millions of years. First used on a large scale less than 200 years ago, the unique richness and apparent abundance of these fuels has led humanity to use them rapidly and inefficiently. The supply of fossil fuels will soon be virtually depleted.

"Modern man seems to believe he can get everything he needs from the supermarket and corner drugstore. He doesn't understand that everything has a source in the land or sea, and that he must respect these sources."
-- Thor Heyerdahl

At various times and places during the earth's history, a small portion of the sun's energy flowing through the earth's systems was separated, condensed, and stored underground. This probably occurred when organic matter from plants and animals was buried in sand or mud before it completely decomposed. Pushed deeper into the earth by the weight of shifting soil and rock, these organic materials were condensed over hundreds of millions of years, creating fossil fuel in solid (coal, shale oil, tar sands), liquid (oil), and gaseous (natural gas) forms. The energy in these fuels is much more concentrated than the radiant energy in the sunlight reaching earth and it has tremendous potential for doing work.

Primitive humans were omnivorous hunter-gatherers, and little more sophisticated than other predator species; all fought for survival and a share of food (energy). The discovery of tools distinguished humans from virtually all other forms of life. (Some apes fashion simple tools, such as grass stems for capturing insects.) The resources of the human race were further enhanced by the discovery of fire, releasing the stored energy in wood. Humanity began to exercise greater independence from nature, rather than being totally controlled by it. Increasingly complex societies have been achieved largely through the organization and use of increasing quantities of energy.

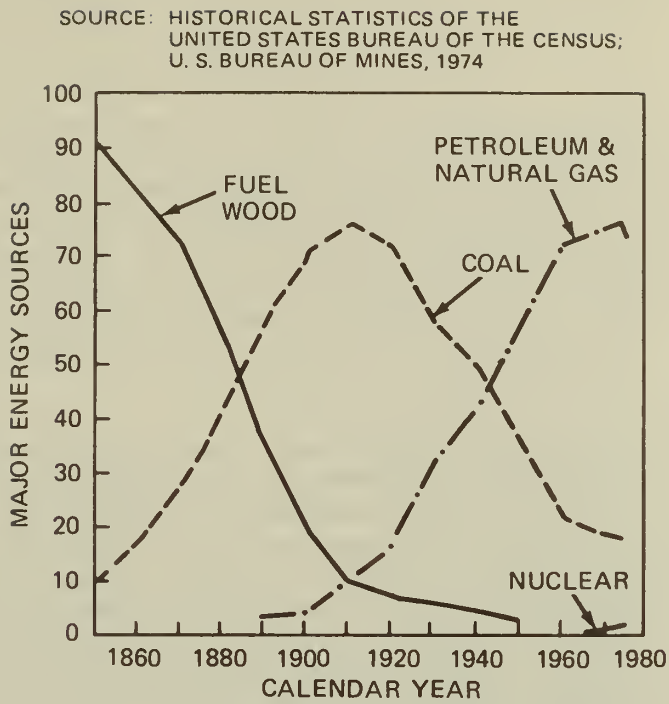
For the most part, humanity turned to fossil fuels only after supplies of wood were depleted due to cutting in excess of new tree growth, or to loss of productivity due to soil damage. Italy, Greece, and some other mediterranean countries were deforested by the time of the Greek and Roman empires; they remain so to this day. Europe began to run short of timber in the mid 1700's and by the turn of the century had begun a large-scale shift to coal. The U.S. and other industrializing nations soon followed. This shift to fossil fuels and the failure to realize their finite supply laid the basis for our current energy dilemma. (Fossil fuels are probably still being formed in the earth but the process takes millions of years; for all practical purposes they are non-renewable.)

Of course many less-developed nations still rely primarily on renewable forms of energy such as wood and animal dung. The latter is a primary source of fuel in India as well as in parts of China, Africa, Ethiopia, and Iraq. With this reliance on renewable energy sources, many of these countries still live in relative harmony with their environments.

Excluding earlier reliance on plants and animals for food, and later animals for work, industrial society has advanced through three "energy eras." It used wood, then coal, and now oil and natural gas. In the U.S., a 60-year pattern has emerged over the last two centuries marking the passing of these eras. The declines have been caused either by insufficient supplies of the once-dominant fuel or by availability of a more versatile replacement.

According to the Energy Research and Development Administration's 1975 annual report, U.S. supplies of oil and natural gas "appear to have reached the 60-year peak." What will the next era be? Can technology find another way to harness energy for industrial society to replace fossil fuel? Many think nuclear power is the answer. It has begun to emerge as a new source and appears to be taking over as oil and gas supplies reach their peak (Figure 3-1). But, as we will discuss in Chapter Five, nuclear power has some very special problems, limitations, and risks.

Figure 3-1



U.S. Energy Consumption Patterns

(Energy Research and Development Administration)

Before tackling our current dilemma and our options, it is worthwhile to explore how we came to rely so heavily on fossil fuels. Perhaps we can learn some things from the past.*

The beginning of the fossil fuel era was delayed considerably beyond the first discovery of these fuels. The existence and properties of coal were known for centuries before it was put to work on a large scale. As long as wood remained plentiful, there seemed to be no need for coal. However, as we pointed out earlier, Europe's timber supply had begun to grow scarce by 1750. The mining of coal was hampered at that time because mine pits filled with water. However, by the end of the century, an efficient steam engine had been invented and effective pumps became available. Extensive coal mining

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* The historical discussion in this chapter is drawn largely from Wilson Clark's book, *Energy for Survival.*

began, and Europe began to build a technology based on fossil fuels. The industrial revolution, already well underway using power from water wheels, quickly took advantage of the even greater work potential of coal's higher quality energy.

The U.S. was slow to switch to coal, even though Europe had demonstrated its value. As late as 1850, 90 percent of the fuel burned in the U.S. was wood. Only when extensive forest cutting had driven up the price and increased the distance to available supplies did the U.S. turn to coal. In 1855 coal surpassed wood in the U.S. as the dominant fuel. It was used largely to fuel steam locomotives, although the developing steel industry was also a major user, and other industries which had formerly relied on water to drive factory turbines began to turn to coal.

Although coal was useful for heat and power, western nations still lacked a plentiful liquid fuel that could be used in lamps. Increasing demand for whale oil as a lighting fuel had made it increasingly scarce and expensive. Europe developed an extensive network of coal gas pipelines to light homes, factories, and street lamps but this system was not practical for the United States because its population was widely scattered. An English coal miner discovered how to make a liquid fuel, kerosene, from coal and by the late 1850's there were over 50 kerosene plants in the eastern U.S.

The second fossil fuel era -- oil -- was born in the U.S. in 1854. In that year a group of Philadelphia businessmen founded the Pennsylvania Rock Oil Company to investigate the commercial potential of a kerosene-like substance which had been found oozing from the earth in parts of western Pennsylvania. Wilson Clark provides a description of what the businessmen learned:

> ... the Pennsylvania Rock Oil Company ... hired a Yale chemistry professor to analyze a barrel of their rock oil. His report, in 1857, concluded that the substance furnished as much light as any fuel that had ever been tested; that it burned more economically; that it did not turn gummy, rancid, or acid upon prolonged exposure; and that it held up well in very cold environments. It was a raw material, the chemist reported, from which some "very valuable products" might be manufactured.
>
> Bolstered by these findings, the Pennsylvania Rock Oil Company hired a former railroad conductor to undertake the job of getting the rock oil out of the ground in sufficient quantities to be commercially profitable. It quickly became obvious

> that drilling, rather than digging, was the best means of getting to the substance; and in September 1859, at a depth of 69 feet, the Pennsylvania Rock Oil Company struck oil.
> (*Energy for Survival*, Anchor Books)

Both coal and oil had been mined and used for fuel before the birth of Christ. But these discoveries had been lost due to disinterest or the passing of certain cultures. When oil was again "discovered" in Pennsylvania, the world was ready to take advantage of the new fuel. Refined oil was cheaper than kerosene and quickly became a major energy source for lighting. By 1880 oil comprised 13 percent of all mineral fuel consumed in the U.S.

Neither coal nor oil are uniform substances which always contain the same properties. The composition and heating value (energy quality) of both vary greatly. Hundreds or even thousands of different chemicals and minerals may be found in a given sample. Coal was less of a problem in this respect in the 1800's because little processing was needed and people were unaware of the environmental threat from burning it. On the other hand, crude oil must be refined to yield its products and its varying properties complicated this procedure. Refining is a catch-all term for treatments which separate the components of crude oil, remove some impurities, and then reunite some of the components to form a new substance.

Oil producers quickly discovered many uses for oil, separating new products from crude oil in the refining process. Lubricants were recognized for their value to industry, while another product, a heating or engine fuel, was slow to be utilized. And another byproduct, gasoline, appeared to be completely worthless.

Faced with growing surpluses of fuel oil, the fast-growing Standard Oil Company undertook a campaign to convince industry that the product was a cheap and efficient substitute for coal in steam engine boilers. The company's drive was successful and by 1889 fuel oil totaled 35 percent of annual petroleum sales.

Coal had served satisfactorily as a fuel for steam engines in trains and ships, but a clear market existed for smaller, family-size vehicles to replace the horse and buggy. Steam powered automobiles had been marketed but were largely impractical. The internal combustion engine had been developed as early as the 17th century but no practical fuel had been found. In 1870 tests began using gasoline and in 1877 the first workable gasoline-fueled engine was invented.

By the beginning of the 20th century 4200 automobiles had been built in the U.S., nearly all powered by steam or electricity. In 1903 America's Henry Ford introduced his gasoline-powered automobile which was an instant success. His practical, inexpensive motorcar revolutionized transportation in developed nations, just as his mass-production techniques revolutionized manufacturing.

The emergence of the diesel engine as a competitor to steam engines, beginning in about 1935, completed the oil producers' conquest of the transportation fuel market. The internal combustion diesel is about 40 percent more efficient than steam engines. In addition, by weight oil has about 50 percent more energy than coal. It should be noted that even after oil and natural gas became industrial society's dominant fuels, coal production continued to increase. But coal has supplied a steadily *decreasing proportion* of total energy supply since 1900, even though it is the world's most plentiful fuel.

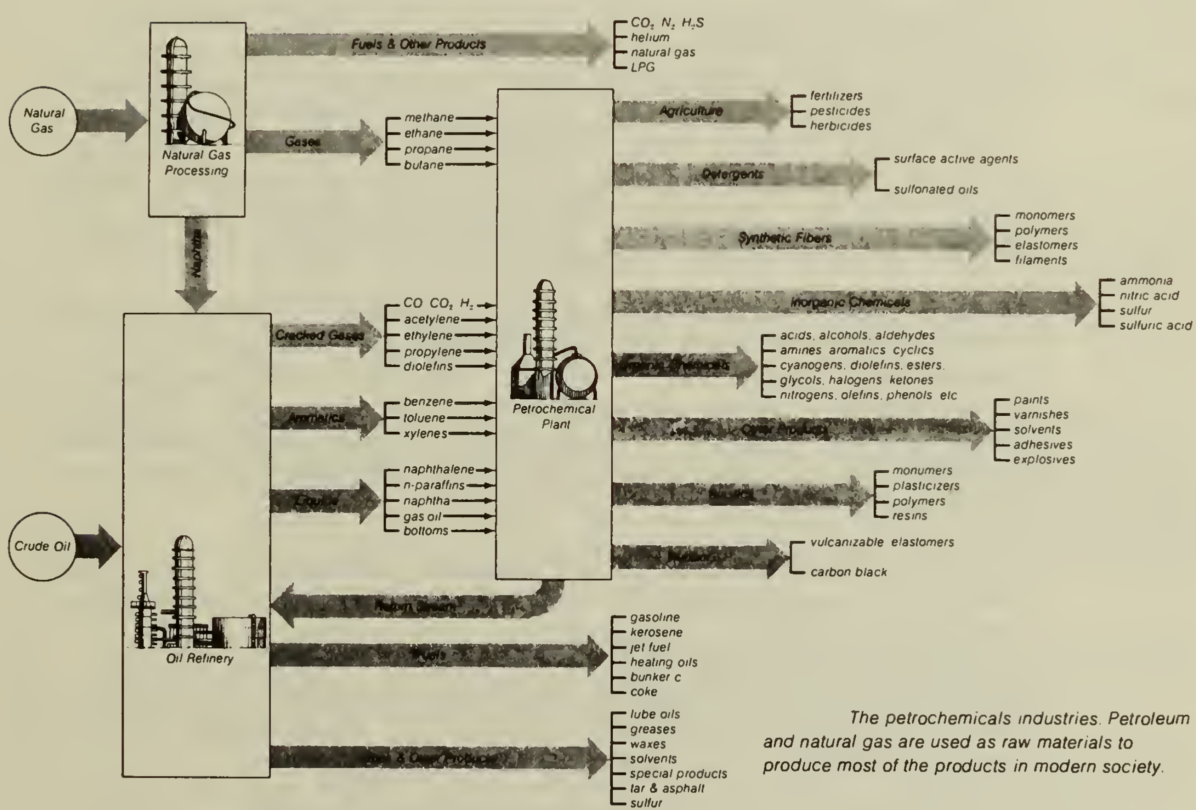
Dozens of new inventions increased the amount of work fossil fuels could do for society. One of the most significant was the development of the first electric power generation and distribution system by Thomas Edison in 1882 -- three years after he invented the light bulb. Wilson Clark describes that plant and its significance to society:

> ... initiated in the heart of New York's downtown Pearl Street financial district ... the generating station was located in a building of ironwork structure on a site 100 by 50 feet, and was designed to serve an area about one-half mile square. Four boilers were located on the ground floor, and six two-hundred-horsepower dynamos, or generators, capable of lighting 1200 lamps each, were installed on the second floor. Edison himself supervised the workmen who dug the trenches and laid the cable after securing permits from the city of New York ...
>
> The electric light and the electric power distribution system required to sustain it were to change the world as have no other technological developments. Electricity made it possible to deliver the work potential generated by the steam engine to distant sites cheaply and without the noise, smoke, size, or other characteristics of the steam engine at the generating site. In effect, it put the steam engine, with all its enormous capability, at the disposal of virtually every home,

business, and industry in America and much of the Western world.
(*Energy for Survival,* Anchor Books)

The list of products that could be refined from oil and its counterpart, natural gas, grew and grew. Synthetic fibers, "miracle" drugs, fertilizers, pesticides, ammonia, acids, paints, adhesives, explosives, plastics, rubber, greases, waxes, solvents, tars and asphalt, and sulfur -- all are made from petroleum and natural gas (Figure 3-2). Many cannot be made from anything else.

Figure 3-2



The petrochemicals industries. Petroleum and natural gas are used as raw materials to produce most of the products in modern society.

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

The harnessing of fossil fuel changed the basic structure of industrial societies. Where most families had once been largely independent, self-sufficient units of production, industrialization made it possible for people to become dependent on one another. Many once agrarian nations which had relied on individuals to raise their own food became societies in which only a small percentage of the population worked to produce food. This allowed the rapid urbanization of many nations, including the U.S. Farmers now comprise only about three percent of our population and almost 80 percent of our people live in urban areas. Most people now work to produce consumer goods and provide social services.

This new structure requires complex distribution networks in which food and industrial products are shipped throughout the nation and around the world. This system relies almost entirely on fossil fuel energy.

This improved transportation network increased industrial society's mobility and changed housing and living patterns. Oil- and gas-based medicines and the ability to move people to doctors quickly revolutionized health care, extending life-times. Fossil fuels brought the industrial revolution to fruition, vastly increasing the goods and services society could produce. New mass communications methods brought once-isolated cultures into contact with the rest of the world.

Many of these changes were good for humanity. Some, in retrospect, may not have been improvements at all. But the momentum of change was so strong that many negative effects were ignored. Among the most serious of these ill effects is pollution. As the second law of thermodynamics dictates, growing use of fossil fuels caused an abundance of disorder in the environment.

We get our energy from fossil fuels by combustion. This converts the stored energy to heat to run industrial machinery, automobiles, electric generators, and so forth. But heat itself is a pollutant and, while a great quantity can be absorbed by the atmosphere, the earth's capacity to handle heat is limited. As we will discuss in Chapter Seven, heat may ultimately be our most serious pollutant.

Other more familiar pollutants are also created when fossil fuels are burned. Carbon, nitrogen, sulfur, and other fuel components do not combust totally and are emitted in varying quantities in exhaust. They may also be converted to different polluting substances when they are burned, including carbon dioxide, sulfur dioxide and sulfates, nitrogen oxides, hydrocarbons, photochemical oxidants, and carbon monoxide.

These emissions are a serious health threat. (Natural gas should be noted as an exception since it burns relatively cleanly.)

There are also many other phases of fossil fuel use which generate pollution. Mining coal or drilling for oil and gas requires machinery which burns fuels and creates heat and other pollutants. The quality of land is often degraded, especially in mining operations. Runoff of mine wastes often pollutes nearby water resources. Strip mining, a method of removing ore near the surface by digging up large tracts of land, seriously degrades land productivity for agriculture or grazing and scars the land visually. In deep mine shafts the air is often so filled with dust and pollutants that the health of miners is endangered.

Transporting fuels also requires machinery which burns fuels, creates heat, and pollutes. In addition, accidents in transportation take their toll; oil spills on land or water are particularly destructive. Most fossil fuels need to be processed before they can be used, again requiring machinery and fuels, creating heat and other pollution.

Products made from fossil fuels are often destructive in a different way because their petrochemical components are extremely slow to decompose. Because modern society produces massive quantities of waste, disposal is an overwhelming pollution problem. We can't really throw anything "away" -- we live in a closed system.

Many of our cities and their surrounding environments are in danger due to the effects of these pollutants. It is not uncommon for cities to be heated as much as 10 degrees above nearby rural areas. Medical scientists attribute a substantial number of illnesses and deaths each year to the chemical pollutants which veil many cities.

Technology has been developed to control some of these pollutants but these devices, although valuable, are usually expensive and often use large quantities of energy.

The apparent abundance of fossil fuels encouraged us to use them to perform tasks previously accomplished by hand or simple machines. Little thought was given to whether the use of highly concentrated fossil fuel was necessary or appropriate to various tasks. This trend encouraged inefficient use of energy -- excess consumption not necessary to productive work. Unfortunately, such inefficient uses create just as much pollution as would result from constructive use of the energy. As we discussed in Chapter One, the laws of thermodynamics dictate that each time energy is transported or changed in form, some is degraded to low level heat and is dispersed into space; it can no longer be used by us. Thus we can never get more energy than we started with, and we can't even break even. Each link in the chain reduces the amount of captured energy we have and its potential for doing work -- the more links, the more energy wasted.

4 ENERGY DEMAND

World demand for energy is growing at a record pace and, despite a temporary halt in growth in the U.S., total energy demand here will keep growing and is expected to double in just over 30 years. Fossil fuels will soon fail to support many of industrial society's energy-consuming activities.

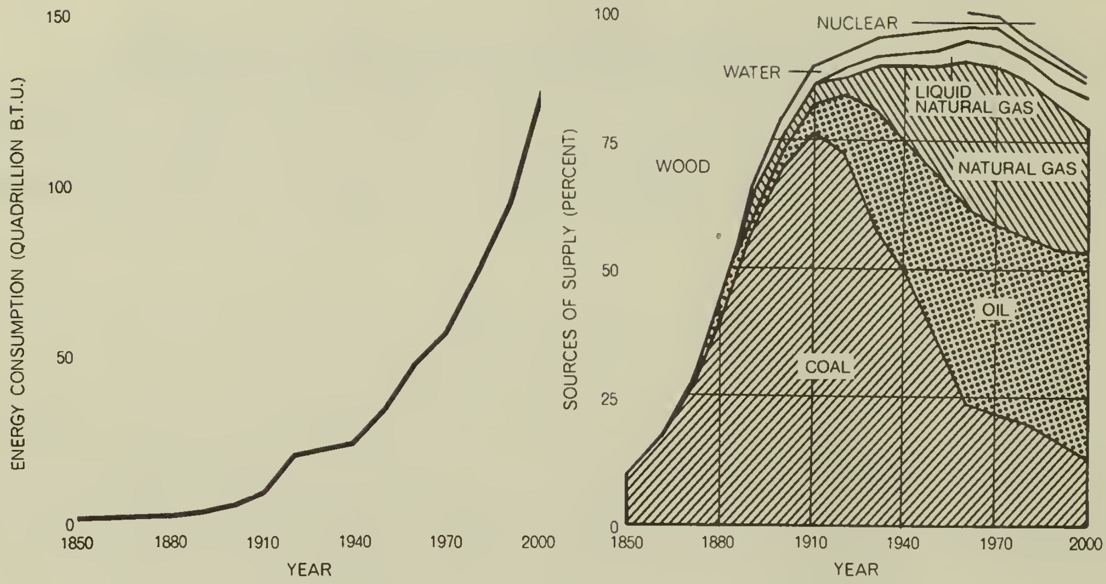
"Today this country has more licensed drivers than registered voters, and two cars are produced for every baby born."
-- Denis Hayes

The United States is a first class piece of real estate. As settlers moved across the land they found a wealth of resources which, along with ingenuity and hard work, made the nation a dominant political and economic power in the world. One of the most important among America's resource riches was its soil, considered to be the best on earth. Also critical were rich deposits of coal, oil, and natural gas.

By 1900 the U.S. had largely forsaken wood as an energy source in favor of these fossil fuels. In that year coal supplied 73 percent of our demand. Oil, natural gas, and hydro-power were of growing importance. By 1950 fossil fuel provided 95 percent of our energy -- 40 percent from oil, 18 percent from natural gas, and 38 percent from coal, according to the U.S. Census Bureau.

Our yearly consumption of energy grew at an astounding rate (Figure 4-1) and soon the U.S. was using more energy per capita than any other nation. This occurred because the U.S. was industrializing at a tremendous pace. Mechanization

Figure 4-1



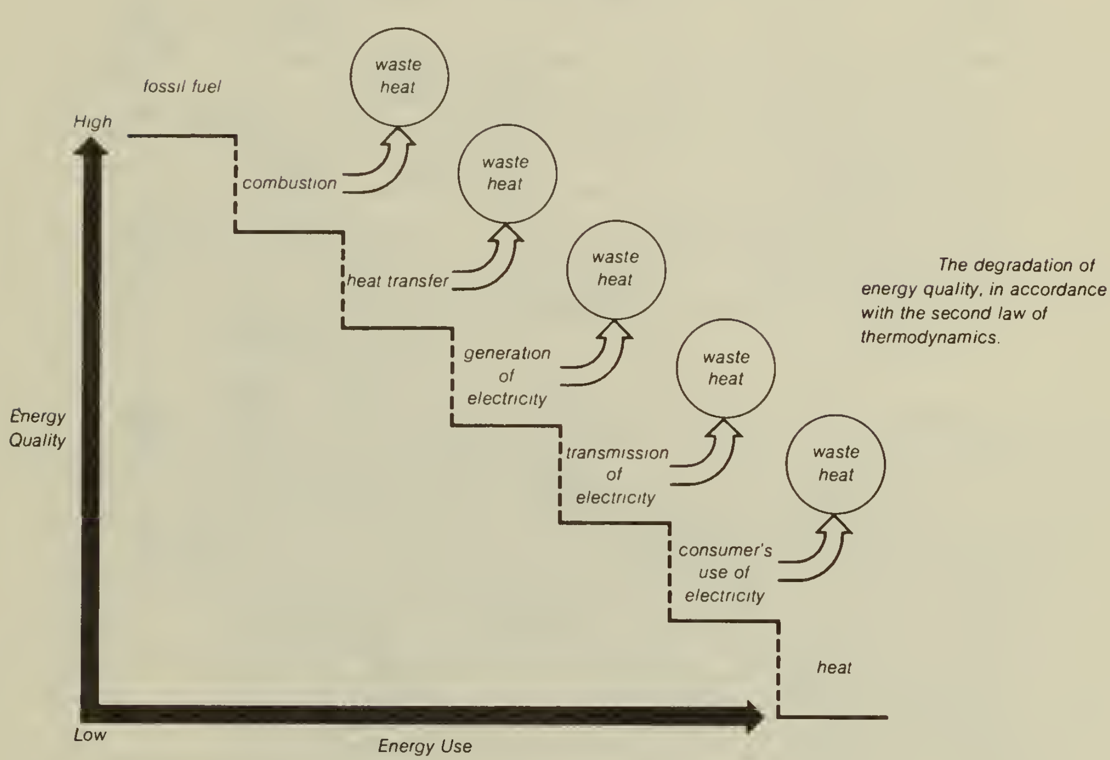
CHANGING SOURCES of energy in the U.S. since 1850 are compared (*right*) with total consumption (*left*) over the same period. At right one can see that in 1850 fuel wood was the source of 90 percent of tbe energy and coal accounted for 10 percent. By 2000 it is foreseen that coal will be back to almost 10 percent and that other sources will be oil, natural gas, liquid natural gas, hydroelectric power, fuel wood and nuclear energy. The estimates were made by Hans H. Landsberg of Resources for the Future, Inc.

(The Biosphere, W.H. Freeman and Company)

and high technology became the norm. These advances, all based on exponentially increasing energy use, reduced our manual labors and provided more leisure time. Increased productivity gave us one of the highest standards of living in the world and made possible tremendous educational and cultural gains for many millions of Americans.

We might or might not have been able to achieve most of these gains with a lower technology, lower energy consumptive approach. However it is clear that our present society is based on massive energy inputs. The more we eased our labors with machines, the more links (and therefore opportunities for energy wastes) were built into the system. For example, from 1960 to 1970 our overall energy consumption grew 51 percent. But instead of using our fuels directly, we relied increasingly on less efficient electricity, the use of which grew 104 percent in the same period. Because of the number of links involved in producing and distributing electricity (Figure 4-2), its efficiency averaged only about 30 percent during the period. Thus we not only used more energy but we used more of a less efficient type of energy.

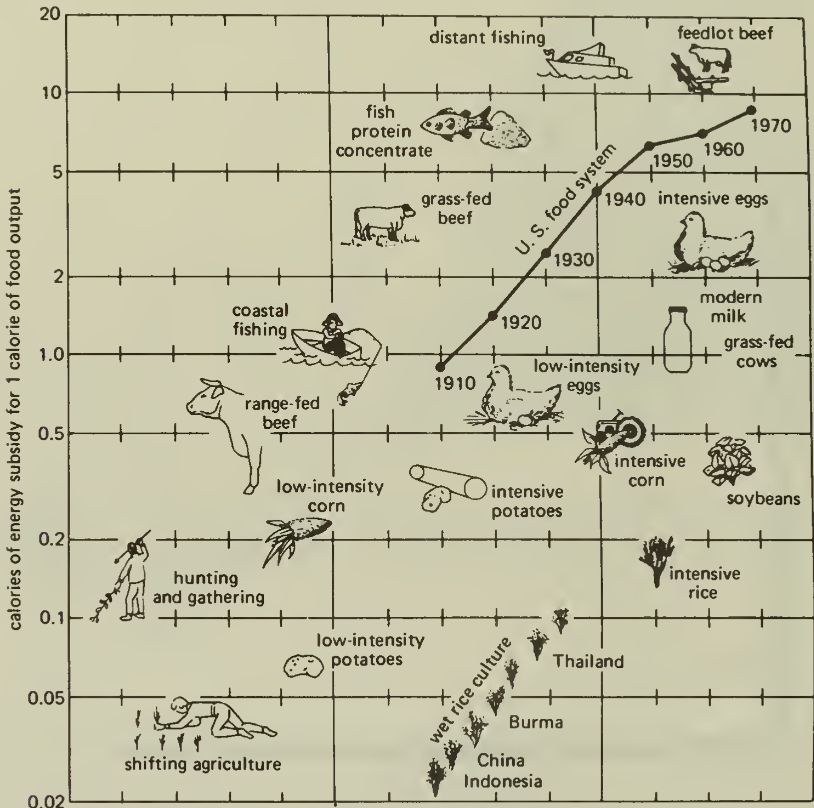
Figure 4-2



(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

Our modern agriculture, food processing, and food distribution system provides another example of increasingly wasteful energy use. Natural food production uses only the sun's energy. Food cultivation by primitive humans used only their energy and that of animals in addition to the sun. In that system, for every one calorie of food and animal energy invested, five to 50 calories of food energy were produced. Modern agriculture, on the other hand -- relying heavily on machinery, petroleum-based fertilizers and pesticides, processing, packaging, refrigeration, and transportation to distant markets -- requires an investment of *five to 10* *calories for every one* calorie of food produced (Figure 4-3) (Carol Steinhart and John Steinhart, "Energy Use in the U.S. Food System," *Science*, Volume 184, 307-315).

Figure 4-3



Energy subsidies for various food crops. The energy history of the U. S. food system is shown for comparison. (After Steinhart and Steinhart, *Science*, Vol. 184, 1974. Copyright © 1974 by The American Association for the Advancement of Science.

Although this type of inefficiency should concern us, it is not an automatic condemnation of these processes. For example, electricity's inefficiency may be tempered in many people's minds by the high convenience and service it provides to society. *Some* inefficient systems may be justifiable when perceived in this manner. However, even if we decide that electricity is essential to society, overall energy efficiency can be greatly improved by substituting more efficient energy systems for many current uses of electricity.

Other industrial nations followed the U.S. example and their energy consumption rates also soared. For a chilling description of this phenomenal growth we quote G. Tyler Miller Jr.:

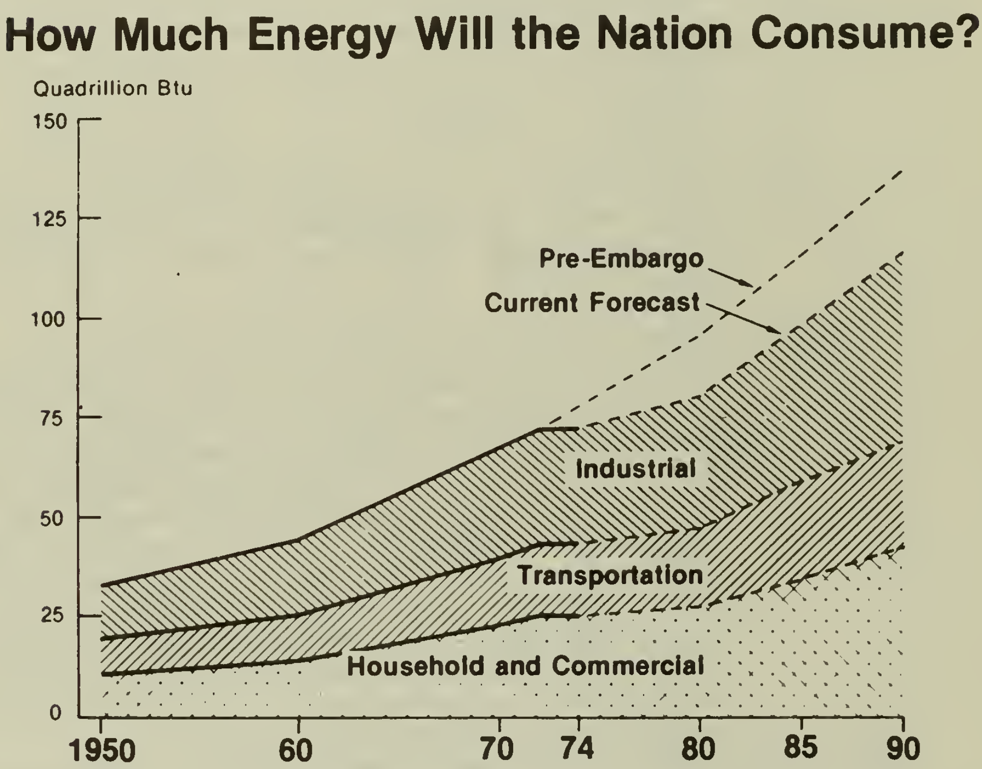
> World energy consumption increased almost 600 percent between 1900 and 1965 and is projected to increase another 450 percent between 1965 and the year 2000. World oil consumption is now so enormous that during the decade between 1970 and 1980 the nations of the world are projected to consume as much oil as was used in the first hundred years between 1870 and 1970. Coal has been mined for 8000 years, but over one-half of it has been extracted in the past 37 years. Petroleum has been pumped out of the ground for about 100 years, but over one-half of it has been consumed during the past 18 years. In sum, most of the world's consumption of energy from fossil fuels throughout all history has taken place during the past 30 years.
>
> ... With only 30 percent of the world's people ... [industrial nations] use 80 percent of the world's energy and this gap is expected to widen. The United States with less than one-sixth of the world's population accounts for over one-third of the world's annual consumption of energy. In contrast, India with about 15 percent of the world's population consumes only about 1.5 percent of the world's energy. Each year 214 million Americans use as much energy for air conditioning alone as 800 million Chinese use for all purposes, and we waste almost as much energy as 105 million Japanese consume for all purposes.
> (*Living in the Environment,* Wadsworth Publishing Co.)

For most of the last 100 years world consumption of fossil fuel energy has increased by four percent annually. In the U.S. energy use grew by about 3.5 percent per year from 1950 to 1965 (*Conservation and Efficient Use of Energy,* House Government Operations Committee, 1974). Then it jumped at an average annual growth of 4.5 percent annually from 1965 to 1973 when Middle Eastern oil supplying nations temporarily refused to ship oil to the U.S. At the same time world prices for oil were drastically increasing and the nation was slipping into a serious economic recession.

The combination of these factors caused an abrupt shift in U.S. energy demand. The U.S. Federal Energy Administration (FEA) reports that demand for the first eight months of 1975 (the latest figures available) was 2.2 percent lower than the same period in 1974 and 4.7 percent below the same period in

1973. However, FEA officials attribute two-thirds of this reduction to the current economic recession. They project that economic recovery, combined with increasing automation and population will cause demand to increase again, soon surpassing 1973 levels (Figure 4-4). From 1976 to 1980 they

Figure 4-4



(Federal Energy Administration, National Energy Outlook: 1976)

expect the nation's energy demand will grow about 2.5 to 3 percent annually. In much of the rest of the world, demand is growing at record rates of six percent or more (Figure 4-5).

The result of increasing demand and decreasing supply, of course, is higher prices. The average world price for oil has more than quadrupled since 1973. These price hikes have had a drastic impact on nations which import most of their energy (such as Japan and most of Europe) and poor nations which cannot pay higher prices.

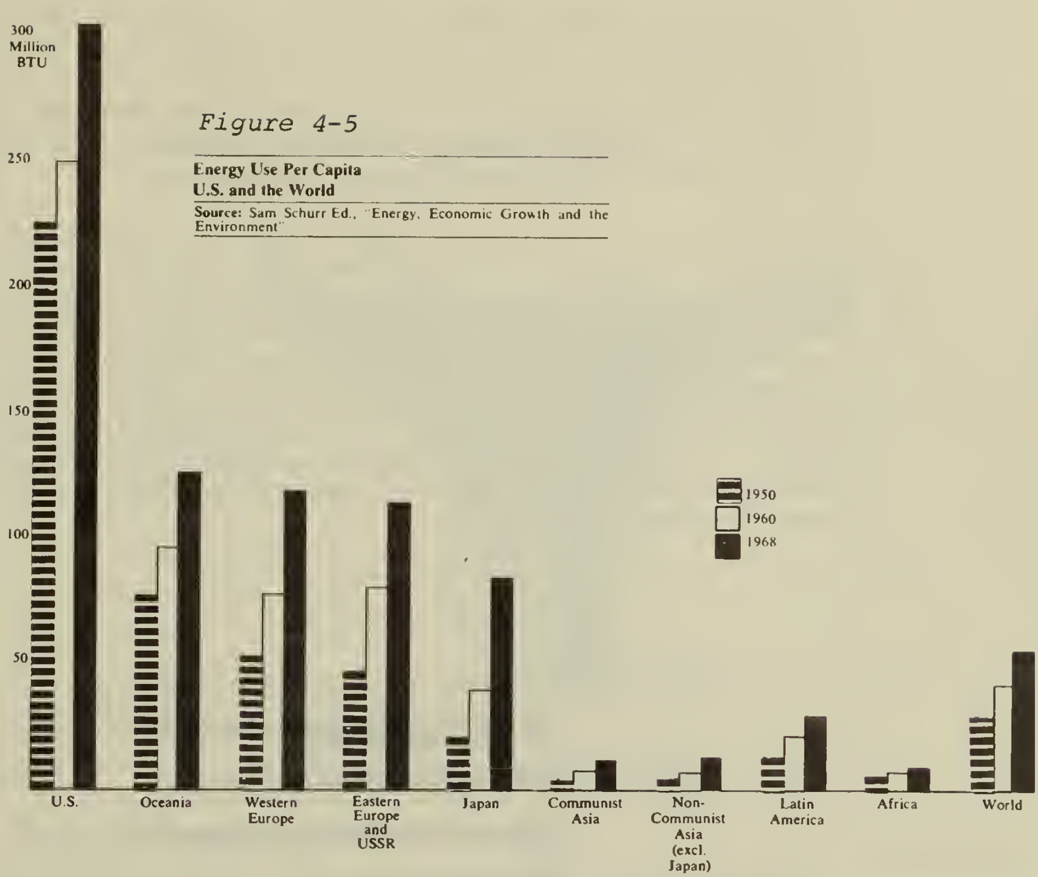


Figure 4-5

Energy Use Per Capita
U.S. and the World

Source: Sam Schurr Ed., "Energy, Economic Growth and the Environment"

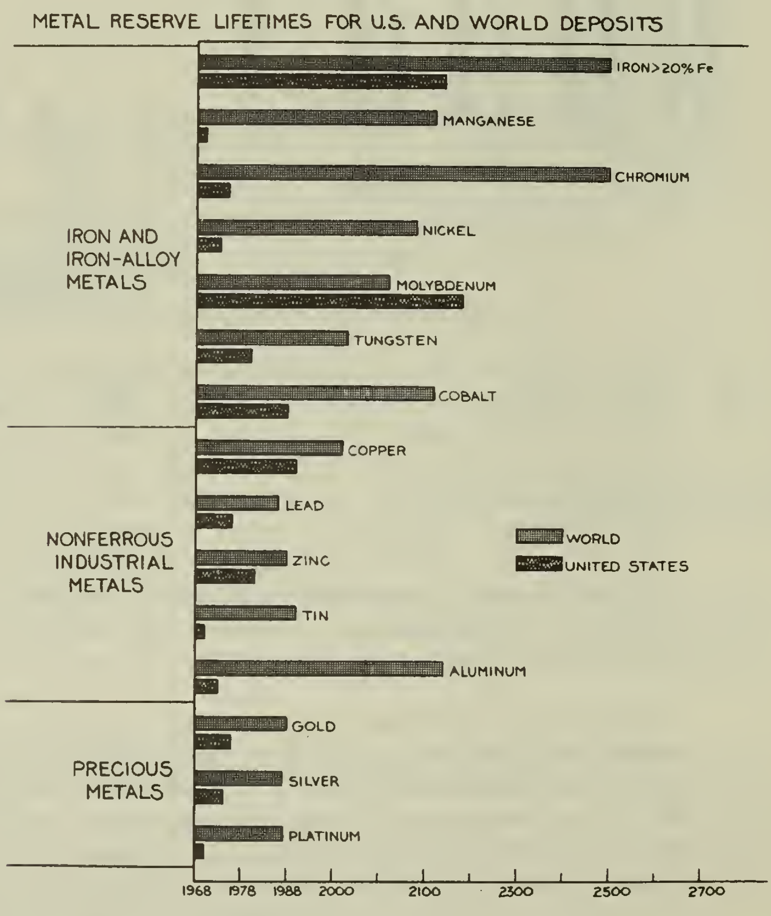
(Exploring Energy Choices, The Ford Foundation)

Energy is not the only resource which has been consumed at breathtakingly increasing rates. Non-renewable resources such as lead, gold, tin, zinc, silver, and platinum, which have also helped build industrial society, will be virtually exhausted by the end of this century at present rates of consumption. Their use, like energy, is growing exponentially. Once so rich in a variety of resources, the U.S. by 1978 will have exhausted virtually all of its known domestic supplies of manganese, chromium, nickel, lead, and tin (Figure 4-6).

This drastic increase in the use of energy and materials is based in part on increasing population. Available energy and other resources made it possible to support more people and this increased total consumption. In 1830, after thousands of years of procreation and human advances, the world's population had reached only one billion. In 1930, a mere 100 years later, it had doubled to two billion. Only thirty years later, in 1960, it reached three billion. Today, after only 16 years, we are four billion. By 2000 we may reach six-and-one-half billion even if we achieve some reduction in the growth rate (Figure 4-7). The last billion of those people would have been added in nine years (*Environmental Quality*, the Fifth Annual Report of the Council on Environmental Quality, 1974).

So you can see that our problem is not only an energy problem. But it should be emphasized that our problem is not simply one of exploding population either. The greatest (and most difficult to justify) cause of our current dilemma is not expanding numbers of people but exploding consumption by some of those people. Increased population in less-developed countries requires more energy simply to feed people. But expanding per capita consumption of energy and other resources places an even greater strain on world supplies (Figure 4-8).

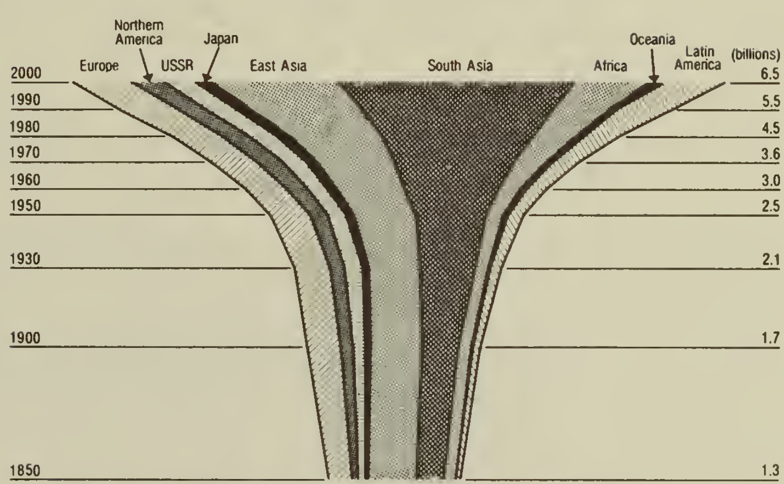
Figure 4-6



(*The Biosphere*, *W.H. Freeman and Company*)

Figure 4-7

Estimated Growth and Regional Distribution of the World's Population, 1850-2000[1]



[1]Assumes continuation of 1963 fertility levels.

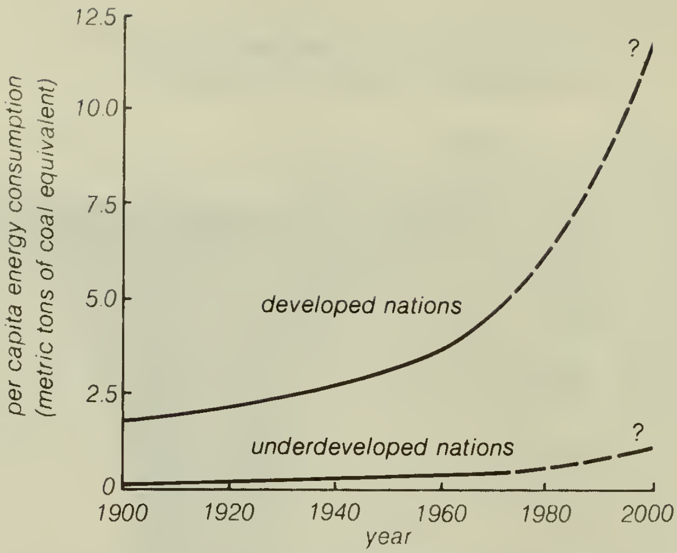
Source. UN Secretariat, Population Division, and J.A. Durand, "The Modern Expansion of World Population," *Proceedings of the American Philosophical Society*, Vol. III, No. 3, June 1967, cited in UN Fund for Population Activities, *WPY Bulletin*, No. 1, May 1973.

(Council on Environmental Quality)

An optimist among us may be saying at this point, "Well, at least we're all in it together." But, unfortunately, the world is losing thousands of people *each day* who are no longer "in it" because they starved to death. A human being needs about 2000 kilocalories of energy per day to survive but one-third to one-half of the world often fails to get that amount and is hungry or malnourished, according to the United Nations. An estimated 1400 people per hour (34,000 per day, 238,000 per week, or 15,000,000 per year) die from starvation, malnutrition, or related diseases, according to the Washington, D.C.-based Population Reference Bureau. Three out of every four persons on earth do not have a safe source of drinking water or sufficient housing, and over one-half of the world's population lives on incomes of less than $100 per year (National Academy of Sciences, *Waste Management and Control*, 1966; G. Tyler Miller, Jr., *Living in the Environment*, 1975).

The irony of our situation from a natural systems perspective should not escape us. By learning to use fossil fuels and high technology, industrial nations have gained considerable

Figure 4-8



The gap in per capita energy consumption between the developed nations and the underdeveloped nations is widening. (Source: United Nations)

(G. Tyler, Miller, Jr.,
Living in the Environment,
Wadsworth Publishing Co.)

independence from the direct control of nature. Our technology is *capable* of feeding all of the world's people. But industrial nations, using far more than their share of the earth's resources, allow less fortunate human beings to suffer poverty and starvation; we have temporarily overcome nature's checks and balances, only to impose similar limits ourselves based on political, geographical, and social divisions.

Given the difficult choices we now face, it is important to apply our best efforts to determining how much fossil fuel remains. This is the key to planning strategies for stretching these supplies and attempting to find new ways of harnessing energy. But predicting when the fossil fuel well will run dry is not easy.

Finding oil and natural gas is still somewhat of a guessing game. Many "dry holes" result even from engineers' educated guesses. Finding coal is somewhat easier. But until the middle of the 20th century, or later, scientists assumed we would find lots more fossil fuel. They now believe that most of the rich, easily-harvested supplies, especially oil and gas, have been located. Determining how much fuel is actually in those discovered deposits is also tricky. As late as 1975, the government's estimates of U.S. oil reserves were subject to controversy as a new study revealed that the method used to calculate our supplies may have overstated them by at least 100 percent. (Figure 4-9 shows one federal government estimate of *fossil* fuels.)

Figure 4-9

ESTIMATED LIFE EXPECTANCIES OF FOSSIL FUELS IN THE U.S.

	Discovered and anticipated reserves[1]	U.S. use in 1974	Life Expectancy[4]
Natural Gas	961 trillion cubic feet	21.6 TCF	2020 A.D.
Petroleum	348 billion barrels	6.1 B barrels[2]	2030 A.D.
Coal	437 billion tons	0.6 B tons[3]	2400+ A.D.

1. These figures include reserves which may not be feasible to recover.
2. Includes imports
3. Includes exports
4. Based on 1974 rate of consumption

Figures adapted from *National Energy Outlook,* Federal Energy Administration, 1976.

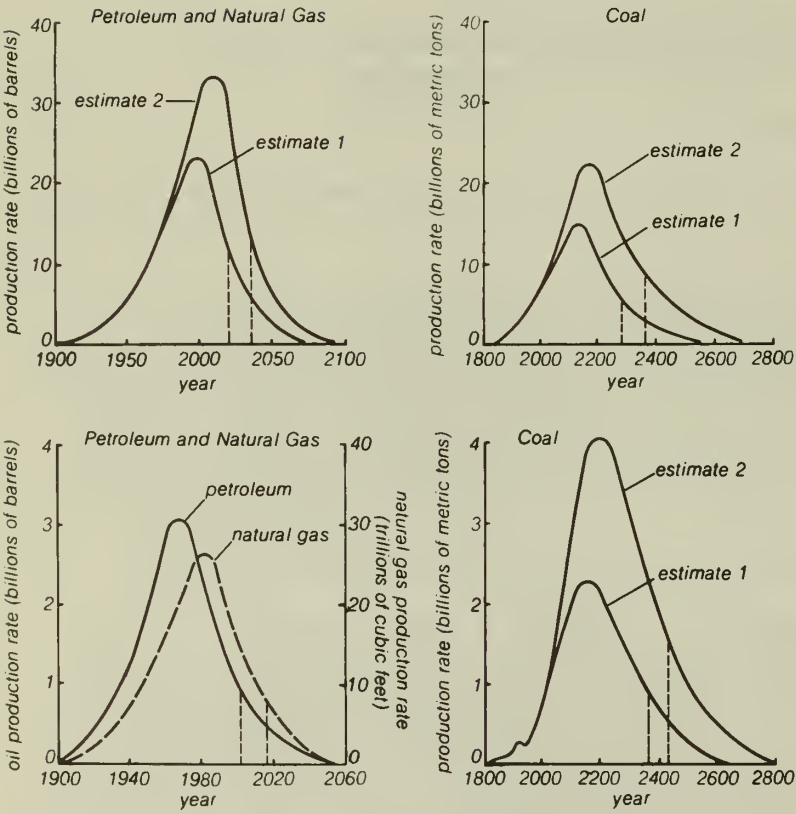
Many geologists disagree about the validity of current estimating techniques. There are numerous methods in use and the resulting figures vary widely. For example, some experts use the amount of a fuel discovered per year over a period of many years to formulate their estimates; others base predictions on the quantity of oil discovered per foot of exploratory well pipe drilled. Figure 4-10 shows estimated depletion curves for coal, oil, and natural gas based on figures by M. King Hubbert of the U.S. Geological Survey.

Another complication in predicting fuel reserves is not reflected in Hubbert's figures or in those by most other geologists. In order to make meaningful use of these estimates it is necessary to consider the amount of energy consumed to remove fuels from the ground and make them available for our use. This "energy investment" includes exploration, mining or drilling, processing, and transportation. The difference between the amount of energy invested and the amount obtained is called the *net energy yield.*

This concept becomes more and more important as energy reserves diminish because most of the high quality and easily exploited fossil fuel in the U.S. has already been used. Remaining deposits are, on the average, deeper in the earth or of lesser quality, so the net energy gain will be less. At some point it will no longer be worth removing residual deposits -- more energy investment will be required than there will be energy yield.

Net energy yield must also be applied to alternative energy technologies. For some of these (such as coal gasification, oil shale, and solar photovoltaic) energy input may exceed energy output -- a net energy loss. (These questions will

Figure 4-10



Estimated depletion curves for world supplies of fossil fuels Dotted vertical lines indicate the approximate time at which 80 percent of the fuel will be depleted. (Modified after Hubbert 1969)

Estimated depletion curves for U.S. supplies of fossil fuels. Dotted vertical lines indicate the approximate time at which 80 percent of the fuel will be depleted. (Modified after Hubbert 1969)

(G. Tyler Miller, Jr., <u>Living in the Environment</u>, Wadsworth Publishing Co.)

be discussed in greater detail in Chapter Five and Appendix C.) As we have already pointed out, it may be desirable to develop some energy systems which have low efficiency (perhaps even negative net energy yields) if the system has extremely high benefits to society.

Considering all of the estimates and net energy aspects, it seems clear that scarcity of fossil fuels will become a debilitating problem for the entire world by around 2015 to 2030 and for the United States by 1990 to 2015 (G. Tyler Miller, Jr., *Living in the Environment*). The era of cheap and unlimited fossil fuel supplies has already ended for most of the world.

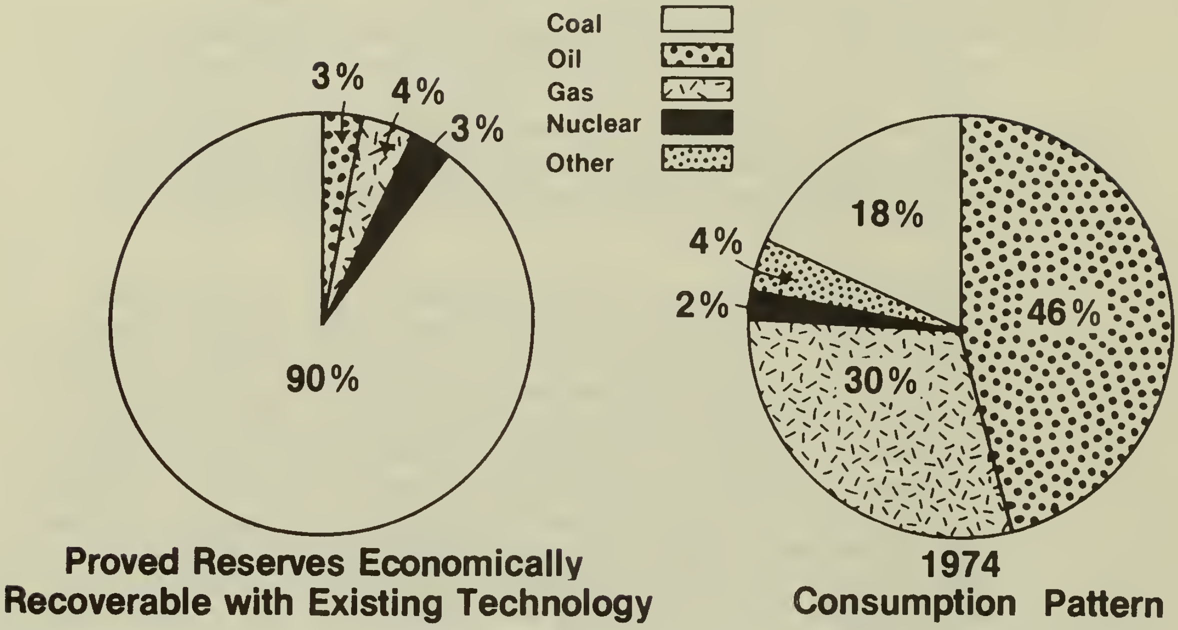
As has always been the case, some people and some nations will be better off than others in the coming era of scarce fossil fuels. In spite of all of our recent energy problems, the U.S. is better equipped to face this crisis than most nations. Although the U.S. has reached, or will soon reach, its peak production of domestic oil and natural gas, large recoverable reserves of coal still remain, enough to maintain our present level of coal consumption for 500 years or more. Only 18 percent of U.S. energy is supplied by coal, so domestic supplies are only partially employed. However, serious problems exist in mining and using this fuel, which will be discussed in the next chapter.

The current energy supply problem in the U.S. is largely that oil and natural gas are providing 75 percent of our energy but comprise only seven percent of our fuel reserves (Figure 4-11). Coal represents 90 percent of our energy resources but supplies only 18 percent of the energy we use. In order to continue our reliance on oil and natural gas expensive foreign supplies must be imported. Imported oil and gas were not always expensive and, in fact, were so cheap before the 1970's that they discouraged domestic production, which peaked in 1970 according to the Federal Energy Administration. The influence of cheap foreign supplies in addition to dwindling domestic reserves caused the U.S. to change in two decades from a net exporter of energy to importing over 15 percent of our total supply. About 37 percent of our oil is now imported, according to the FEA, and 1975 oil and gas imports cost just over $26 billion -- a greater than six-fold increase over the 1970 energy import bill of $3 billion. We are now paying about $125 per person each year compared to $15 per person in 1970. These increases are an important factor in our economic problems.

Other nations which are best equipped to meet the age of scarce fossil fuels are the Middle Eastern countries which have the largest portion of the world's remaining oil; the

Figure 4-11

What Are the Roots of Our Energy Problem?



(Federal Energy Administration, National Energy Outlook: 1976)

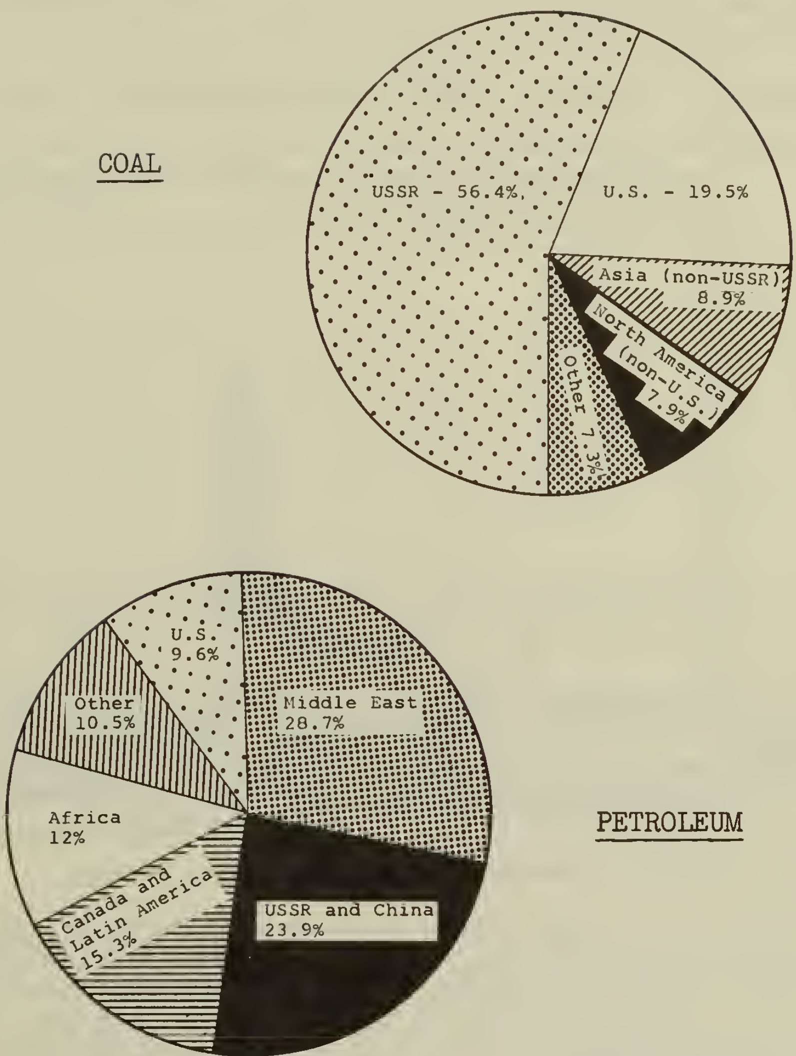
Soviet Union, with more than half of the world's remaining coal; and China, Canada, and several African and Latin American nations, which have substantial reserves of oil or other fuels (Figure 4-12).

Given all of these facts, you may be thinking that the obvious answer to our problems is to develop a new non-fossil-fuel energy source -- nuclear, solar, geothermal, or wind power -- or to solve some of the problems associated with coal production. Unfortunately, none of these alternatives offer an easy way out, as we will discuss in the next chapter.

One additional perspective on our fossil fuel dilemma is in order. Using depletion figures from Hubbert for oil, gas, and coal, a single depletion curve can be plotted for the world's fossil fuel resources. In order to dramatize the fossil fuel era's role in history, consider this curve on a time scale of 10,000 years, a tiny fraction of humanity's known existence. The result, shown in Figure 4-13 is start-

Figure 4-12

WORLD DISTRIBUTION OF COAL AND PETROLEUM



(Superintendent of Public Instruction, State of Washington)

ling and, considering our dependence on fossil fuels, frightening. Some other prominent eras have also been entered on the time line.

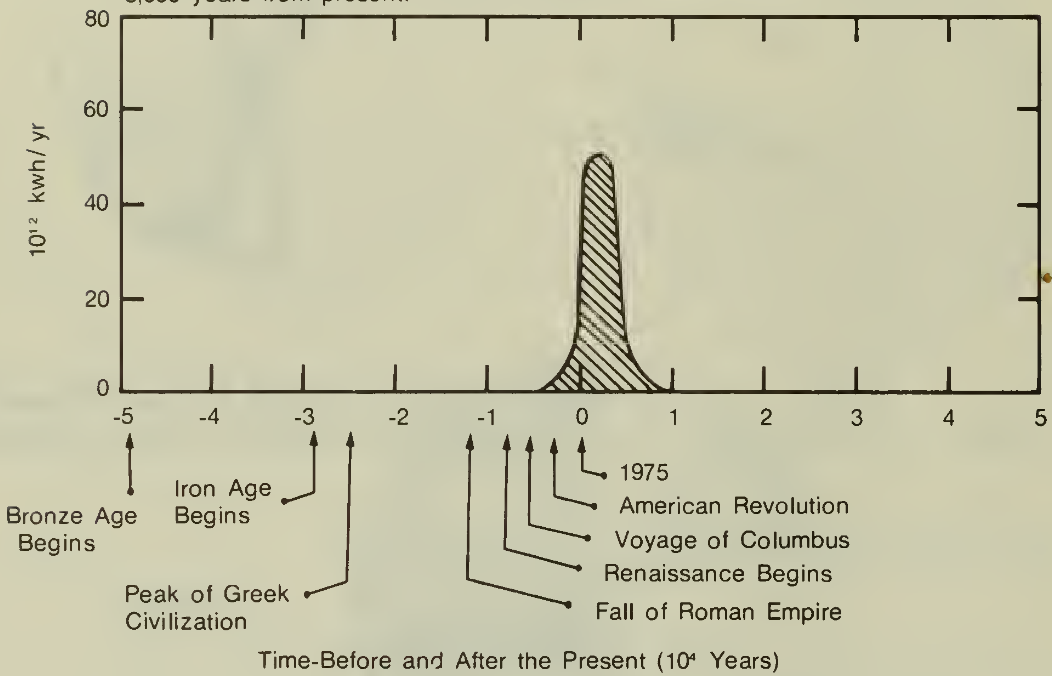
Commenting on this now-famous curve, its originator, M. King Hubbert, has written:

> On such a time scale, it is seen that the epoch of the fossil fuels can only be a transitory and

ephemeral event -- an event, nonetheless, which has exercised the most drastic influence experienced by the human species during its entire biological history.
(*Resources and Man*, W.H. Freeman and Company)

Figure 4-13

Epoch of exploitation of fossil fuels in historical perspective from minus to plus 5,000 years from present.



(modified from Hubbert)

5 ENERGY ALTERNATIVES

Research is progressing on alternative methods for harnessing energy, either by increasing the efficiency of using remaining fossil fuels, or by developing new sources. A number of alternative energy technologies show great promise and some have immediate application. However, no easy solutions are apparent.

"Making the transition to a lower-energy-based society, in which natural energy forms can serve as the prime movers of a new civilization, will perhaps be history's most challenging experience to Americans and other inhabitants of the high-energy world."

-- *Wilson Clark*

In order to understand the status of alternative energy systems in the U.S., one must understand the central role of the federal government. It is directing and financing most of the research to develop new energy technologies. The agency responsible for this work, the Energy Research and Development Administration, plans to spend $1.7 billion on energy development programs in the 1976 fiscal year (Figure 5-1). The research is conducted by government installations and by private companies working under federal contracts.

In addition the federal government owns over 50 percent of U.S. fossil fuel reserves, according to data collected by the Ford Foundation's Energy Policy Project (Figure 5-2). The government controls the near-shore resources of the U.S. continental shelf where most of our remaining domestic oil and natural gas is located. It owns millions of acres of land which are used for military bases, parks, recreation

Figure 5-1

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Operating Budget for 1976 Fiscal Year
Energy Research, Development and Demonstration Programs*
($ Millions)

FOSSIL FUEL --	Coal	280.1	
	Petroleum, natural gas	34.5	
	Oil shale	10.1	
	Other	8.7	
Total fossil fuel			333.4
SOLAR --	Solar electric	49.1	
	Heating and cooling	24.8	
	Technology support	4.6	
	Other	7.5	
Total Solar			86.0
GEOTHERMAL			31.7
CONSERVATION --	Electric energy systems	14.1	
	Transportation	10.4	
	Industry conservation	2.0	
	Buildings conservation	8.2	
	Storage, waste, conversion	20.8	
Total conservation			55.5
FUSION --	Magnetic	144.8	
	Laser	79.0	
Total fusion			223.8
FISSION --	Liquid metal fast breeder reactor	371.0	
	Clinch River demonstration breeder	57.0	
	High temperature gas cooled reactor	24.5	
	Light water reactor technology	3.0	
	Other	66.2	
Total fission			521.7
NUCLEAR FUEL CYCLE AND SAFEGUARDS R&D			162.5
BASIC RESEARCH			187.9
ENVIRONMENTAL EFFECTS			184.8
TOTAL			1,787.3

* These figures do not include other programs conducted by ERDA including uranium enrichment, space technology, and military weapons, which bring the agency's total budget for the year to $4.045 billion.

areas, national forests, wildlife sanctuaries, and other purposes. Often these lands have rich energy deposits. The U.S. government also retains ownership of mineral resources underlying millions of acres of former government land which has become privately owned, primarily through the Homestead Act (many land owners and some states dispute this claim). Although there are no concrete estimates, it is clear that these federal lands also hold a wealth of non-fossil fuel energy.

In this chapter we will briefly discuss known alternative forms of energy. A more detailed discussion of each is presented in Appendix C.

Energy from the sun is available in a variety of forms as it passes through the earth's systems. In addition to the sun's energy in long-term storage on earth, fossil fuels, solar rays can be used directly or can be captured in other forms, such as wind and ocean currents. Energy from our sun or other stars (depending on your theory of how the earth was formed) is also stored in the earth's crust as uranium and other radioactive matter. The intense heat in the core of the earth escapes to the surface in some locations and can be captured for our use. Even some of the "wastes" created by nature and humans can supply us with energy. The spectrum of energy forms available on earth is shown in Figure 5-3.

Figure 5-2

Federal resource ownership and 1972 production

	Reserves	*Percent of Domestic Total*	*Resources*	*Percent of Domestic Total*	*Production*	*Percent of Domestic Total*
Oil[a] (Billions of barrels)						
OCS	8.7–10.7	11	58–116	30	0.41	10
Onshore	2.8– 3.3	4	15– 30	8	0.22	5
Total	11.5–14.0	15	73–146	37	.63	16
Gas[a] (Trillion cubic feet)						
OCS	57.8–76.8	15	355–710	36	3.04	16
Onshore	24.2–31.2	6	75–150	8	1.06	6
Total	82.0–108.0	21	430–860	43	4.1	22
Coal[b] (All categories, billion tons)	186.9	48	Not available		10 million tons	2
Oil shale[c] (Billions of barrels oil)						
25 gallon-per-ton shale (10-plus thickness)			480	81	(No commercial production)	
15–25 gallons-per-ton shale (15-plus thickness)			900	78		
Geothermal	No breakdown available—approximately 50 percent of domestic total				(No commercial production on federal lands)	
Uranium	No breakdown available—approximately 50 percent of domestic total				Not available	

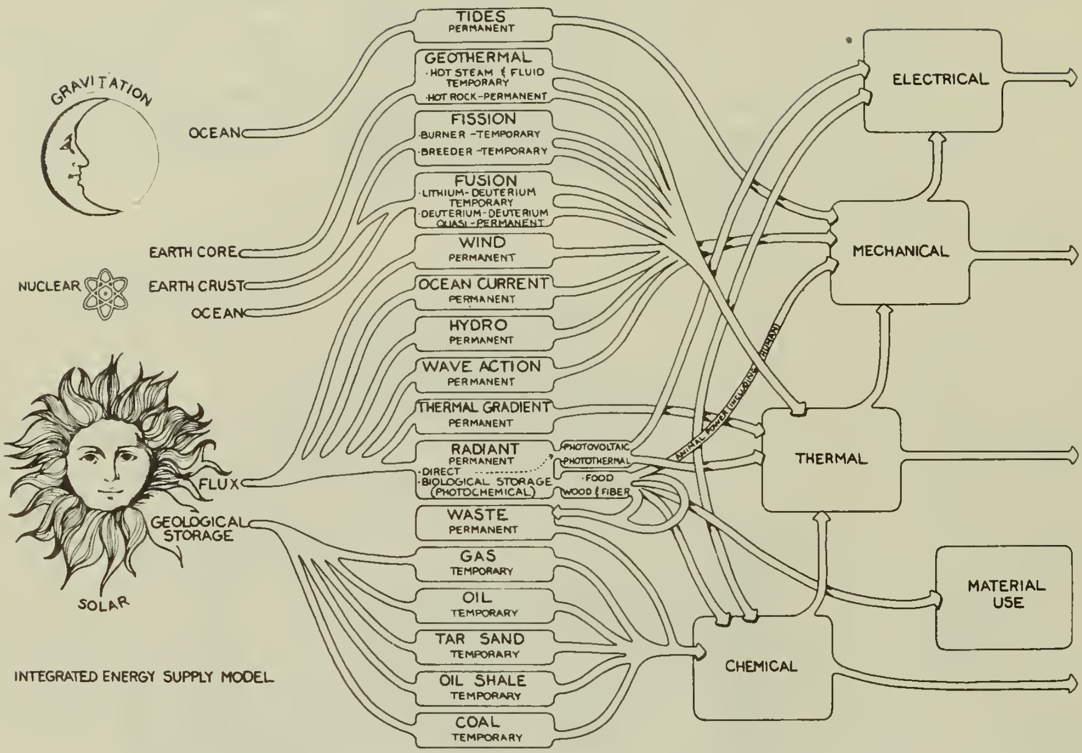
[a] USGS Press Release, February 1974. Reserves include measured reserves, indicated reserves and inferred reserves. (See definitions, Appendix D). Percentages computed using mid range of estimates.

[b] USGS. Circular 650; Federal reserve estimates derived from "Draft Environmental Impact Statement for the Proposed Coal Leasing Program."

[c] Derived from U.S. Department of the Interior Environmental Impact Statement, Prototype Oil Shale Leasing Program. Estimates for Colorado, Utah, and Wyoming.

(A Time to Choose,
The Ford Foundation)

Figure 5-3



(Office of Energy Research and Planning, State of Oregon)

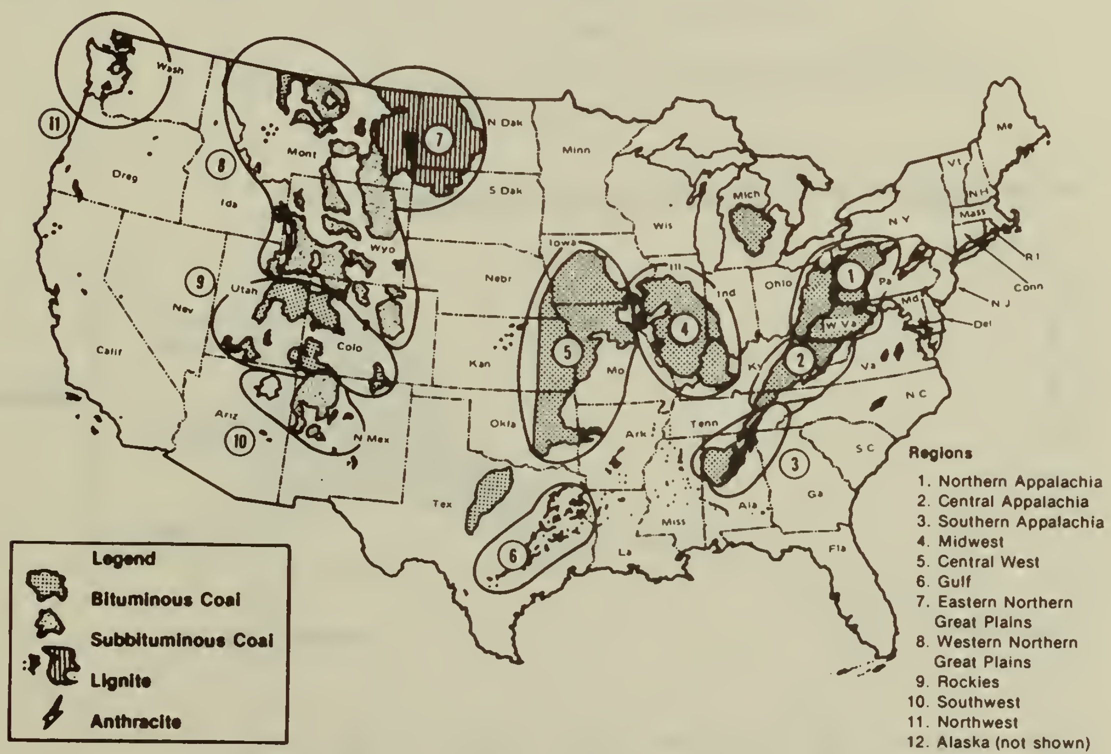
FOSSIL FUEL

Excluding the solar energy we use to grow crops, or to partially warm our bodies and homes (or cool them with wind), the U.S. and other industrial nations are currently taking nearly all of their energy from the fossil fuels segment of the energy spectrum. This is no accident; fossil fuels provide the very concentrated, high quality energy needed to power the machinery of our current industrial society.

However, world supplies of fossil fuels appear to have reached their peak and will become increasingly more scarce and more expensive. The most abundant remaining fossil fuel in the U.S. and the world is coal, comprising 90 and 95 percent, respectively, of anticipated reserves. (U.S. coal deposits are shown in Figure 5-4). But coal is difficult to mine in deep shafts, and surface mining destroys the productive value of land for many years. Coal is also the most polluting of the fossil fuels, emitting varying quantities of sulfur oxides and particulates. Increasing our use of coal for industrial, commercial, or residential purposes will require large new investments in pollution control equipment unless society is willing to accept dirtier air and more cases of respiratory disease. In addition, there is no satisfactory means of using coal as a fuel for transportation other than the inefficient process of producing electricity to power trains, buses, and cars.

Figure 5-4

Coal Supply Regions



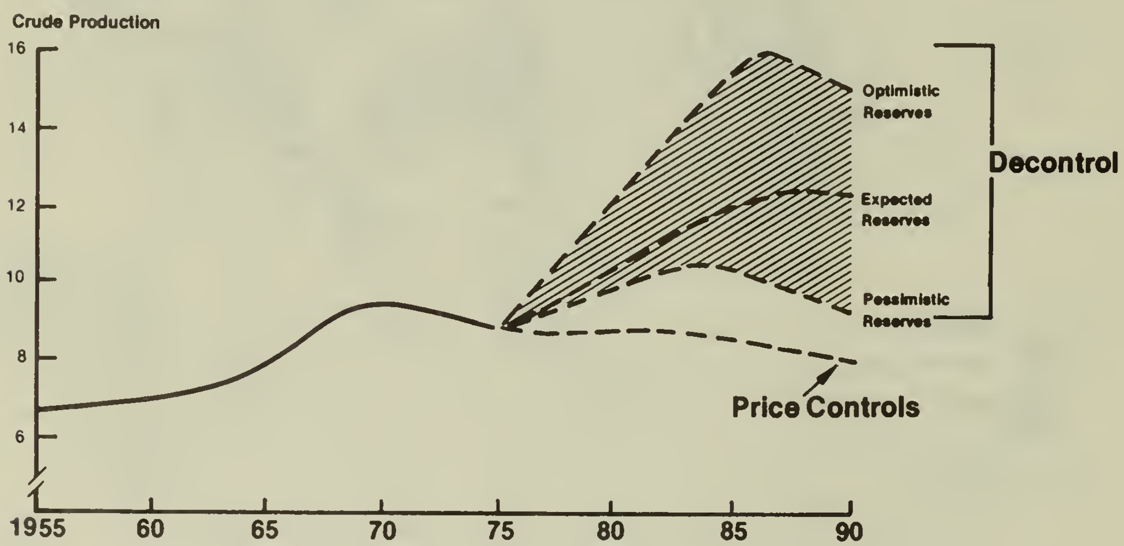
(Federal Energy Administration, *National Energy Outlook: 1976)*

In spite of these difficulties, coal's relatively abundant supplies make it an important asset in the upcoming era of scarce fossil fuels. New ways to process or burn coal may be found to minimize some of these problems. Research is currently underway in the U.S. to perfect processes to gasify and liquify coal -- hopefully also removing most harmful pollutants. But these systems are expensive and energy-intensive. It is not clear if they will provide a net energy yield.

Oil and natural gas now provide over 75 percent of U.S. energy needs, although there will soon be insufficient supplies to maintain this level unless greater quantities are imported. Experimental methods to increase the amount of oil and gas recovered from wells may partially ease this dilemma. Newly exploited oil and natural gas from Alaska will also help, but will not boost total supplies for more than a few years. The extent to which the price of oil and gas are regulated will also affect supply and "enhanced recovery" efforts; higher prices will encourage more of these activities. (Figure 5-5 shows one government estimate of future oil supply with varying price levels.)

Figure 5-5

How Quickly Will This Country Run Out of Oil?



(Federal Energy Administration, National Energy Outlook: 1976)

Two other forms of fossil fuel, oil shale and tar sands, are available in abundance in the U.S. but high processing costs and environmental problems will likely prevent their large-scale use.

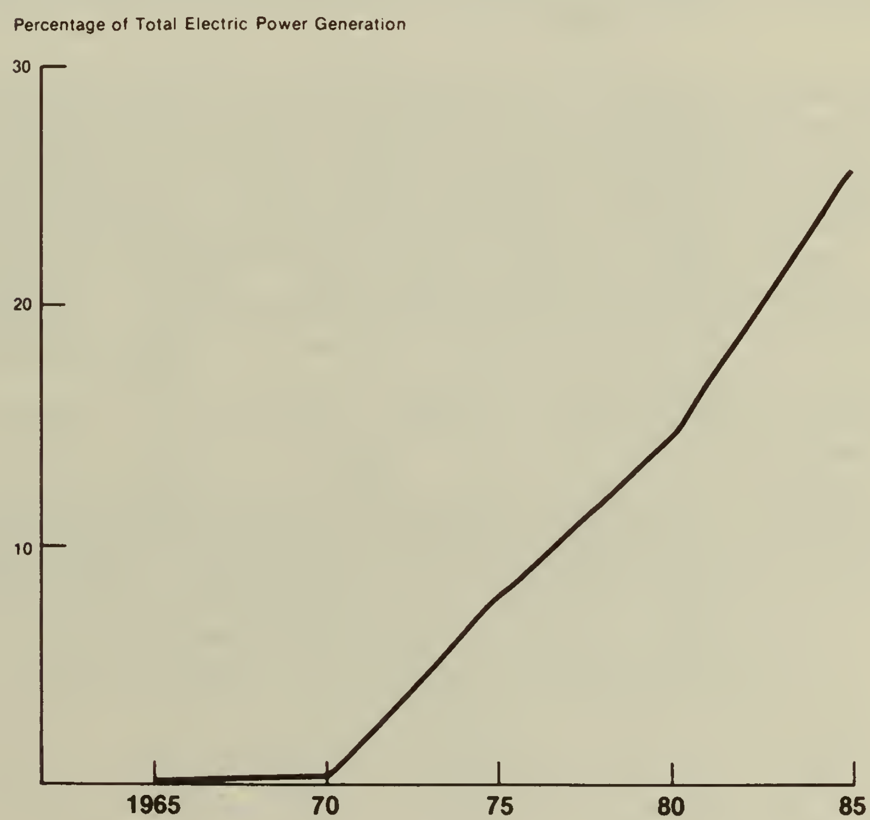
NUCLEAR POWER

The power of the atom locked in uranium and other radioactive material is actually an even more concentrated energy than that of fossil fuels, but the only current technology to use this energy, nuclear fission-produced electricity, is less efficient than fossil fuel-produced electricity. Attempts are also being made to capture energy from hydrogen, the source of the sun's energy, in a different nuclear process called fusion. This work is still in experimental stages.

The U.S. now has 59 operating nuclear fission power plants with more under construction. Those we now have supply eight-and-one-half percent of our electricity (Figure 5-6).

Figure 5-6

Nuclear Power's Role in Generating Electricity



(Federal Energy Administration, National Energy Outlook: 1976)

Considering that fission-produced electricity is a complicated, new technology, these facilities have operated reliably and, considering the dangerous materials they use, quite safely. However, safety and the adequacy of future fuel supplies are the subject of an emotional national debate. Federal energy officials and the nuclear industry believe these problems can be overcome but some individuals and organizations question this judgment. Although the complexity of nuclear processes makes it difficult to resolve these debates, voters in a number of states will find citizen-sponsored referenda on ballots this year which, if passed, will place restrictions on new nuclear power plant construction.

Regardless of the important safety questions (which are discussed in detail in Appendix C) there will soon be insufficient uranium to fuel the world's growing number of fission electric plants unless new nuclear technologies are developed. At the increasing rate uranium is being consumed, world supplies will be virtually depleted before the end of this century. This problem could be partially offset by reprocessing plutonium, a byproduct of the fission reaction, for use as a fuel. But plutonium is one of the most toxic substances on earth and its use would greatly increase the dangers of nuclear power.

The other hope for stretching uranium supplies is the development of the Liquid Metal Fast Breeder Reactor, which would theoretically use uranium fuel more efficiently and produce more plutonium byproduct. Now undergoing advanced federal research and demonstration work, the breeder reactor, if successful, could stretch our usable supply of uranium for decades, or perhaps centuries. However, the uses of the breeder would also involve increased risk. Not only would more plutonium be created and used to fuel other reactors, but unlike conventional fission reactors, the fuel in a breeder would be of sufficient concentration to explode if the reaction got out of control.

In spite of these problems, U.S. energy officials believe that nuclear power and the breeder reactor represent our most promising energy alternative at least through the end of this century. Billions of dollars have already been spent on nuclear power development and it still receives the largest share of the U.S. energy research budget -- more than one-third of the total.

SOLAR POWER

The sun's renewable forms of energy -- direct sunlight, photosynthesis, wind, tides, etc. -- are much more diffuse and have a lower quality energy than fossil fuels and nuclear power. For high temperature applications (processes which require high energy quality, such as the generation of electricity) most renewable energy forms must be concentrated -- a difficult, and often self-defeating, activity.

In some cases nature concentrates these dilute energy forms, as in trees and flowing water. Trees store and concentrate solar power over time in their structure. They can be harvested and burned to release medium quality energy (about 500 degrees Fahrenheit). Water gains kinetic energy as drops of rain which have fallen over thousands of acres of land are funneled downhill through watersheds, eventually flowing into rivers and the oceans. To harness the highly concentrated energy of running water in rivers (nature's pipelines to the oceans) we build dams to store some of the water in reservoirs. When released it can turn water wheels for mechanical power or turbines to generate electricity.

Most of the solar energy reaching earth is not so conveniently concentrated to provide high quality energy for industrial society, and both water power and wood are already being fully exploited by industrial nations. While the more dilute forms of solar energy show great promise for easing our dependence on fossil fuels, these energy systems have many technical hurdles to overcome and a large-scale commitment to research in most of the technologies has come only in the last five years.

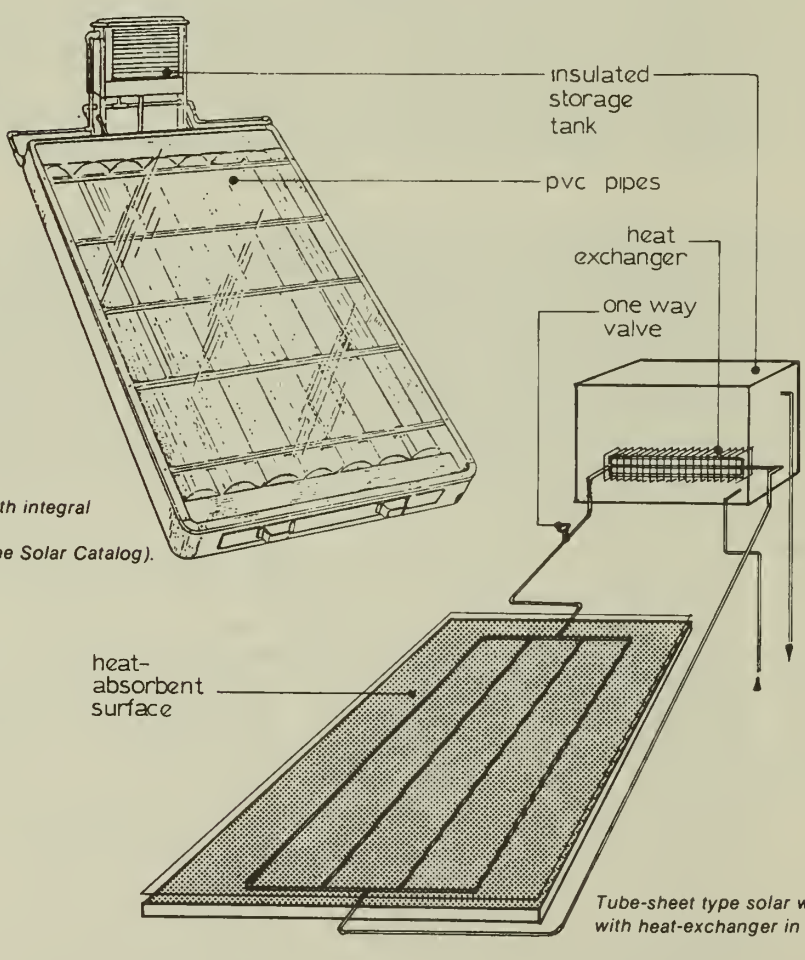
The sun's direct rays have been used for warmth and agriculture for thousands of years. More recently, poor nations have used simple solar reflectors to cook food and simple solar condensation devices to desalinate water. Industrial society has developed solar heating and cooling units for homes and buildings, as well as devices to convert the sun's rays directly to electricity (photovoltaic conversion).

Production of electricity by photovoltaic conversion, a chemical process using silicon cells, has been used extensively in the U.S. space program but is still far too expensive to be practical for everyday electricity needs. If costs can be reduced and a favorable net energy yield achieved, solar cells could eventually supply large quantities of electricity while producing relatively little pollution.

Solar electricity can also be produced indirectly by concentrating the sun's rays with a parabolic trough or by reflecting the rays from a large number of mirrors onto one collecting surface. The concentrated heat boils water to make steam which then turns conventional steam generators. This technology is still in the experimental stage but is one of the main projects of the federal government's solar research program.

Building heating and cooling, as well as hot water production, are possible now using simple solar collectors. In fact, solar water heaters were once a common home appliance in Florida and some other southeastern states, but were abandoned when fossil fuels became plentiful. They are widely used now in some other nations, especially Japan and Israel (Figure 5-7). The U.S. government is now sponsoring

Figure 5-7



Solar water heater with integral hot water storage, common in Japan (see Solar Catalog).

Tube-sheet type solar water heater with heat-exchanger in storage tank.

(Peter Clegg, Energy for the Home, Garden Way Publishing)

the installation of hundreds of solar heating and cooling units for homes and commercial or government buildings. These systems should soon be a widely-accepted alternative to fossil fuel heating and cooling, especially in warmer parts of the U.S. However, solar systems are currently more expensive to install (although not to operate) and require a backup system in colder U.S. climates. Their net energy yield is uncertain.

WIND POWER

Wind is a solar energy form which results from the uneven heating of the earth's atmosphere by the sun. Wind is even more variable than sunlight, changing with location, season, and the weather of the moment. Wind seldom blows at a constant speed but rather swells and ebbs in an irregular fashion. Its flow is also affected by landscape.

Wind can also provide both mechanical and electrical power and has a long history in the U.S., having been used extensively for water pumping and other mechanical chores by settlers as they developed the western states. But by the middle of the twentieth century most wind machine companies had gone out of business and fossil fuels had taken over their former chores. Now, increasing costs and shortages of fossil fuels have given the windpower industry new life. Small, private companies are flourishing again and the federal government has begun to invest millions yearly in windpower research. The government program is focused primarily on large windmills which could supplement electric utility generating capacity.

Windpower creates very little pollution, although the machines are unsightly. Net energy yields are also uncertain. However, both small- and large-scale wind systems have great potential.

OCEAN TIDES AND THERMAL GRADIENT

Two forms of energy stored in the oceans -- tides and thermal gradient -- are potentially available to humanity. Tides are created by the influence of the moon's gravity on earth. It is a very limited resource because there are few locations in the world where a sufficiently large tidal influx can be captured.

Thermal gradient is created when the sun heats water near the surface of the ocean. The difference in temperature between surface water and that several thousand feet down is often as much as 50 degrees in tropical latitudes. This temperature differential may provide a source of energy to humanity if heat engines can be perfected to use the gradient. This process is still highly speculative.

GEOTHERMAL POWER

Geothermal energy from the heat of the earth's interior has been used in the U.S. and other parts of the world, but the potential of this resource is very limited. The intense heat in the earth's core is largely dissipated by the time it reaches the earth's crust. But some pockets of heat collect within a few thousand feet of the surface. When ground water seeps into these pockets (or water is pumped in to encourage the process) hot water or steam result which can be used for direct steam heating or electricity production.

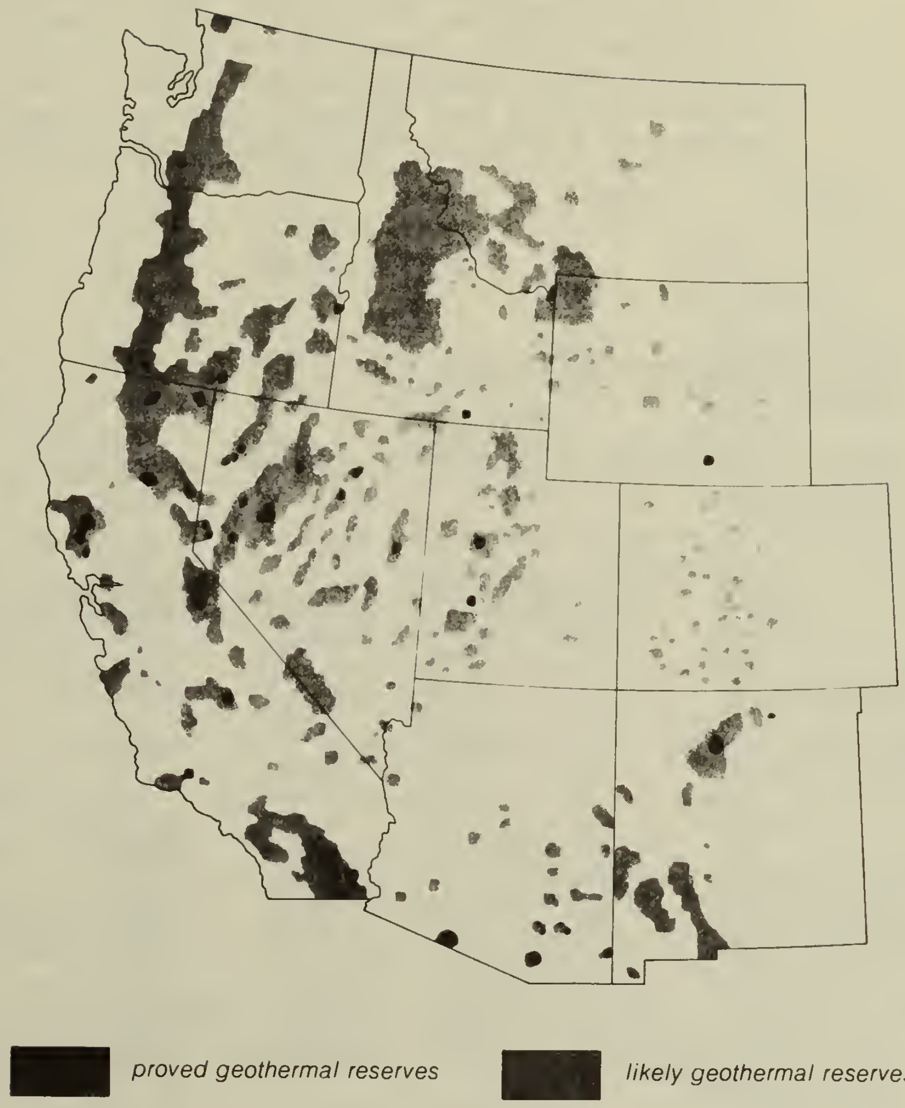
Geothermal power has been harnessed in many nations, including the U.S., which has a geothermal electric plant in California and steam heating systems in two communities in Oregon and Idaho. A number of additional developments are being considered in the U.S. but the resource is largely limited to the western states (Figure 5-8) and there is some concern that tapping geothermal energy may prompt earthquakes.

WASTES

Refuse from human activities, as well as animal and plant "wastes" (excrement and leaves or dead plants) can provide a useful source of energy while simultaneously reducing some waste disposal problems. In the U.S. three billion tons of organic (from living matter) and inorganic waste are produced each year -- city garbage, animal manure, sewage sludge, crop waste, logging waste, industrial waste, etc. This refuse contains a wealth of energy, recoverable minerals, and organic products.

Organic material can produce methane, a substance similar to natural gas, in a process called bioconversion. In the absence of oxygen this occurs naturally, as microorganisms break down the material. Other processes can be used to release synthetic oil or gas from organic material, or to reclaim valuable minerals from inorganic refuse, or to simply burn garbage as a supplementary fuel for power plants. The energy producing potential of these processes is substantial and a number of facilities are now in use in the U.S. and elsewhere. However, many problems remain, such as pollution, processes for separating wastes, and net energy uncertainties.

Figure 5-8



(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

Do any of these alternative forms of energy offer an escape from our fossil fuel dilemma? A judgment based on current technology indicates that no single alternative form can replace our fossil fuel dependence. (Figure 5-9 shows one analysis of the potential of various energy forms.) However, several of the most promising alternatives could at least ease our traditional fossil fuel demands. And, the use of alternative forms may offer substantial reductions in pollution (Figure 5-10). Viewed from a natural systems perspective, this may be the most prudent course in any event. Nature teaches us that diversity is a key to survival; dependence on a single source of sustenance invites disaster.

Figure 5-9

Evaluation of energy options for the United States

Option	Estimated availability* Short term (present to 1985)	Intermediate term (1985 to 2000)	Long term (2000 to 2020)	Estimated net energy	Potential environmental impact†
Conservation	Fair	Good	Good	Very high	Decreases impact of other sources
Natural gas	Good (with imports)	Fair (with imports)	Poor	High but decreasing‡	Low
Oil					
Conventional	Good (with imports)	Fair (with imports)	Poor	High but decreasing‡	Moderate
Shale	Poor	Moderate to good?	Moderate to good?	Probably very low	Serious
Tar sands	Poor	Moderate? (imports only)	Good? (imports only)	Probably very low	Moderate
Coal					
Conventional	Good	Good	Good	High but decreasing‡	Very serious
Gasification (conversion to synthetic natural gas)	Poor	Good?	Good?	Moderate to low	Very serious
Liquification (conversion to synthetic oil)	Very poor	Poor to moderate?	Good?	Moderate to low	Serious
Wastes					
Direct burning	Poor to fair	Fair to poor	Fair	Moderate (space heating) to low (electricity)	Fairly low
Conversion to oil	Poor	Fair to poor	Fair	Moderate to low	Low to moderate
Hydroelectric	Poor	Poor	Very poor	High	Low to moderate
Tidal	Very poor	Very poor	Very poor	Unknown (moderate?)	Low
Nuclear•					
Conventional fission	Poor	Good	Good to poor	Probably very low	Very serious
Breeder fission	None	None to low	Good?	Probably low	Extremely serious
Fusion	Poor	Moderate to low?	Moderate to low	Unknown (could be low)	Unknown (probably moderate to low)
Geothermal	Poor	Moderate to low?	Moderate to low	Unknown (probably moderate to low)	Moderate to low
Solar	Poor (except for space and water heating)	Low to moderate?	Moderate to high?	Unknown (probably low)	Low
Wind	Poor	Poor to moderate?	Moderate to high?	Unknown (probably moderate to low)	Low
Hydrogen	Negligible	Poor	Unknown§	Unknown (probably moderate to low)	Unknown§
Fuel cells	Negligible	Poor	Unknown§	Unknown (probably moderate to low)	Unknown§

Based on estimated supply as a fraction of total energy use and on technological and economic feasibility.
† If stringent safety and environmental controls are not required and enforced.
‡ As high grade deposits decrease, more and more energy must be used to mine and process lower grade deposits, thus decreasing net energy.
§ Depends on whether an essentially infinite source of electricity (such as solar, fusion, wind, or breeder) is available to convert water to hydrogen and oxygen gas by electrolysis or direct heating. Impact will vary depending on the source of electricity.

(G. Tyler Miller, Jr.,
Living in the Environment,
Wadsworth Publishing Co.)

Any new energy system will require a number of years for development of manufacturing techniques, installation, and user acceptance. Even solar heating and cooling, which is now rapidly gaining acceptance and for which equipment is

Figure 5-10

Comparative environmental impacts of energy options

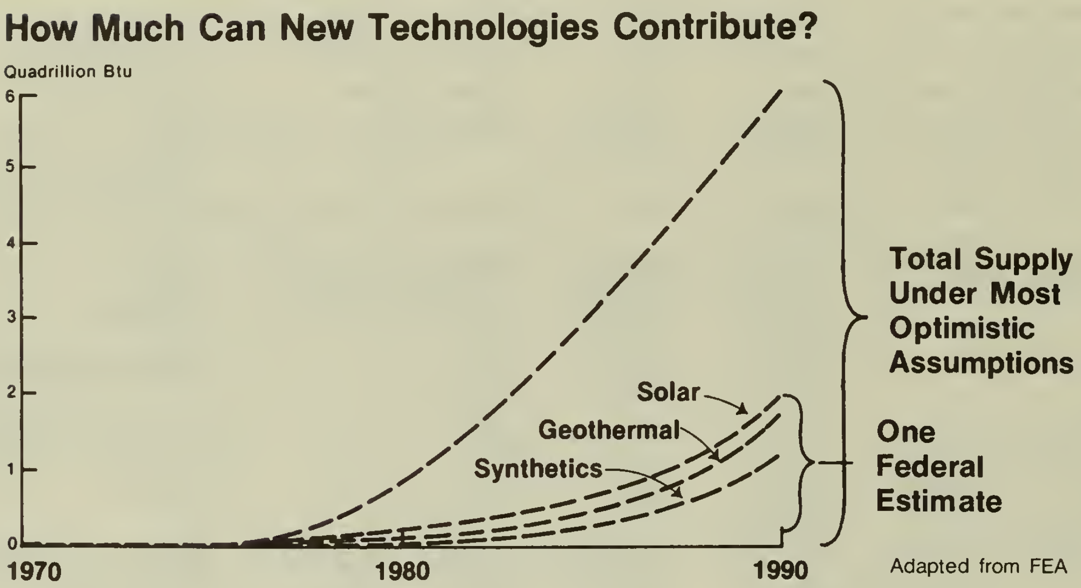
Energy option	Air pollution	Water pollution	Solid waste	Land use impact	Occupational health	Possible large scale disasters
Conservation	Decreased	Decreased	Decreased	Decreased	Less	None
Natural gas	Low	Low	Negligible	Low	Low	Pipeline explosion; earthquakes if nuclear blasts used for stimulating wells
Oil						
Offshore wells	Moderate	Serious	Very low	Very low	Low	Massive spill on water from blowout or pipeline rupture
Onshore wells	Moderate	Serious	Very low	Low	Low	Massive spill on land from blowout or pipeline rupture
Imports	Low to moderate	Serious	Very low	Very low	Low	Massive spill from tanker accident
Shale	Moderate	Moderate to serious	Serious	Serious	Low	Massive spill on land from blowout or pipeline rupture; earthquakes if nuclear blasts used for production in wells
Tar sands	Moderate	Moderate to serious	Serious	Moderate	Low	Massive spill on land from blowout or pipeline rupture
Coal						
Deep mined	Very serious	Very serious	Moderate	Moderate	Very serious	Mine accidents
Surface mined	Very serious	Very serious	Very serious	Very serious	Serious	Landslides
Gasification	Low	Very serious (more coal mined)	Very serious (more coal mined)	Very serious (more coal mined)	Very serious	Mine accidents; landslides, pipeline explosion
Liquification	Low	Very serious (more coal mined)	Very serious (more coal mined)	Very serious (more coal mined)	Very serious	Mine accidents; landslides, spills from pipeline rupture
Wastes						
Direct burning	Moderate	Very low	Decrease	Decrease	Low	Fire or explosion in furnace
Conversion to oil	Moderate	Low	Decrease	Decrease	Low	Fire or explosion in furnace
Hydroelectric	Negligible	Negligible	Negligible	Serious	Low	Rupture of dam
Tidal	Negligible	Negligible	Negligible	Low to moderate	Low	None
Nuclear						
Conventional fission	Negligible for normal pollutants but serious for radioactive releases	Low for normal sources but serious for radioactive releases	Low but very serious for radioactive releases	Low but very serious for radioactive releases	Low but very serious for radioactive releases	Meltdown of reactor core, sabotage of plants, shipping accidents; highjacking of shipments for use in nuclear bombs or for release into environment
Breeder	Negligible for normal pollutants but serious for radioactive releases	Low for normal sources but serious for radioactive releases	Low but extremely serious for radioactive releases	Low but extremely serious for radioactive releases	Low but extremely serious for radioactive releases	Meltdown of reactor core; sabotage of plants, shipping accidents, highjacking of shipments for use in nuclear bombs or for release into environment (radioactivity more dangerous than from conventional reactors)
Fusion	Negligible for normal pollutants but moderate for radioactive releases	Low?	Low?	Low	Low	Meltdown or explosion of reactor with release of gaseous radioisotopes
Geothermal	Moderate	Moderate to serious	Very low	Low to moderate	Low	Earthquakes
Solar	Negligible	Negligible	Negligible	Low to moderate	Low	None
Wind	Negligible	Negligible	Negligible	Low to moderate	Low	None
Hydrogen*	Variable	Variable	Variable	Variable	Variable	Variable
Fuel cells*	Variable	Variable	Variable	Variable	Variable	Variable

* The systems themselves have low environmental impacts in all phases, but the environmental impact of the systems of electricity used to generate these fuels must be added.

(G. Tyler Miller, Jr., <u>Living in the Environment</u>, Wadsworth Publishing Co.)

now available, will take a number of years to become a major supplier of energy. Thus these alternative systems, many of which still must be proven workable, will not be a major energy supply factor in the next 10 years even if an expanded commitment is made to develop them (Figure 5-11).

Figure 5-11



(Federal Energy Administration, National Energy Outlook: 1976)

It is also important to remember that development of alternative systems, and their manufacture once developed, requires an investment of energy, likely from fossil fuels. The amount of energy investment and the time needed for the new system to repay this loan are crucial questions in determining the value of a new system.

6 CONSERVATION

Our only safe and reliable option for the near term is to use less energy. This can be accomplished by eliminating unproductive energy waste in existing processes, and by increasing the use of available renewable energy technologies for tasks which do not require the concentrated energy of fossil fuels. These steps would not only relieve current shortages but would provide needed time for research on new energy systems, reduce environmental impacts, and (in the long term) save money.

"A man who cannot fill his bathtub because the water keeps running out does not need a bigger water heater; he needs a plug."

-- Malcolm MacEwen

In truth, we can never completely exhaust *all* of the earth's nonrenewable natural resources. We will never extract the last barrel of oil, or the last pound of coal or copper. As we approach these limits, resources will be increasingly difficult to obtain -- under the oceans, for instance, or deep within the earth -- and hence will become more difficult to procure and more expensive to use.

Even if new energy systems, such as the breeder reactor or nuclear fusion, are perfected and proven safe, or if we learn to use renewable sources for all of the energy we need, it is clear that our use of energy and other resources cannot continue to grow forever. Our planet has finite resources and can support a finite number of people, things, and pollution. There is no way to escape these natural limits so we might as well plan for them -- either sooner, with probably some painful disruption; or later, with enormous stress on social, economic, and political systems.

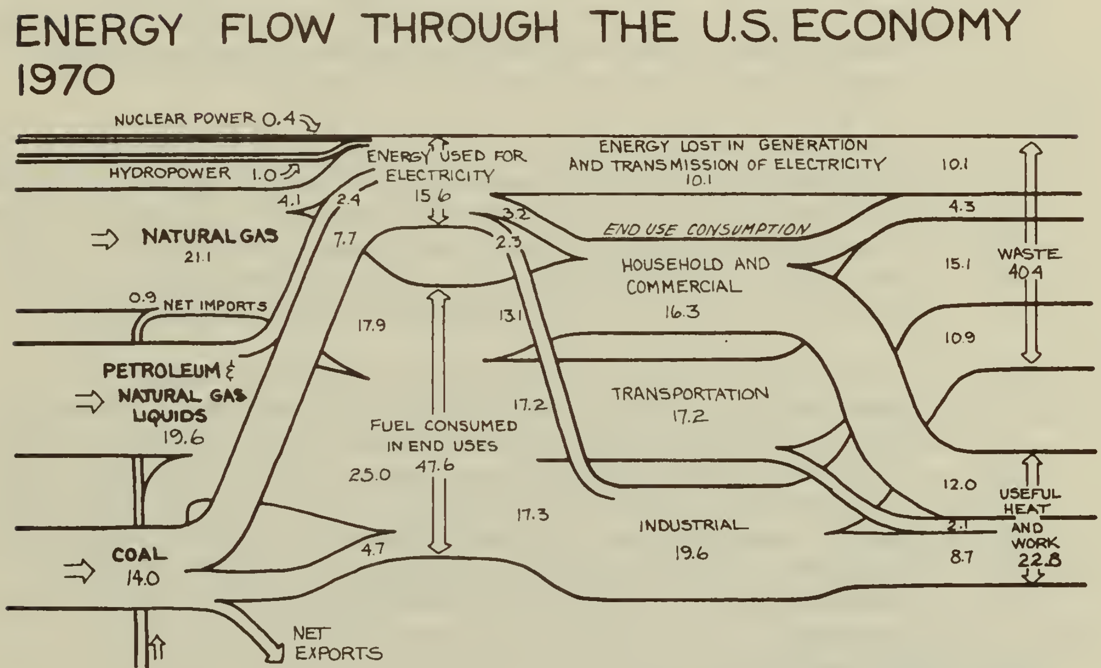
Consequently, there will come a time when conservation will no longer be merely a social option, but will be imposed on us by the limitations of supply and the carrying capacity of the earth. As the British physicist Amory Lovins has pointed out, "in the next few years we shall learn that however much energy people 'demand,' they cannot use it if it is not available. People will learn to conserve energy whether they want to or not. From now on the choice will become rapidly clearer: whether to reconcile demand with need according to an orderly plan, or by panicky improvisation in the face of imminent shortages" (*World Energy Strategies*, Armory B. Lovins, 1975).

The fact that energy has been freely available and that many benefits are obtained from it, makes it difficult for us to think about change. When energy seemed limitless, the primary concerns were to find, mine, and pump it, as well as to sell as much as possible as cheaply as possible to provide energy, jobs, and profits. Now that the question of finite limits has been added to energy equations, more complicated and controversial issues must be faced. Should we save some of these valuable nonrenewable resources for our children and future generations?

The weight of such decisions is eased by the fact that we have so many opportunities to save energy. Almost everyone agrees that a great deal of our energy use is simply unnecessary and could be avoided. Earl Cook of Texas A&M University, a pioneer in the energy efficiency field, has estimated that the U.S. wastes almost two-thirds of all the energy it consumes (Figure 6-1). A large portion of this, usually more than one-half, is inevitable (because of the Second Law of Thermodynamics), but the rest is not. Denis Hayes, a noted American environmentalist, contends that "we could lead lives as rich, healthy, and fulfilling -- with as much comfort, and with more employment -- using less than half of the energy now used." ("Energy: the Case for Conservation," 1976).

Other experts also report that many opportunities exist for saving energy in massive quantities. The American Institute of Architects (AIA) for instance, has calculated that a serious attempt to reduce energy use in building construction could reduce demand the equivalent of 12.5 million barrels per day by 1990. Adding more emphasis to this projection, Leo A. Daly, the Chairman of the AIA Task Force on Energy Conservation, has stated that conservation represents "a proven technology, in a more advanced state than nuclear technology", which could provide as much energy "as nuclear technology is expected to provide within the next 20 to 30 years -- and it could start now   Others point out ways of saving enormous quantities of energy in transportation, in industry, in recycling and waste disposal processes, in agriculture -- in all aspects of our lives.

Figure 6-1



(Earl Cook, Resource Conservation, Resource Recovery, and Solid Waste Disposal, 1973)

We could all use less energy simply by turning out unneeded lights, keeping thermostats at 68 degrees, walking rather than driving for short trips, doing simple tasks (like can opening) by hand rather than by electrical gadgets, and so on.

However, it is important to note that reaching the full potential for energy conservation in this country will not be that simple. Clearly, individuals and institutions can save a wealth of energy by eliminating unnecessary or wasteful activities. But another large percentage of potential savings can only be achieved by redesigning equipment, changing the products manufactured, retraining individuals employed in high-energy industries, and changing public attitudes about energy. And many of these steps -- especially when taken on a large scale -- could cause disruptions in personal lives as well as in society at large.

For example, the practive of bicycling to work and to other destinations makes sense from several perspectives. No gasoline is consumed, a bicycle requires less energy to manufacture than an automobile, less pollution is produced, the cyclist saves money, and the practice is good for one's health (unless air pollution and traffic conditions make it unsafe). A switch by some commuters to bicycles would have only minimal effect on the economy while saving fuel. However, a large-scale shift by commuters to bicycles or mass transit would have a drastic effect on the economy and other people's lives.

Detroit assembly line workers would be laid off because cars would be less used and because many people would decide they no longer needed one. Many tire dealers would suffer hard times or go out of business as demand decreased for their product. Auto repair shops would have less business, as would gasoline stations and numerous other businesses.

In the long run these disruptions would be cured by increased demand for other products. The Detroit assembly line worker might get a job building bicycles or rail cars for public transportation systems. The tire dealer might start a home insulation service. And the auto repair shop worker could become a windmill repair expert. Government programs could ease these transitions by sponsoring the teaching of new skills and providing income to displaced workers.

We have made little headway with energy conservation thus far -- there's too little information ("I don't know how to insulate may house"), or it's too much trouble ("the buses run too infrequently"), or we're waiting for the other person or the government to do something ("I don't know anyone who wants to car-pool"). Business and government have been just as guilty as indivuduals. Thus the most important question is whether our society *will* begin to plan for the inevitable.

We must remember that adjusting the American lifestyle to a more sensible use of energy and other natural resources will take years and will be painful in some cases. But this does not mean that we should continue to waste resources simply because change will be difficult. We have the intelligence to perceive that waste of finite resources is foolish; we should use this intelligence to remedy the situation as quickly *and* smoothly *and* equitably as possible.

OUR ENERGY HISTORY

The attitude of using energy without regard to the consequences -- either to the environment or to the remaining supply -- is deeply ingrained in our American tradition. Early American pioneers, for instance, brought with them the legacy of cutting wood, the fuel of the time, with no thought of restraint. Later, in the early years of the fossil fuel era, new forms of energy (including electricity) were so expensive that they were used sparingly. But after World War II, energy costs began to go down. Cheap oil and gas gradually replaced coal as our dominant fuel. As engineers increased the efficiency of electricity production (from five percent in early plants to nearly 40 percent in advanced coal-burning units) its price dropped substantially and consumption increased.

Wasteful use was further encouraged as centralized production of energy replaced the time and labor of chopping wood. Electrical outlets in modern homes seemed to provide virtually free energy. The cost of energy in manufacturing ceased to be a major concern and -- at least until very recently -- industry paid little attention to whether or not processes and machines used energy efficiently. A 1974 report by Congress' House Government Operations Committee noted that industrial management "has simply regarded energy as too cheap to worry about its waste" (*Conservation and Efficient Use of Energy*). As an example, Ernest S. Starkman, Vice President for Environmental Activities for General Motors Corporation, told the Committee that "while we like to think we run a highly efficient operation, in one plant we were able to cut back 20 percent on energy use in the first year of a major conservation effort." When Dow Chemical Company initiated an energy conservation program in 1972, it achieved a 10 percent reduction in two successive years.

In addition, industry has been unconcerned about the energy efficiency or useful life of the products it supplied to consumers. In fact, the maximization of profit seemed to draw industry toward supplying an ever-increasing quantity of non-essential gadgets of low durability in order to minimize unit prices and increase sales. For their part, consumers gave little thought to the energy needed to run all of the automobiles, appliances, lights, and gadgets offered by industry. Home and leisure activities became increasingly mechanized and it was common for people to leave lights and other appliances on when they were not needed.

Worst of all, neither industry, government, nor consumers paid any attention to the phenomenal amount of waste the society created. We tossed "obsolete" or malfunctioning goods in trash cans, without ever thinking about where they went or how we might reclaim the valuable materials they contain.

The federal government often added to the problem by setting national policies which subsidized waste. Tax subsidies for the use of virgin materials, and promotion of certain energy-consumptive industries such as airlines, are examples.

The direct result of this wasteful attitude toward energy use, combined with our expanding population, was a breathtaking spiral of consumption of energy and "things". Our level of energy consumption now dwarfs that of any other country in the world, although some actually have higher living standards than we do.

The Department of Interior has pointed out that maintaining the average American at the current level requires 21,600 pounds of non-metal resources (sand, gravel, salt, etc.), 1450 pounds of metal and materials, 18,600 pounds of fossil fuels, and a little over an ounce of uranium every year. As Wilson Clark has observed, that amount of energy is equal to each American citizen having 300 slaves working 24 hours per day (*Energy Conservation Training Institute Manual*, 1976).

Similarly, G. Tyler Miller, Jr., has estimated that, given the current consumption trends in 1973, a baby born in that year would require:

26 million gallons of water
52 tons of iron and steel
1,200 barrels of petroleum
13,000 pounds of paper
21,000 gallons of gasoline
50 tons of food
10,000 pounds of fertilizer

In his or her lifetime he or she will discard

10,000 no-return bottles
17,500 cans
27,000 bottle caps
2.3 automobiles
126 tons of garbage
9.8 tons of particulate air pollution

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

Extravagant use of energy has pervaded our lives and our economy to the extent that we seldom give a passing thought to the hidden energy costs that underlie many of our daily activities. In buying food, for instance, we think nothing of reaching into the supermarket freezer for foods grown and flown halfway around the world, incurring energy costs at every juncture.

The same energy-blind economics has rendered nearly an anachronism the small farmer who uses livestock manure for fertilizer and rotates his crops to revitalize soil and reduce insect infestation. These farmers have been displaced by multi-national corporations which grow hybrid grains in multi-thousand acre blocks, often using low-wage labor and pouring many times more fossil fuel energy into the food in the form of fertilizers, pesticides, herbicides, tractor fuel, etc., than the food returns once it is harvested. Because of the "economies of scale", which accrue partially from artificially cheap fossil fuels, and due to artificial preservatives which prevent spoilage, these gigantic agribusinesses are frequently able to produce and fly their products to supermarkets thousands of miles away cheaper than the local grower can grow them and truck them. Few people stop to make these comparisons when we start loading up the grocery cart.

Similarly, synthetic fibers manufactured from a petroleum base have for the past several years forced natural cloth, which is much less energy-intensive, almost out of the marketplace. Few shoppers have taken these energy costs into account when they made their selection between artificial and natural fabric.

The U.S. ceased to be a net exporter of oil in 1949 and has imported increasing quantities of fossil fuel since that time. Even so, it took a quadrupling of the price of oil in the 1970s by our major foreign suppliers before the U.S. fully realized its predicament. Drastic price increase by coal suppliers followed. In the U.S. the only fuel which has not doubled in price in the 1970s is natural gas, the price of which has risen less sharply in recent years because it is regulated by the federal government.

Thus, as in the days of wood fuel and early fossil fuel use, U.S. consumers have again become aware that energy does not come through the wall socket free of charge. Increasing prices will help to change our profligate energy lifestyles, although for low-income families which cannot afford higher energy prices, the explanation that energy *should* cost more will be of little comfort.

Even with the help of the price mechanism, large scale energy conservation will not be easily achieved because the consumption habits of industry, government, and individuals will be difficult to reverse. It was certainly easier to fall into a wasteful energy lifestyle than it will be to adopt a responsible one. And, as long as abundant supplies of energy are available, energy will continue to be used abundantly, say some scientists. Bruce Hannon at the Center for Advanced Computation at University of Illinois at Urbana-Champaign, for instance, believes that voluntary efforts to conserve energy won't really result in energy being conserved at all so long as severe energy curtailment seems far, far in the future. Hannon has written:

> Imagine the U.S. as an altruistic society. The President makes an impassioned plea for all consumers to reduce energy consumption by 10 percent, and each person does so immediately. Each citizen would soon find he would have saved money and would spend it, but not on gasoline, electricity, or any direct form of energy consumption. Perhaps he would dine out more, buy new furniture, a new car, or a color television set with the money saved by reducing direct energy purchases...These products contain embodied energy, and their purchases would reduce and perhaps nullify the voluntary energy savings of 10 percent.
> (Bruce M. Hannon, "Energy, Growth, and Altruism", Center for Advanced Computation, Urbana-Champaign, 1975).

One might assume that a better alternative than spending the money on material things or activities might be to save it. But Hannon points out that the savings institution must reinvest it -- and often in activities that are even more energy intensive than what the individual might have spent money on. Of course some products and services are a good energy investment. Figure 6-2 compares the energy invested in some common examples.

Even if society cannot be prodded into voluntary conservation while energy remains relatively cheap and abundant (and we're not ready to give up yet), we clearly *can* make use of our present high-energy system to develop the methods to live well with less energy for the future.

The following sections explore the potential for energy conservation in the U.S. transportation, buildings, and industrial sectors. Figures 6-3 and 6-4 summarize the major energy consuming activities in each of these sectors.

Figure 6-2

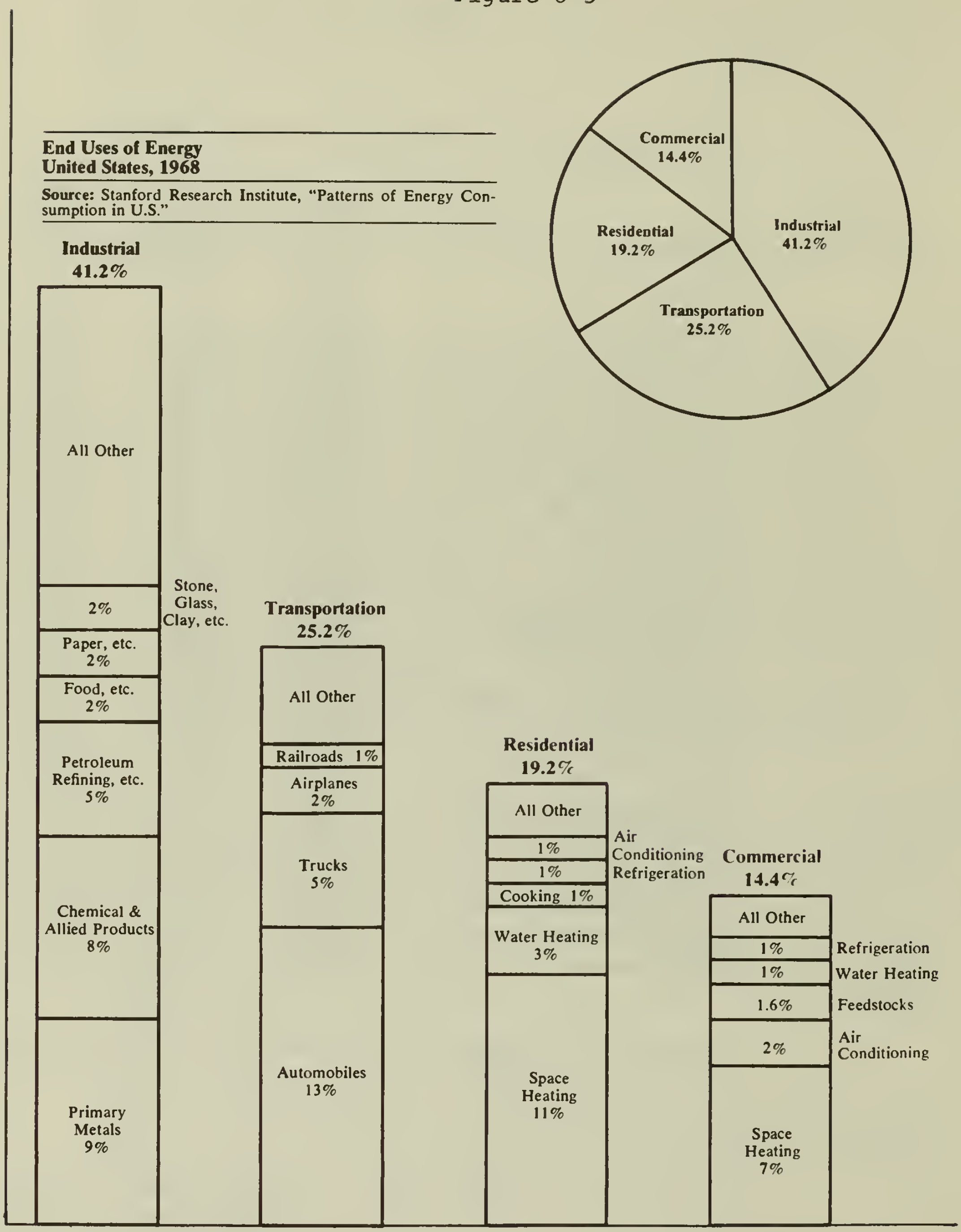
Btu Content and Energy Value Content of Selected Goods and Services: Partial List

PRODUCT	ENERGY CONTENT (Btu/$)	GALLONS OF GASOLINE EQUIVALENT	ENERGY VALUE CONTENT (¢/$)
Plastics	218097	1.74	13.2
Man-made Fibers	202641	1.62	7.4
Paper Mills	177567	1.42	7.9
Air Transport	152363	1.22	12.0
Metal Cans	136961	1.10	7.3
Water, Sanitary Services	116644	.93	11.6
Metal Doors	109875	.88	6.7
Cooking Oils	94195	.75	7.1
Fabricated Metal Products	91977	.74	5.8
Metal Household Furniture	91314	.73	5.9
Knit Fabric Mills	88991	.72	6.5
Toilet Preparations	85671	.70	5.1
Blinds, Shades	81472	.65	6.3
Floor Coverings	79323	.63	5.8
House Furnishings	75853	.61	5.3
Poultry, Eggs	75156	.60	7.3
Electric Housewares	74042	.59	5.6
Canned Fruit, Vegetables	72240	.58	5.2
Motor Vehicles & Parts	70003	.56	5.9
Photographic Equipment	64718	.52	3.8
Mattresses	63446	.51	4.5
New Residential Construction	60218	.48	4.5
Boat Building	60076	.48	4.9
Food Preparation	58690	.47	4.8
Soft Drinks	55142	.44	4.5
Upholstered Household Furniture	51331	.41	4.1
Cutlery	50021	.40	4.0
Apparel, Purchased Materials	45905	.37	4.0
Alcoholic Beverages	43084	.34	3.0
Hotels	40326	.32	5.4
Hospitals	38364	.30	5.4
Retail Trade	32710	.26	4.4
Insurance Carriers	31423	.25	4.4
Misc. Professional Services	26548	.21	4.3
Banking	19202	.15	2.5
Doctors, Dentists	15477	.12	1.9

These values are for producer's prices, and do not take into account mark up to retail price, about 66%.

(Lee Schipper, "Explaining Energy: A Manual of Non-Style for the Energy Outsider Who Wants In")

Figure 6-3



(Exploring Energy Choices, The Ford Foundation)

Figure 6-4

Total Fuel Energy Consumption in the United States by End Use

End use	Consumption (trillions of Btu) 1960	1968	Annual rate of growth (%)	Percent of national total 1960	1968
Residential					
Space heating	4,848	6,675	4.1	11.3	11.0
Water heating	1,159	1,736	5.2	2.7	2.9
Cooking	556	637	1.7	1.3	1.1
Clothes drying	93	208	10.6	0.2	0.3
Refrigeration	369	692	8.2	0.9	1.1
Air conditioning	134	427	15.6	0.3	0.7
Other	809	1,241	5.5	1.9	2.1
Total	7,968	11,616	4.8	18.6	19.2
Commercial					
Space heating	3,111	4,182	3.8	7.2	6.9
Water heating	544	653	2.3	1.3	1.1
Cooking	93	139	4.5	0.2	0.2
Refrigeration	534	670	2.9	1.2	1.1
Air conditioning	576	1,113	8.6	1.3	1.8
Feedstock	734	984	3.7	1.7	1.6
Other	145	1,025	28.0	0.3	1.7
Total	5,742	8,766	5.4	13.2	14.4
Industrial					
Process steam	7,646	10,132	3.6	17.8	16.7
Electric drive	3,170	4,794	5.3	7.4	7.9
Electrolytic processes	486	705	4.8	1.1	1.2
Direct heat	5,550	6,929	2.8	12.9	11.5
Feedstock	1,370	2,202	6.1	3.2	3.6
Other	118	198	6.7	0.3	0.3
Total	18,340	24,960	3.9	42.7	41.2
Transportation					
Fuel	10,873	15,038	4.1	25.2	24.9
Raw materials	141	146	0.4	0.3	0.3
Total	11,014	15,184	4.1	25.5	25.2
National total	43,064	60,526	4.3	100.0	100.0

Note: Electric utility consumption has been allocated to each end use.

Source: Stanford Research Institute, *Patterns of Energy Consumption in the United States*, prepared for the Office of Science and Technology, Executive Office of the President, 1972.

(*Exploring Energy Choices*, The Ford Foundation)

CONSERVATION IN TRANSPORTATION

Transportation -- the means by which we get from one place to another -- has become so important in our daily lives that 42 percent of all energy used in the U.S. goes either into manufacturing transportation vehicles or making them run. But the U.S. now moves people and goods less efficiently than it did in 1950. Why? Because the use of our most efficient forms of transport is declining while business is booming for the least efficient modes.

Of course, the major factor in this American transportation picture is the automobile, which uses the most transportation energy and is nearly the least efficient form of moving people (See figures 6-5 and 6-6). As John R. Quarles, Jr., deputy administrator of the Environmental Protection Agency, has observed:

> "The automobile is set in the center of the stage in this drama of energy conservation. It is a big part of the problem in and of itself. And it is a symbol for all the rest. If we are unwilling to face up to the problem of the automobile and do something about it, we might as well forget the goal of energy conservation. We are kidding ourselves if we think the job can be done without attacking the problem at its core."
> (House Committee on Government Operations, *Conservation and Efficient Use of Energy*)

Figure 6-5

Transportation Mode	Energy Consumption (%)	
Automobiles	55.0	
Trucks	20.0	
Buses	1.0	
Other (including motorcycles)	.48	
Total highway transportation		76.48%
Airplanes	9.87	
Railroads (freight)	3.51	
Railroads (passenger)	.06	
Shipping (inland and coastal barges and ships)	4.84	
Fuel pipelines	5.24	
Total		100.00%

Source: U.S. Department of Transportation

(Wilson Clark, Energy for Survival, Anchor Press)

The private automobile uses 55 percent of the energy consumed in the U.S. and carried 97 percent of urban and 87 percent of inter-city passenger traffic in 1970 ("Energy Intensiveness of Passenger and Freight Transport Modes, 1950-1970," Eric Hirst, 1973).

Eight of every 10 U.S. households now owns one car; three of every 10 households owns two; and one of every 10 households owns three or more, according to the Motor

Vehicle Manufacturers Association. In 1971 the 207 million people of the U.S. had 92 million automobiles. This is more than double the 1950 car population. And, according to the Federal Highway Administration, average fuel economy of cars has decreased from 15 miles per gallon in 1950 to 13.5 miles per gallon in 1972. Average mileage has improved somewhat since 1972 due chiefly to increased sales of smaller cars. The problem of poor mileage has been compounded by the increasing reliance on the automobile by an expanding population.

In urban driving, characterized by frequent stops and starts, the efficiency of the automobile drops even more, using almost as much energy per mile (an average of 8100 BTUs) to move people as the most wasteful form of transportation, airplanes (Hirst). For travel between cities, cars used an average 3400 BTUs per passenger mile, bringing the average for all automobile travel down to 5400 BTUs per passenger mile.

Figure 6-6

FREIGHT TRANSPORT

Mode	Energy intensiveness, expressed in BTUs of energy needed to move 1 ton of freight 1 mile
Airplane	42,000
Truck	2,800
Waterway	680
Railroad	670
Pipeline	450

PASSENGER TRANSPORT

Mode	Energy intensiveness, expressed in BTUs of energy needed to move 1 passenger 1 mile
Airplane	8,400
Automobile (urban)	8,100
Mass transit (urban)	3,800
Automobile (intercity)	3,400
Railroad (intercity)	2,900
Bus (intercity)	1,600

Source: Energy Intensiveness of Passenger and Freight Modes 1950-1970 by Eric Hirst, Oak Ridge National Laboratory, 1973

(Wilson Clark, Energy for Survival, Anchor Press)

Automobiles are so inefficient because they are heavier and more powerful than they need to be, often have inefficient accessories such as air conditioning, and seldom carry more than one or two passengers. In addition, the production of automobiles uses massive quantities of other resources such as rubber, steel, lead, aluminum, copper, and zinc. Many of these, especially aluminum, require large amounts of energy for their manufacturing or processing.

Use of airplanes, the least efficient form of passenger and freight transport, has also grown drastically since 1950 and, like automobiles, they are becoming less efficient. According to Hirst's study, the share of passengers carried by air was five times greater in 1970 than in 1950, and the share of freight carried by air had increased seven-fold.

Speed is the major culprit in air transport's decreasing efficiency. Average flying speed in 1950 was 180 miles per hour. By 1970 it increased to 400 miles per hour. Over the same period the average amount of energy used to move a passenger one mile increased from 4500 BTUs to 8400 BTUs. Freight transport also used more energy in 1970 than 1950, increasing from an average 23,000 BTUs to move a ton of freight one mile to 42,000 BTUs per ton mile (Hirst).

Trucks, buses, and railroads are normally better methods for moving people and freight. Diesel-powered trucks are most useful for short trips of under 200 miles. They are only moderately efficient, but are the best way to move goods from rail terminals to markets. Truck fuel efficiency has decreased slightly since 1950, from 2400 BTUs per mile to 2800 BTUs per mile in 1970 (Hirst). The main reason -- again -- was increased speed.

Hirst's study also found that buses and electric-powered rail systems use an average of only 3800 BTUs per passenger mile to move people in cities -- less than half that consumed by autos in urban use. But the percentage of people using these forms of travel has declined steadily. Buses carried five percent of intercity passengers and eight percent of urban passengers in 1950. By 1970 the bus's share of each category had dropped below two percent. Similarly, the percentage of passengers carried by urban rail systems decreased 57 percent from 1950 to 1970, even though their energy efficiency increased by 47 percent.

Another alarming change in our transportation habits since 1950 is the decreasing use of railroads, an increasingly efficient way to move people and goods. In contrast to urban rail systems, which are powered by inefficient electricity, cross-country diesel locomotives are highly efficient. Railroads make the best use of fuel to move passengers over long distances and are nearly the most efficient to move freight -- only pipelines can compete with the railroad's efficiency in moving goods.

According to Hirst's study, it takes an average of only 670 BTUs to move a ton of freight one mile by railroad, only one-quarter of the energy required by trucks to do the same work. In 1950, half of U.S. freight moved by rail, but by 1970 the figure had dropped to a little over one-third, and railroads also lost much of their share of the passenger market during the same 20 years (from seven to one percent).

These reductions have occurred in spite of the fact that, unlike all of the other methods of moving people and goods, the efficiency of railroads has increased. Hirst found that railroads use energy *five times* more efficiently now than they did in 1950, due primarily to shifting to diesel engines.

Although waterways and pipelines also move freight with great efficiency, they have limited application. Use of waterways, including the Great Lakes, increased in volume by 41 percent from 1950 to 1970, but their percentage of the freight market decreased from 31 percent to 27 percent.

Significant energy conservation in the transportation sector would require a radical shift in priorities by the federal government, since most of our federal transportation budget is devoted to airplanes and highways, our least efficient options. The much more efficient rail system has been allowed to fall into neglect and disrepair. Many factors have combined to bring us to a point where, despite renewed interest in train travel, rail service is inadequate. Only increased federal emphasis and funding can properly address many of the railroad problems.

There are many personal strategies to reduce energy use in getting from one place to another. Walking is a transportation option that most of us forget about, and it requires only the energy that goes into making our shoes and "fueling" our bodies. In many situations this is not a feasible alternative, but where it's possible, it's both energy efficient and healthy.

The bicycle is another highly desirable option for many trips. Approximately the same amount of energy goes into making a bicycle as it takes to make a man's suit, but the bicycle converts that small amount of energy into a machine with the potential for covering many thousands of miles --

without consuming a single gallon of gas. Many cities are beginning to provide bike paths and lanes for the increasing number of bicycle users. Recent legislation authorized grants to cities for this purpose. One proposal receiving serious attention in many areas is the conversion of existing unused railroad rights-of-way for bicycle use.

Individuals have many alternatives besides walking or biking which range from energy-intensive to only moderately energy-intensive. Figures 6-7 and 6-8 show energy savings possible in urban and inter-city transit by switching from one mode of transportation to another.

Figure 6-7

INTERCITY TRANSPORTATION* THE ENERGY THAT WOULD BE SAVED BY SHIFTING FROM EACH TRANSPORTATION MODE TO ANOTHER. BTU SAVED PER DOLLAR SAVED.

SHIFTING FROM	SHIFTING TO			
	CAR	PLANE	BUS	TRAIN
CAR		+355,000+	-200,000-	-633,000-
PLANE	-355,000-		-374,000-	-414,000-
BUS	+200,000+	+374,000+	-260,000-	+260,000+
TRAIN	+633,000+	+414,000+		

*PLUS OR MINUS SIGNS PRECEDING NUMBERS INDICATE, RESPECTIVELY, AN INCREASE OR A DECREASE IN ENERGY USE. PLUS OR MINUS SIGNS AFTER THE NUMBERS INDICATE, RESPECTIVELY, AN INCREASE OR DECREASE IN DOLLAR COST.

(Bruce Hannon, "Energy, Growth and Altruism ")

Figure 6-8

URBAN TRANSPORTATION. THE ENERGY THAT WOULD BE SAVED BY SHIFTING FROM EACH TRANSPORTATION MODE TO ANOTHER.*
BTU SAVED PER DOLLAR SAVED.

SHIFTING FROM	SHIFTING TO				
	CAR	BUS	MOTORCYCLE	BICYCLE	ELECTRIC COMMUTER
CAR		-100,000+	-392,000-	-177,000-	+17,000+
BUS	+100,000-			-51,000-	+200,000+
MOTORCYCLE	+392,000+			-61,000-	+80,000+
BICYCLE	+177,000+	+51,000+	+61,000+		+84,000+
ELECTRIC COMMUTER	-17,000-	-200,000-	-80,000-	-84,000-	

*PLUS OR MINUS SIGNS PRECEDING NUMBERS INDICATE, RESPECTIVELY, AN INCREASE OR A DECREASE IN ENERGY USE. PLUS OR MINUS SIGNS AFTER THE NUMBERS INDICATE, RESPECTIVELY, AN INCREASE OR DECREASE IN DOLLAR COST.

(Bruce Hannon, "Energy, Growth and Altruism ")

Gasoline shortages during the 1973 oil embargo brought a sharp increase in national interest in public transportation systems, which in most cities, meant buses. Only a few cities in the U.S. boast subway systems; and while many cities once utilized trolleys, few still have them today.

One reason for this, according to a 1974 report to the Senate Judiciary Committee by Bradford C. Snell, is that automobile manufacturers in the 1930s and 1940s acquired control of many mass transit systems and converted them from trolley to bus systems.

In the early 1900s heyday of trolley systems, 80,000 electric streetcars carried 11 billion passengers per year on 45,000 miles of track, according to Wilson Clark. Today only about 1,500 trolley cars remain in service. Now called "surface light rail vehicles," the trolley is once again being eyed by many cities as one of the potential solutions to the urban transportation dilemma. Cost of installation, at $4 million to $8 million per mile, is sharply lower than the $50 million and more per mile current estimate for heavy rail, or subway systems.

According to a study by Eric Hirst of Oak Ridge National Laboratory, 1970 figures show that both the bus and electric light rail vehicles were about half as energy intensive as automobiles, though the "trolleys" were slightly more energy intensive than the buses ("Energy Implications of Several Environmental Quality Strategies," 1973).

In many locations the potential for such savings may be sharply limited. Mass transit may not be available or practicial. In most locations, however, people can make increased use of car pooling with "a substantial long-term reduction in the energy consumed," according to the House Government Operation Committee report. "Increasing the average load factor of urban automobiles from the current 1.5 persons per car to 2.5 persons could reduce total fuel consumption automobiles by more than 20 percent," the Committee estimated.

Even if one is still required to rely for transportation on his or her own automobile, there still is ample opportunity for savings. Simply holding down highway speed significantly reduces fuel consumption. Regular tune-ups, properly inflated tires, and better driving habits (eliminating fast starts and stops, for instance) can improve gas mileage by more than 10 percent in existing cars. Doing without power-consuming luxury items, like air conditioners and power steering, brakes, and windows also offers substantial savings. For example, the Environmental Protection Agency has estimated a nine percent loss in fuel economy in average driving for air conditioned vehicles, and as much as 20 percent for urban driving on hot days.

Another obvious possibility is smaller cars, which not only save energy in use because they weigh less, but also because they require less energy in manufacturing.

Some of the most important ways of reducing energy consumption in transportation are beyond the control of any individuals and require social and institutional changes that may take months or years to bring about.

Eric Hirst and his collegue, John C. Moyers, estimated in 1973 that the fuel used for transportation in 1970 could have been cut in half "with no reduction in total travel" if, in inter-city traffic:

- Half the freight carried between cities by truck and air were shifted to rail

- Half the inter-city passenger traffic carried by air and one-third the traffic carried by car were shifted to bus and train
- Railroad load factors were increased by 10 percent
- Existing technological improvements were incorporated in automobiles, trains and airplanes

And if in cities:

- Half the urban auto traffic were shifted to mass transit
- Both mass transit and urban auto load factors were increased 10 percent
- Urban automobiles were redesigned

In its 1974 study, "Efficient Use of Energy - A Physics Perspective," the American Physical Society (APS) pointed out that potential energy savings in automobiles:

> ...by technical means alone have been estimated at 25 to 30 percent, a figure which we regard as conceptually conservative. When combined with possible new transportation strategies to reduce U.S. dependence on the automobile as the dominant mode of personal transportation, an ultimate reduction in fuel consumption by road vehicles down to less than half of projections of present use appears to be quite possible...
> ("Efficient Use of Energy-A Physics Perspective," The American Physical Society, 1974).

It is possible to reduce by half or greater the long-term energy requirements for transportation in the U.S. This will require serious efforts by individuals and an unprecedented openness by traditional institutions -- both government and private enterprise -- toward change. The alternative is to sustain and increase fuel demands which at some point can continue to be met only at the expense of other social needs.

CONSERVATION IN BUILDINGS

The energy needed to heat, cool, and light residential and commercial buildings accounts for 20 and 15 percent respectively of our total national energy use, and almost 55 percent of total electric power consumption. Few architects and builders have been concerned with energy conservation and new buildings are often highly inefficient. Commercial buildings are especially prone to use inefficient heating and air conditioning systems, and exterior materials which provide poor insulation. Many commercial structures use lighting wastefully. And both residential and commercial buildings employ a myriad of appliances that usually operate inefficiently.

Energy use in residence grew an average of 4.8 percent in the 1960s, a rate far surpassing simple growth in the number of homes. (*Patterns of Energy Consumption in the United States*, Stanford Research Institute, 1972). The Federal Energy Administration estimates that 20 percent of all of the energy consumed in the U.S. is used in the nation's 70 million households.

The Ford Foundation's Energy Policy Project found that virtually all U.S. homes now have five basic energy-consuming items: central heating, hot water heater, stove, refrigerator, and electric lights. Nearly all homes have at least one radio and one television. Seventy percent have washing machines, nearly half have clothes dryers, 25 percent have dishwashers, and 15 percent have central air conditioning.

As the numbers of these appliances and energy-powered services increased, many of the items also became less, rather than more, efficient. Frost-free refrigerators, for example, use two-thirds more energy than earlier models. Color television sets use nearly 50 percent more electricity than black and white models.

Commercial buildings (stores, schools, theatres, hospitals, office buildings, and others) have used an average of 5.4 percent more energy since 1960 (Stanford study). This increased energy use is due to energy-inefficient construction materials, higher lighting levels, sealed windows and mechanical ventilation, large window areas, and increasing use of elevators, electric typewriters, copying machines, computers, and other electrically-powered machines.

There are enormous possibilities for reducing energy consumption in this sector -- both for individuals and for society. This has been clearly demonstrated by the Federal Government, the largest single energy consumer in the U.S., in a concerted energy conservation program which reduced the use of energy in the operation of federal buildings and facilities by 15.2 percent in 1975, compared with 1973.

It has been estimated that the number of kilowatt hours of electricity needed to refine the aluminum used in a typical new office building could be cut by two thirds by switching to stainless steel (Denis Hayes). The Environmental Protection Agency has pointed out that seven times as much heat is lost through aluminum frames as through wood frames.

Proper insulation in buildings can offer savings of up to 40 percent of the energy used for heating, or seven percent of the energy used yearly in the U.S., according to an unpublished 1972 report by Charles Berg of the National Bureau of Standards. Adding insulation is difficult in many commercial buildings, so improvements in that sector must come primarily with new structures. Better exterior wall insulation is most important. The trend toward double-glass or reflective windows is a slight improvement but less window area, particularly on the south and west walls in warm climates, is the best approach.

In homes, where heating and cooling use more than 50 percent of energy consumed, storm windows can cut heat loss by 50 percent and reduce fuel costs by 15 percent (Federal Energy Administration). The American Institute of Architects has released an even higher estimate, based on nation-wide application of more stringent building standards. In contrast to commercial buildings, some insulation can be easily added to most homes. According to Berg's study for the National Bureau of Standards, upgrading home insulation to at least six inches in ceilings and three-and-one-half inches in walls can offer savings of 20 percent per year and pay for itself in three years in many parts of the country.

Furnaces for space heating in buildings are fueled by oil, gas, or electricity. Oil and gas heaters are about 75 percent efficient, losing about 25 percent of their heat in exhaust. The EPA calls improved efficiencies in furnaces themselves "the primary method of conserving energy." Poorly maintained furnaces could roughly double the amount of energy otherwise needed. A simple measure like setting home thermostats two degrees higher during summer and two degrees lower during winter could produce energy savings of more than half a million barrels of oil per day.

Heat systems powered by electricity are nearly 100 percent efficient in the home. But electricity is more expensive and much less efficient than oil or gas when generation and transmission are considered. Generating one kilowatt-hour of electric heat requires the equivalent of three kilowatt-hours in fuel while about 10 percent of the electricity is lost in transmission, according to *Energy and the Future*, an American Association for the Advancement of Science publication. Electric heat pumps, which operate much like an air conditioner in reverse, are an efficient form of electric heating practical for areas of the U.S. which do not have severe winters. Drawing heat from the outside, heat pumps deliver about two units of thermal energy for each unit of electrical power consumed.

Since oil and natural gas heat are about twice as efficient as most electrical heating, some energy experts have proposed that electrical heating be phased out. Gas is also more efficient for operation of water heaters, ovens, and dryers. Using gas for these purposes can save 40 percent over homes using electricity for the same tasks. (Of course, other uses of oil and natural gas would have to be curtailed in order to make more available for home consumption.)

Another example of the energy-intensiveness of present-day architecture is the high-rise air conditioning system. Heat conduction from the outside and solar radiation through windows accounts for only 15 to 20 percent of the air conditioning load, while over half the air conditioning burden is actually heat generated by lighting and about one-fourth is due to ventilation needs.

The air conditioning load could be cut sharply by such changes as reducing the electric power for lighting and reducing ventilation rates.

Lighting levels in homes and commercial buildings have increased 300 percent in the last 15 years, according to G. Tyler Miller, Jr.'s *Living in the Environment*. About 20 percent of all electric power went into lighting in 1973. Miller ways that lighting levels could be cut by one-half without reducing efficiency, safety, or health.

The biggest commercial saving would be to "use bright light only where it is needed rather than to illuminate uniformly a whole office or a whole floor; to switch more completely to fluorescents; and to use timed controls to switch off lights after working hours (ERDA).

One of the most promising innovations for reduced energy consumption in buildings involves the use of waste heat released in the generation of electric power. Generally known as "total energy systems," an experimental project in Jersey City, New Jersey, is expected to cut overall energy needs for the system by one-third.

Non-fossil fuel energy can help relieve some of the burdens in the home and reduce fuel costs. Solar hot water heaters could replace one-half of the conventional water heaters in the U.S., saving one percent of our yearly national energy needs. Solar heating and cooling, although expensive, are highly efficient and proven technologies.

As has been demonstrated, although every individual can make significant personal contributions to energy conservation through his or her own conscious efforts in homes and commercial buildings, by far the greatest opportunities for energy conservation in building lies with those who are responsible for actual design and construction decisions, including those who determine standards, codes and criteria. We must change many existing constraints and attitudes to achieve these very real savings.

CONSERVATION IN INDUSTRY

Industry has the potential to reduce consumption by 20 percent per unit of product output within five years if a "comprehensive effort" is initiated, according to *Conservation and Efficient Use of Energy,* the 1974 report by the Congressional House Government Operations Committee. These energy savings would not curtail product output but they would require initial capital investment. The report states:

> Until recently there have been very few thorough examinations of industrial energy consumption and, therefore, early estimates of the potential for energy conservation have varied widely. At first many experts thought that there was relatively little potential for energy conservation in industry because, it was believed, industrial management made every effort to eliminate unnecessary wastes. This, however, has been largely refuted by the often dramatic savings achieved through the recent implementation of comprehensive energy management programs in a wide range of industrial plants. Previously management had simply regarded energy as too cheap to worry about its waste.

Now industry has two very good reasons to study the way it uses energy. First, it is becoming more costly. Second, and perhaps more important, industrial supplies of fuel (especially natural gas) have already been curtailed in some cases and these shortages promise to become worse. According to the U.S. Commerce Department, industry now obtains 37 percent of its energy from natural gas, 23 percent from coal, 22 percent from electricity, and 18 percent from oil. Natural gas is most popular because it produces less pollution and because government price regulation makes it cheaper. Fortunately, many industries can switch between oil and natural gas (and sometimes coal), thus reducing the impact of shortages from this fuel.

About half of the energy used in industry goes into various heating processes such as direct heating and steam production. Recovery of unused heat is one of industry's most promising energy savings areas. The heat efficiency of boilers and furnaces can often be improved by adding insulation. Heat can be recovered from exhaust stacks for space heating or other low-level heat needs. A number of factories are now using infrared photography to locate areas where heat escapes and might be reclaimed.

A wide range of conservation possibilities is available if more plants construct their own steam and electricity plants. Not only would the electricity be cheaper (and more efficient for society), but the heat produced in the generating process could be used extensively in the factory.

Six energy-intensive industries (food processing, paper, chemicals, petroleum refining, stone, clay and glass products, and primary metals) consume about 77 percent of all energy used in manufacturing (*Patterns of Energy Consumption in the United States,* Stanford Research Institute, 1972). An industry-government program has been initiated to reduce energy consumption in these key industries. Conservation goals of from 10 to 15 percent have been set for these six industries. Other industries will soon be added to the program.

Equally important to conserving energy in the manufacturing process is reducing energy waste in the goods that industry produces. This potential can be achieved in three ways: first, by maximizing the efficiency of energy using products; second, by increasing product lifetimes; and third, by recovering more scarce and energy intensive resources from discarded products.

Maximizing product efficiency means more than making sure that the appliances and other manufactured products work efficiently, although this is very important. It means that products should be *marketed* in their most energy-efficient form. Beverage containers are a good example. In recent years beer and soft drink manufacturers and consumers have largely forsaken the returnable bottle in favor of throwaway glass or aluminum cans. But according to studies on the containers by Bruce Hannon of the University of Illinois' Center for Advanced Computation, throwaways represent from three to five times as much total energy use as returnable bottles. Hannon says that if the State of Illinois required returnable bottles, consumers would save

$71 million each year. Energy would also be saved by removing the throwaway containers from garbage systems. The burden of unnecessary wastes often falls to cities, many of which are already having trouble dealing with the millions of tons of garbage collected daily.

G. Tyler Miller, Jr., suggests that government should require a doubling of the planned lifetime of most manufactured goods. Additional costs to consumers would be involved in such a plan, but in the long run they would pay less.

More extensive use of recycled metals in industry could also bring substantial energy savings. The Institute of Scrap Iron and Steel estimates, for instance, that using scrap instead of iron ore to make new steel means a 74 percent energy savings. Recycled scrap also reduces air pollution emissions by 86 percent; water use by 40 percent; water pollution by 76 percent; and mining wastes by 97 percent below the amount that would be generated in the production of the same amount of steel from virgin iron ore.

THE CONSERVATION POTENTIAL

Though knowledge of the total potential is lacking, it is clear that energy conservation can provide significant relief from our energy dilemma. However, it is also clear that we know shockingly little about how the nation uses energy and how to improve efficiency. Two governmental agencies, the Federal Energy Administration and the Energy Research and Development Administration, have energy conservation programs, but this effort is still a weak link in our research programs.

Conservation is a politically sensitive issue. Many economists and planners insist that energy demand and economic growth are inextricably tied together and that in order to maintain a healthy economy we must have abundant (that is, ever increasing) supplies of energy. This relationship is based upon an examination of historical energy and gross national product growth in industrial countries. But does it have to be that way? Can we grow without using more energy? Is a no-growth economy ultimately the only way to live within the earth's finite resources? These answers simply aren't known with certainty. Until they are, our best cource is to eliminate that portion of our energy consumption which is clearly wasted. Squandered energy cannot be the basis for future prosperity.

7 A FINITE EARTH

Even if more energy becomes available for our use, the laws of nature indicate that humanity cannot indefinitely increase energy and resource consumption without threatening the earth's ability to support life.

"How much of the energy that runs the biosphere can be diverted to the support of a single species: man?"
-- George M. Woodwell

What will the future hold if technology provides a solution to the fossil fuel crisis? Suppose that society overcomes the severe environmental and economic drawbacks to the nuclear fission breeder reactor, or perfects nuclear fusion. With a virtually unlimited supply of energy it would seem to be possible to reach new heights of technology with more automation and more consumer goods. We could all drive electric cars, leave the lights on all the time, and use all the energy we wanted.

But there are sobering reasons why such a lifestyle would be a bad choice, even if unlimited supplies made it possible. The first is the increasingly serious shortage of resources other than energy. The era of cheap and abundant supply of most metals and other resources has ended. Second, as the second law of thermodynamics tells us, regardless of how energy is produced and used, heat pollution results -- even if production processes were virtually free of other pollutants. Third, the earth has finite resources and space. If society continues to grow and to produce more, we will eventually surpass the earth's carrying capacity -- its ability to support life.

Natural systems offer interesting perspectives on this problem. When a system in nature reaches the limit of its resources, it stops growing and reaches a state of climax or equilibrium. George Woodwell has written an interesting description of this process:

> ... In the successional [eco]system the total respiration is less than the gross production, leaving energy (net ecosystem production) that is built into structure and adds to the resources of the site. (A forest of large trees obviously has more space in it, more organic matter, and probably a wider variety of micro-habits than a forest of small trees.) In a climax system, on the other hand, all the energy fixed is used in the combined respiration of the plants and the heterotrophs [an animal or plant that cannot produce its own food]. Net ecosystem production goes to zero: there is no energy left over and no net annual storage.
>
> Climax ecosystems probably represent a most efficient way of using the resources of a site to sustain life with minimum impact on other ecosystems. It is of course such ecosystems that have dominated the biosphere throughout recent millenniums.
> (*The Biosphere,* W.H. Freeman and Company)

The human species should be able to anticipate the earth's inescapable limits and adapt to them in an organized and painless fashion. But if we fail to recognize the warnings and wait for increasing population, resource depletion, and global pollution to force the issue, the result will be chaos.

Humanity is causing widespread change in the features of the earth, many of which are undoubtedly harmless. But some of these changes threaten natural systems and thus may threaten our lives. Our constant development of more land for roads, buildings, and specialized agriculture reduces gross vegetation and thus photosynthetic production. Although we are in no immediate danger of running out of oxygen (all of which comes from plants), the impact on soil of this reduced ground cover is less certain. Valuable topsoil which has taken hundreds of years to form has been washed away in many parts of the world due to deforestation or overgrazing. This has a direct impact on the amount of food the soil can produce.

Our ever-expanding development and its related pollution have pushed many animal and plant species to extinction, and others are threatened. These living things all have a function in ecosystems and their disappearance can create a void which will allow dangerous insects or organisms to multiply unchecked, threatening crops or human health. Many pests show signs of becoming immune to pesticides which have been used to control their numbers; the pesticides were initially used largely because those forces in the ecosystem which controlled the pests naturally were destroyed.

Pollution of the oceans and the destruction of coastal wetlands directly threatens vital food chains which support millions of people. The increasing introduction of toxic chemicals into the production process has added elements which are extremely dangerous to man, and which are not easily broken down by the natural system.

As we seek to expand the development of energy resources, more and more difficulties can be expected. Strip mining, for example, is a concern not only because of the ugly and disruptive influence upon the surface of the land, but because it may result in damage to the underground water supply which is essential to support an entire area or region. As energy consumption grows, the related disorder necessary to support that growth must be absorbed somewhere on the planet.

The fossil fuel era has pushed the earth toward the limits of its carrying capacity. The burning of fossil fuels has spewed billions of tons of pollutants into the air, the most abundant in the U.S. being carbon monoxide, sulfur oxides, hydrocarbons, nitrogen oxides, and solid particles. Scientists believe that the earth's atmosphere has thus far assimilated most of these successfully. But one of these pollutants, carbon dioxide, has seriously disrupted natural cycles on earth and may be the source of serious environmental problems in the future. There is a measurable growth in the atmospheric concentration of carbon dioxide -- from about 290 parts per million in 1860 to about 320 parts per million in 1970 -- nearly a 10 percent increase. With more and more fossil fuels being burned, some scientists project that the carbon dioxide concentration will reach 375 parts per million or more by the year 2020.*

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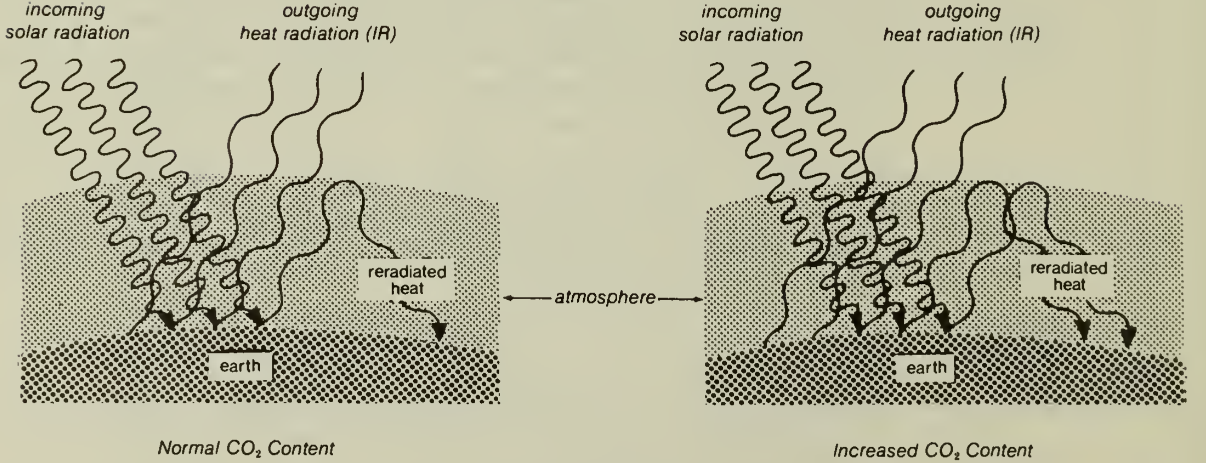
* G.S. Callendar, "On the Amount of Carbon Dioxide in the Atmosphere," *Tellus*, volume 10, 1958; B. Bolin and W. Bischoff, *Tellus*, volume 22, 1971; L. Machta, "The Role of Oceans and the Biosphere in the Carbon Dioxide Cycle," *Nobel Symposium*, volume 20, 1971.

The oceans, which dissolve carbon dioxide as part of nature's carbon cycle, have not been able to keep up with the amount of carbon dioxide being produced. This buildup is cause for concern because the level of carbon dioxide in the atmosphere affects its temperature (Figure 7-1). G. Tyler Miller, Jr., describes the potential effects of this imbalanced chemical cycle:

> ... Probably the best mathematical model for projecting future changes in CO_2 content is that of S. Manabe and R.T. Wetherald (1967). They found that the projected increase ... could cause the average air temperature near the earth to increase about 0.5 degrees Celsius (0.9 degrees Fahrenheit) assuming that relative humidity and other factors remain constant. A doubling of CO_2 levels, which with increasing fossil fuel consumption might occur by 2050, could raise the average temperature by about two degrees Celsius (3.6 degrees Fahrenheit).
>
> A one to two degree Celsius change would significantly modify global climate. It could trigger the relatively rapid melting of the floating Arctic ice pack ... Eventually glaciers and even Antarctic ice might slowly melt ...

Figure 7-1



The greenhouse effect. Short wavelength solar radiation strikes the earth and is transformed into longer wavelength heat radiation, some of which is absorbed and reradiated back to the earth by the CO_2 in the atmosphere. As CO_2 content increases more heat is retained and the atmosphere becomes warmer.

(G. Tyler Miller, Jr., Living in the Environment Wadsworth Publishing Co.)

> Gradual melting of the land-based Antarctic ice could eventually raise world sea levels 200 to 300 feet. This would flood about 20 percent of the planet's present land area, including most of the world's major population centers and the flood plains that produce most of our food. Despite stories in the popular press predicting imminent global flooding, this process if it occurred, would probably take place very slowly over at least 1000 years.
>
> Melting of the Arctic ice cap and the glaciers, however, could be much more rapid. Since the Arctic ice pack is afloat, its melting would not raise the water level in the oceans. But the absence of polar ice would change ocean currents and undoubtedly would trigger major unpredictable changes in climate.
> *(Living in the Environment,* Wadsworth Publishing Co.)

Carbon dioxide may not be the most serious heat threat. Heat-producing machines and heat-producing people are also a problem. The vast increase in total and per capita heat production on earth can be seen in Figure 7-2. Even though humanity's heat production is estimated to total only about 0.005 to 0.01 percent of the sun's heat input to earth, the

Figure 7-2

Increase in man's energy consumption and environmental heat load

Cultural stage of man	Per capita energy use (kcal per day)	Per capita continuous heat load (watts)
Early hunter–gatherer	2,000	100
Advanced hunter–gatherer	4,000	200
Primitive agricultural	12,000	600
Advanced agricultural	25,000	1,250
Early industrial	70,000	3,500
World average in 1972*	40,000	2,000
Modern industrial:		
U.S. citizen in 1972	250,000	12,500

Source: Cook 1971, MacDonald 1972.

*The figure is lower because most of the world still exists at an intermediate agricultural level, with about 30 percent at the modern industrial level.

(G. Tyler, Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

potential for climatic impact is very real.* According to the calculations of numerous scientists, this growth in heat could begin to affect world climate in 60 to 80 years.

Other scientists are less concerned about atmospheric heating than about a buildup of particles in the atmosphere which could screen out enough of the sun's rays to cause a new ice age. The particles produced by burning fossil fuels are only a portion of those presently in the atmosphere. Nature takes a hand too, adding particles from salt sea spray, ashes produced by volcanoes and forest fires, and dust storms. Cloud cover, water vapor, and other factors also affect the atmosphere's transparency and thus its ability to absorb heat. Mean global temperature would have to drop only two to 3.5 degrees Celsius for several years before a new ice age would begin on earth. This is the conclusion of a study prepared by a group of scientists for the 1972 United Nations Conference on the Human Environment, *Man's Impact on the Global Environment*.

Historical temperature trends do little to prove or disprove either the heating or cooling theory. Scientists have estimated that the average temperature of the northern hemisphere increased slightly between 1860 and 1940 but then dropped slightly between 1940 and the present time. The long-range trend is simply not clear.

We have presented only a few examples of the possible dangers of human-induced changes in our environment. The earth is a remarkable machine and may successfully assimilate these changes. But sooner or later, if we continue to grow and to pollute, the earth will fail to support us.

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* John Holdren, *Global Ecology*, Harcourt Brace Joanovich, 1971; Theodore Brown, *Energy and Environment*, Charles E. Merrill, 1971; A. Weinberg and R. Hammond, "Global Effects of Increased Use of Energy," *Bulletin of the Atomic Scientists*, March, 1972.

8 ADAPTING

Fortunately, the same intelligence which led us to develop industrial society can lead us to an equal or better life without wasting our resources or destroying our environment. Humanity is highly adaptive and can adjust to a limited energy situation. Nature can teach us many lessons in adaption during these challenging times.

"...One...ability has been developed, apparently by man alone, the newest, most powerful of all the forces of life. That is the power to deal with abstract ideas, to analyze causes and effects, to recognize the principles that underlie them, to use these concepts as building blocks for new ideas in a process of creative imagination. From this imagination there has grown that restless urge which leads man to constant fresh activity -- to heights of achievement when guided by wisdom, and to depths of stupidity when wisdom is lacking.

-- John Storer

Fortunately, the same intelligence which led us to develop industrial society can lead us to an equal or better life without wasting our resources or destroying our environment. Humanity is highly adaptive and can adjust to a limited energy situation. Nature can teach us many lessons in adaption during these challenging times.

This chapter was written by Jean Matthews, Office of the Chief Scientist, National Park Service, and Loran Fraser, of the Project Staff.

All living organisms in the natural system occupy a specific ecological niche. This niche includes all the chemical, physical and biological factors that define the position and function of the organism in the total community structure. Humanity has added a whole new factor -- culture, and used it to make humanity's own niche worldwide.

Plants and animals are limited to, and have adapted to specific locations or habitats in the ecosphere, barred from a wider range of climatic and other environmental conditions by their own intolerances. Humans, on the other hand, live over much of the planet by virtue of a learned ability to manipulate energy. This ability has introduced into world ecology a new energy niche, occupied by no other species in the natural system. The technological string in humanity's cultural bow has enabled it to modify and change the environment, thus eliminating the need to adapt organically to varying climatic and environmental conditions.

All living things in the natural world draw from their surroundings and use all the energy available to them. The discovery and exploitation of fossil fuel energy by our society is the natural cultural extension of this fact of biological life.

We have used fossil fuels to supplement the daily deliveries of solar energy and the results seemed to constitute successful defiance of nature's limitations. But, as Barry Commoner notes, nature bats last. As industrial society busily built and adapted to an artificial world of its own making, it failed to notice that the result was a world supported and sustained by a dwindling, non-renewable energy source.

Moreover, the by-products of massive energy consumption have over-burdened nature. The dilemma today is a classic double bind: No one wants to run short of energy, yet natural systems struggle unsuccessfully to absorb the accumulating energy wastes we call pollution. If we win one race, it seems we must lose the other.

The availability of fossil fuel is on the wane, and Western society is being forced to turn increasingly to natural energy flows -- to adopt less energy-intensive lifestyles. These energy flows are present as part of the great earth energy systems and their structures and processes hold ages-old lessons for humanity about how life thrives on the sun's radiance. Humans may be about to use their great brains to pull off another adaptation stunt that will dwarf everything done with them before. They may be about to discover, with the rational bump in their nervous systems, that survival of the fittest can mean survival of those human systems that achieve the best fit with the age-old natural systems.

Ecosystems are self-sustaining. Producers, consumers, decomposers, and chemicals, tap available energies to perform specific functions and meet specific requirements of whatever community they constitute. The natural system provides for its own needs. The sun's energy runs *through* the system, driving its chemical cycles; matter and nutrients are used again and again in the process of forming and supporting all life.

Cities and suburbs, on the other hand, are not self-sustaining. To live, they require massive imports -- food, fresh air, water, materials and energy; and they produce equally massive exports -- solid wastes, liquid wastes, gaseous wastes, and heat. These wastes are the raw material of nature's building process, but with the injection of fossil fuels in a one-way, linear cultural trip, the circular systems of nature are suffering from a massive overload. To nature, human wastes represent "an embarrassment of wealth."

Fossil fuels have provided the energy which moves materials in and out of our human communities, making life possible in artifically maintained ecosystems. Today's urban areas are world-wide ecosystems in the sense that all of them are hooked into the whole world, trying to occupy the same global niche, and exploit the same limited resources. For millions of years, earth's biomass built slowly while the sun's surplus energy was banked in the crust under the surface. Now human life exceeds the total living mass of any previously known animal, and without the fossil fuel energy subsidy from a million years of thinner-lived prehistory, our present human settlements could not sustain themselves.

Industrial soceity must now turn to designing communities for a less energy intense future by imitating the self-sustaining processes of natural ecosystems. Modeled after nature, the community of the future should increasingly meet employment, home, service, entertainment and recreation needs locally.

Nature has demonstrated that in diversity lie quality and stability. Diversity insures that a natural system is not seriously affected by the loss of some component; the same principle applies to human communities. The more functions a community can perform with its own local resources, the greater that community's strength, self-reliance and richness of experience.

Replacement of one kind of community by another within an ecosystem over a period of time is called "ecological succession." The end product (in the longer time frame) is called a "climax" community -- a balanced complex of nutrients, energy, and interconnecting species of diverse life, forming a stable, self-perpetuating system.

A climax community is said to be in dynamic steady state -- a "quivering balance" in which the ecosystem makes optimum use of all available materials and energy resources. When such a state of life has been achieved, the system is described as having reached its carrying capacity.

Culture -- especially technological culture -- was humanity's way of dramatically raising the carrying capacity of its own particular world. So long as energy and resources were available, human growth was unimpeded. No reason existed for us to focus on how to make do with less.

It is possible that humanity is now in a late state of ecological succession, pushing resource exploitation to the limits and exhausting its energy subsidy sources. This, together with exploding population growth, seems to indicate that we either are reaching or have surpassed the carrying capacity of the planet for culturated humanity. The danger signs are everywhere.

When all systems are carrying at full capacity, the population is one that can be adequately supported by the resources available. When a population out-races the resources capable of maintaining life, it crashes, usually from starvation or disease. Humans, always the special case, have added warfare and man-induced ecological disaster to the choice of future scenarios.

The steady-state ecosystem is nature's model for the energy-short future. A steady state is by no means a static state. The dynamics of the Eastern deciduous forest are infinitely richer, more complex, tougher and more stable than the dynamics of a field of dandelions. The challenge for modern society is to begin discarding our linear mode of living in favor of the self-sustaining circular state of balanced equilibrium, hooking our culture at its richest, most diversified best, into the natural energy systems in ways that preserve *their* best. Such a transition will involve the reshaping of architecture, manufacture, delivery and disposal systems, and the expectations and attitudes of the population itself.

Nature is constantly experimenting with new approaches, new mechanisms to solve age-old problems. Americans like to experiment too, and to devise new and ingenious methods of meeting complex problems. The problems facing us as we strive to adapt to an entirely new energy situation may mean that "survival of the fittest" will reflect not the sheer power or cunning of the competitive consumer game, but the cleverest fitting of our most diverse, complex, humanly regarding systems into the renewable energy plugs that nature has provided.

APPENDIX A

PARK PROJECT ON ENERGY INTERPRETATION

HISTORY

Energy is upon us.

The American public has for the past few years been subjected to a cacaphony of energy messages: "The shortage is the fault of the government -- the Congress -- the oil industry -- the Arabs -- all of us -- none of us -- there is no shortage." "Turn down your thermostats -- form car pools -- turn out your lights -- abandon cars -- shut off appliances -- there's no way out."

These confusing and conflicting messages come from a variety of sources; the energy industries, conservation-oriented organizations, local, state and federal governments, the business community, and candidates for office. Energy related bumper stickers, buttons, cartoons, comic strips, and television specials have become part of the "energy culture." Have these messages aided the general public in understanding either the short or long-range implications of their energy consumption habits?

Energy resource savings directly attributable to these messages are questionable. It does appear that patterns of energy consumption have changed somewhat, and so some resources have been conserved. It is inevitable that our society will come to grips with its energy-related problems, but only time will reveal the impact on our economy, our environment, and our way of life.

There are at least three clear reasons why the success of energy conservation efforts has been limited:

1. Conservation strategies are aimed principally at short-term solutions to long-term problems;

2. The public is highly skeptical about the credibility of energy messages; and,

3. The public sees small reason to change consumption patterns when energy supplies are still available to those who can pay. Most families can absorb the cost increases. Few believe that costs will continue to rise steadily, or that changes in private consumption can make a difference.

New methods, oriented to the future, are required to make the American people fully aware of the magnitude of energy-related problems and their potential impact. But awareness is not sufficient -- the public must actively integrate energy conservation practices into their lives, and call for conservation in other sectors. They must be motivated to act for personal and national survival.

In an attempt to create a program dealing with these concerns which might be able to bring these issues home to the public, the Federal Energy Administration, Office of Energy Conservation and Environment, has contracted with the National Recreation and Park Association.

The National Recreation and Park Association is a private, non-profit organization devoted to the improvement and expansion of park, recreation and leisure systems and services for all people. It has a membership of individuals, agencies and organizations, including lay persons responsible for public policy for parks, recreation and leisure, and professional and technical staff who directly plan and manage a diverse range of park and recreation facilities and services in both the public and private sector.

NRPA has undertaken to develop and demonstrate a variety of materials and information for use in public park and recreation systems. The objective of the proposal is to utilize the expertise of park naturalists, managers, community center supervisors, playground leaders, and others who come into daily contact with those who will ultimately have to deal with the effects of energy shortages upon lifestyles -- the public. In July 1975, the FEA awarded NRPA a $140,000 contract to conduct a nine month demonstration program, using specially developed material at varying park sites. In March of 1976, a new contract was signed, enlarging the Project and extending it for one year.

In the first phase of the Project, park systems were selected for demonstration work. Criteria for selection included quality existing interpretive programs, stable visitor population levels during the demonstration period, park resources and facilities, and interest in participation by park management. Based on these criteria, the following sites were chosen:

California State Park System
East Bay Regional Park Authority (Oakland, CA)
Everglades National Park
Golden Gate National Recreation Area
Huron-Clinton Metro Authority (Detroit, MI)
Washington State Park System

These park systems worked with Project materials in many ways, and provided the Project staff with evaluation of the ways in which energy conservation can legitimately become part of on-going park interpretive programs. Reaction of park visitors to Project ideas and materials was also tested. Based upon the success of the work at the demonstration sites, the Project has now entered a new phase with greatly enlarged participation.

MATERIALS

The first step in defining materials for the Park Project on Energy Interpretation was an extensive survey of park interpreters, park managers, energy specialists, government officials, organizations and companies to determine:

1) what the materials should convery to the public;

2) what materials were already available.

The results of this survey confirmed what many suspected: While most people have questions about energy conservation, they are not certain why it is an important element of our energy future.

In order to explain the importance and applicability of energy conservation for today's society, a decision was made by the Project to base the materials on how nature uses energy, and how man often abuses it. Parks, examples of natural systems, are uniquely suited to illustrate the energy flows in nature. The natural systems approach to energy contrasts distinctly with the inefficient approach taken by modern society. Accordingly, a series of thematic statements was developed which define the philosophy of all project materials. These statements focus on natural systems, provide a view of the development and use of energy in modern society, and describe the role of energy conservation in terms of man's adaptive capacities and the lessons to be learned from nature.

ACTIVITIES GUIDE -- This booklet is a pictoral and written elaboration of energy facts designed to immediately involve the reader. It contains information enabling the reader to make direct connections between energy and his daily life in a clear way. Articles from energy specialists are included to provide substantive information of a more advanced level for the interested reader, and activities are included to stimulate involvement, comparison and thought. Pictures, charts and explanations of natural processes have been chosen to make the reader aware of the pervasiveness of energy. A list of additional references and other resources is included.

TIPS FOR ENERGY SAVERS -- This excellent booklet provided by the Federal Energy Administration gives practical information applicable to everyone on immediate energy savings.

ENERGY MANUAL FOR PARKS -- A critical aspect of this effort is the direct contact and communication between the park interpreter (naturalist, guide or other staff person) and the park visitor. Through walks, talks, tours and casual discussions, the interpreter can communicate to the visitor many facts about energy and nature. Because of the prime importance of the interpreter, a special book has been prepared to provide both a basic reference on energy and information on park applications of the Project. The *Manual* contains factual data which has never been assembled in a similar form, and which should be usable by interpreters with varying levels of experience and backgrounds.

The *Manual* is used in the Project but is a product of NRPA.

NEW MATERIALS -- During the remainder of the Project year (through March 1977), the Project staff and participating interpreters will develop and test new materials. These will include audio-visual presentations, an energy publication designed specifically for children, a newsletter, and a publication on various analyses of energy use in natural systems. As these materials become available they will be integrated into the Project, and information on how to use them will be provided. Comments on how the materials are working or what else would be helpful are of great value to the Project staff, and are encouraged from any source.

USING PARK PROJECT MATERIALS IN PARK SETTINGS

Parks represent a natural setting for the discussion of energy, and effective use of the materials of the Park Project on Energy Interpretation. An historical, cultural, natural or urban park all represent environments where the issues of energy use and energy conservation can effectively be raised.

For instance, a program at an historical area could directly compare and contrast energy use today to that of one or two hundred years ago. The differences in structure, work and the use of energy today compared to those of pre-1900 America are striking, and clearly observable in the historical park. Nature walks in a natural area are well-suited to explain how natural systems use energy and matter differently than our human sub-system does. The natural park also may be used by interpreters to show how nature can provide some answers to our energy dilemma.

Urban parks and, in fact, all other park sites, show direct examples of energy use and impacts on people, and these topics can usefully be incorporated into the program materials. The question of how people come to parks, and the energy their presence requires (both in direct energy consumed and indirect energy use), are important first steps in energy education. Many parks are near areas being used or considered for resource extraction or processing to meet our nation's rising energy demands.

A goal of this program is to demonstrate to ALL park visitors, users and staff that each of us consumes energy in many ways, and must seek to reduce our private use in order to cut total consumption. Talking about energy in the park provides an opportunity for visitors to explore their immediate "energy connections," and thus begin thinking differently about their general attitude toward energy.

No matter what the theme of a participating park may be, the display and distributional materials can be used in a variety of ways. When necessary they can stand without any additional explanation from park personnel. In those settings where the materials can be developed into new programs or merged with existing materials, there will be an almost limitless number of approaches and uses.

Since energy is a basic aspect of all living things, it will naturally emerge as a specific topic in connection with on-going talks, walks, and tours. Each site and each interpreter will use the materials and the concepts differently. Some examples of implementation identified from the first period of the project include:

A puppet show starring Horsepower Harry and Energy Urd

Daytime Star Walk -- A Focus on the Sun's Work

Composting -- An Energy Conservation Process

The Successional Climax forest -- How Coastal Redwood Areas show Energy Flows in a Dynamic Steady-State

Nature Walk -- The Cycle of Solar Energy

Energy Flows in Subtropical Estuarine Waters -- How the Mangrove Leaf begins a Food/Energy Chain

Wind Energy -- What Can it do here at our Park/Farm?

Trees -- Nature's Most Efficient Energy Conservers

As interpreters work with the material, many new uses will be discovered. New questions and new needs for material will be raised. The Project staff will be providing help on implementation in the form of audio-visual presentations, tips on what worked well at other parks, new information on energy facts and policies, and articles and papers on energy.

The object of this Project is to communicate an energy conservation message in parks. This means that the materials and the total approach must be examined and repeatedly evaluated. Tell the Project Staff and other participating interpreters of any needs or questions which arise. Every attempt will be made to supply needed information and resources. Please share your experiences with the material, both good and bad, so that everyone can profit from your observations and efforts. We promise to do the same.

APPENDIX B ENERGY MEASUREMENTS AND CONVERSIONS

(Source: *Handbook of Chemistry and Physics*. Cleveland, Ohio: Chem. Rubber Publ. Co.; *Ecology* by Eugene Odum, New York: Holt, Rinehart, Winston.)

A--Units of potential energy

calorie or gram-calorie (cal or gcal)--heat energy required to raise 1 cubic centimeter of water 1 degree centigrade (at 15°C)
kilocalorie or kilogram-calorie (kcal)--heat energy to raise 1 liter of water 1 degree centigrade (at 15°C) = 1000 calories
British Thermal Unit (BTU)--heat energy to raise 1 pound of water 1 degree Fahrenheit
joule--work energy to raise one kilogram to height of 10 centimeters (or one pound to approximately 9 inches) = 0.1 Kilogram-meters
foot-pound--work energy to raise one pound, one foot = 0.138 Kilogram-meters.

Conversions:

1 calorie = 4.18 joules
1 kcal = 1000 cals = 3.97 (about 4) BTU = 4185 joules

1 BTU = 252 cal = 0.252 (about ¼) kcal
1 joule = 0.74 foot-pounds = 0.239 cal
1 foot-pound = 1.36 joules = 0.324 cal

B--Units of Power (energy-time units)

watt (w) (the standard international unit of power) = 1 joule per second = 0.239 cal per second
kilowatt-hour (kwhr) (the standard unit of electric power) = 1000 watts per hour = 3.6×10^9 watts
horsepower (hp) = 550 foot-pounds per second

Conversions:

1 watt = 0.239 cal (per second)
1 kilowatt-hour = 860 kcal or 3413 BTU (per hour)
1 horsepower = 746 watts = 178 cal (per second)

C--Energy content of some familiar quantities (in round figures)

1 gram carbohydrates = 4 kcal
1 gram protein = 5 kcal
1 gram fat = 9 kcal
1 gram average plant biomass = 2 kcal/gm wet wt.; 4.5 kcal/gm ash-free dry weight
1 gram average animal biomass = 2.5 kcal/gm wt.; 5.5 kcal/gm ash-free dry weight
1 gram coal = 7.0 kcal
1 pound of coal = 3,200 kcal
1 gram gasoline - 11.5 kcal
1 gallon of gasoline = 32,000 kcal

APPENDIX C

ALTERNATIVE ENERGY FORMS

This appendix includes more detailed summaries of the status of numerous alternative energy systems.

NON-RENEWABLE FORMS

RENEWABLE FORMS

NON-RENEWABLE FORMS

FOSSIL FUEL - COAL

Coal comprises 93 percent of the world's remaining fossil fuel supplies, with most of the known reserves existing in the U.S. (where coal represents 90 percent of fossil fuel reserves) and the Soviet Union. But although the most abundant in supply, coal is the least used of the fossil fuels, supplying only 18 percent of the energy consumed in the U.S. in 1974.

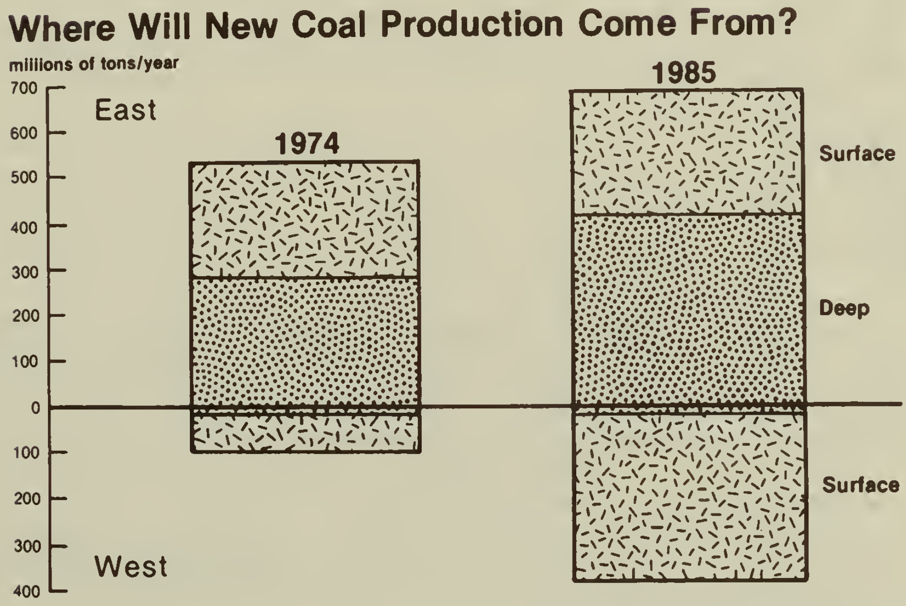
Three basic reasons account for this incongruity. Coal is often dangerous and destructive to mine; it releases large quantities of pollution when burned; and it cannot be used for most transportation needs with current technology.

Like oil and natural gas, coal is a complex and widely varying substance. It is composed primarily of carbon but may also include dozens of other elements. Normally found in layers of varying thickness in sedimentary rock, coal is dark brown or black in color. It is classified in types as anthracite, bituminous, sub-bituminous, or lignite. Bituminous and sub-bituminous coals comprise 70 percent of all U.S. deposits (*Energy Alternatives: A Comparative Analysis*, Council on Environmental Quality).

Coal is mined by either surface or underground methods. Both have serious disadvantages. Surface mining is destructive to the land and underground mining is dangerous for workers. Strip mining uses earth moving equipment to plough away topsoil, rock, and other near-surface material to expose coal seams. The danger to workers is about the same as other jobs where heavy equipment and explosives are used. But less than half of the acreage mined by this method has been reclaimed to date (*Energy Alternatives: A Comparative Analysis*, Council on Environmental Quality). Reclamation means that once coal is removed, the disrupted land is graded, sometimes replacing topsoil and planting new vegetation.

Reclaimed or not, the productive value of surface-mined land is reduced or eliminated for many years. In arid lands where vegatation is difficult to reestablish, it may never be returned to its original productive state. This is especially significant since the surface mining industry is moving increasingly to more arid western lands, especially the northern great plains (Figure C-1). Until recently nearly all of the surface coal mining in the U.S. took place in Appalachia.

Figure C-1

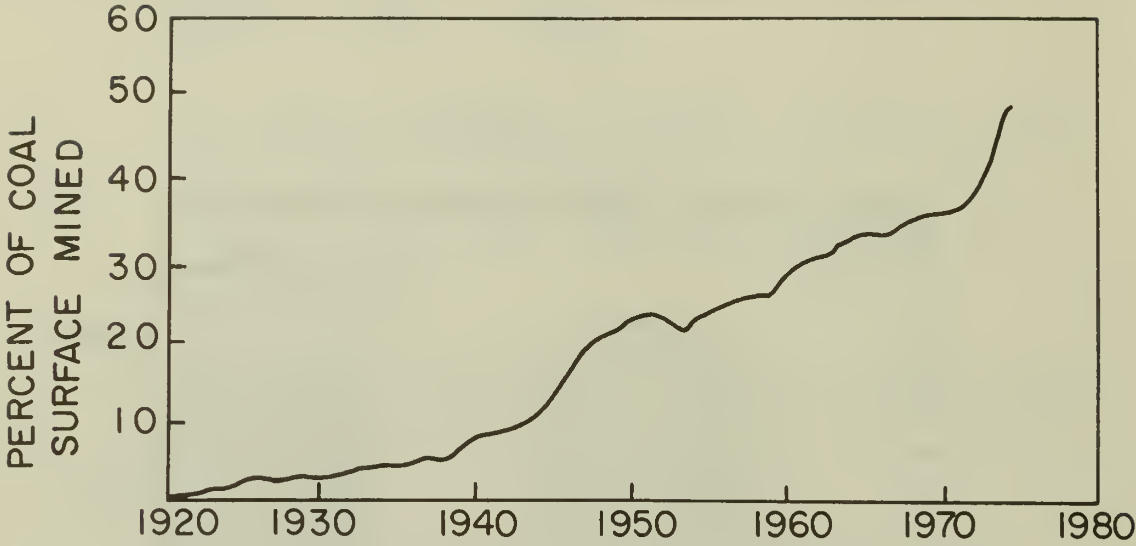


(Federal Energy Administration, National Energy Outlook: 1976)

The effects of surface mining are all the more important since it has supplied a steadily increasing percentage of domestic coal since 1920 (Figure C-2). Among the important environmental effects of surface mining are loss of agricultural land (although not all surface-mined land is agriculturally productive), pollution of streams and rivers by runoff from mining waste piles, wind erosion due to loss of protective cover on the land, and unsightly and unstable mounds of mine waste, except in cases where these are graded or covered with topsoil.

Two primary reasons account for the increased use of surface mining: it is cheaper than underground mining and mine development can be accomplished many times faster. Underground mining has pollution problems too, chiefly acid drainage which can pollute water supplies, but they are far outshadowed by those of strip mining. The chief problem of underground mining is safety to workers and the correspond-

Figure C-2



Increase in Coal Production by Surface Mining

(*Energy Alternatives: A Comparative Analysis*, *Science and Public Policy Program, University of Oklahoma*)

ing expense of improving mine safety. Even though mine deaths and accidents have been steadily decreasing, over 1600 accidental mine deaths and some 75,000 injuries have occured since 1966 (*Living in the Environment*, G. Tyler Miller, Jr.).

Coal's problems, unfortunately, do not end when it is removed from the ground. Oil, natural gas, and coal all contain impurities which are released into the air when the fossil fuels are burned. However, these impurities, such as ash and sulfur, are more of a problem in coal. Sulfur is the most troublesome and its percentage in the composition of U.S. coal varies from 0.2 percent to as much as seven percent. Most of the low-sulfur coal in the U.S. is in the West although, on the average, eastern coals have a higher heating value.

The technology to remove the coal's harmful emissions before they are released into the air is developing but is far from perfect. Effective methods to remove large percentages of nitrogen oxides and particulates are in use on many plants but sulfur dioxide removal technology is less well developed. Most coal burning electric power plants currently use low-sulfur coal to meet sulfur emission standards.

Many experts believe that converting coal to a synthetic gas or liquid fuel represents the best hope for using our coal resources without sacrificing human health or ravaging the land. The Energy Research and Development Administration is currently funding projects to test numerous methods of gasification and liquifaction. These processes, which basically break down the component parts of the coal and rearrange some of the elements into a new substance, would make the coal available in a more convenient form while removing most of the polluting impurities. Coal gasification was first used in Europe in the early 1800's to provide fuel for street and home lighting. It is still widely used in Europe, although now mainly to make products for use in chemical plants.

The synthetic gas or liquid produced from coal is low in BTU value and cannot be substituted for natural gas or oil for most uses. The U.S. research program is investigating ways to obtain a more concentrated product. However, problems have been encountered in applying successful small-scale technology to full size plants, and more problems are expected. In addition, both the demonstration plants and planned commercial plants are very expensive. Since there is no certainty that the plants will be successful, the large investment needed has hindered development of the processes. Although several private companies have planned gasification and liquifaction units, escalating costs and technical uncertainties have prompted postponements of most projects. Nearly all of the U.S. research investment is now coming from the federal government. The Energy Research and Development Administration plans to spend $280 million in the 1976 fiscal year on coal research, including gasification and liquifaction.

Environmental problems have also dampened enthusiasm for gasification and liquifaction. Large quantities of water are needed for the plants and unless it is reused, the heated and polluted water will require treatment. Recovery and treatment systems will also be needed to minimize air pollution. And large quantities of solid waste such as sulfur and ash will require disposal.

Considering all of these factors, gasification and liquifaction must be considered speculative. The net energy yield of the processes is uncertain. Even if the technology is found to be commercially feasible, the time needed to build and test demonstration plants and then commercial plants means that no significant impact on energy supply will be felt before 1985 or later. At best, gasification and liquifaction will contribute only 10 to 15 percent the nation's energy needs by the end of the century.

Regardless of the development of gasification and liquifaction, coal will likely supply a growing percentage of our energy needs, simply because other fossil fuel supplies will become more scarce. Both the federal government and private industry have extensive research programs in hopes of finding new ways to mine, process, and burn coal, as well as methods to treat its pollution.

FOSSIL FUEL - SHALE OIL

Oil shale is an underground rock formation that contains a hydrocarbon mixture known as kerogen. The shale rock could be strip mined or deep mined much like coal and transported to a nearby processing plant where it would be crushed and heated to yield low sulfur shale oil, which can then be refined to yield petroleum products. Vast oil shale deposits exist in a 16,000 to 17,000 square mile area of Colorado, Utah, and Wyoming, with 80 percent of the deposits on government-owned land. Proved reserves in this area alone are estimated to be about eight times our total petroleum reserves and greater than all the oil in the entire Middle East.

But unfortunately there are some thermodynamic, economic, and environmental catches. Because the kerogen is so widely dispersed in the rock and because it must be heated to be converted to shale oil, more energy may be needed to mine, process, and ship it than the energy it contains. At best it may produce only a slight gain in net energy at a high cost. In addition, a 1973 environmental impact evaluation by the U.S. Department of Interior indicated that an oil shale industry would create serious environmental side effects including disruption of land, a decrease in air quality, destruction of vegetation and wildlife, lowering of water tables, and a decrease of the quality of surface water in a region already experiencing serious water problems.

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* This discussion of shale oil is reprinted from G. Tyler Miller, Jr.'s *Living in the Environment*.

Another drawback is the staggering amount of solid waste produced, which would take up at least 12 percent more space than the original rock. The only obvious way to dispose of this powdered waste is to dump it into canyons and mountain valleys. The waste from strip mining a single oil shale tract [of about 5000 acres] would fill six 700 acre canyons to a depth of 25 feet.

A suggestion for avoiding some of these problems is to distill the kerogen out of the rock below the surface either (1) by blasting underground chambers with conventional explosives and then injecting natural gas (the net energy problem again) into it and setting it afire, or (2) by exploding atomic bombs in deep layers of shale rock. But... just to supply 10 percent of our projected oil needs by 1985 would require about six underground nuclear blasts per day, with unknown geological and ecological hazards.

The Interior Department has leased six tracts of government-owned land to private industry for an experimental oil shale program. But without strict environmental controls and a more favorable net energy gain, oil shale may have little to do with our energy future, despite its potential.. Its most promising use may be as a source of raw materials for the petrochemicals industry.

[The Energy Research and Development Administration plans to spend $10.1 million on oil shale research and development projects in the 1976 fiscal year.]

FOSSIL FUEL - TAR SANDS

Tar sands are deposits of rock or sediments containing a heavy oil or tar-like fossil fuel substance too thick to be pumped to the surface by drilling.

Although large deposits of tar sands were discovered in North America in the late 19th century, little effort has gone into exploiting the resource except in Canada, which has very rich deposits. One of Canada's tar fields alone, the Athabasca deposit in Alberta, is estimated to contain the equivalent of 700 billion barrels of processed oil.

Tar sands have been one of the last energy resources to receive attention because formidable obstacles stand in the way of development. First the rock or sediments containing the tar must be mined. The tar is very diluted in this material and a concentration of 14 percent is considered very high quality. Surface mining is the usual extraction method. Once mined the ore is removed from the rock. It is converted to an oil-like substance in processing plants.

The problems are many. Surface mining of tar sands deposits has most of the same negative impacts on the land and water of the area as coal surface mining. Waste sand left over from the processing stage must be transported back to the mining site or disposed of in some other fashion. Many of the deposits are so deep that even conventional deep mining would be too expensive. Most important, after all of the processing and transporting steps, it is not clear whether a net energy yield can be achieved even for the high-grade ore.

Significant deposits of tar sands have been discovered in Kentucky, New Mexico, Texas, and Utah. Total reserves in the U.S. are estimated to be an equivalent of 30 billion barrels (*Energy Alternatives: A Comparative Analysis,* Council on Environmental Quality). The concentration of tar in U.S. deposits ranges from 9 to 16 percent and the content of its most harmful polluting impurity, sulfur, varies.

The Energy Research and Development Administration has made only a slight commitment to tar sands. Research on this alternative is combined with oil and natural gas categories, for which the agency plans to spend a total of $34.5 million in the 1976 fiscal year.

NUCLEAR FISSION

There is some energy stored on earth that may or may not have come directly from our sun. This energy is stored in uranium and other radioactive material which scientists believe were created in the interior of our sun or other stars and deposited in the earth when it was formed. Industrial society has succeeded in harnessing uranium's energy in a process called nuclear fission.

The power of uranium was first unlocked on December 2, 1942, when the first successful chain reaction was achieved in experiments to construct nuclear weapons. After World War II, the Atomic Energy Commission (since replaced by the Energy Research and Development Administration and the Nuclear Regulatory Commission) was established to carry on nuclear research for military and civilian purposes. Scientists learned that fission could be controlled to produce electricity. The heat released in the reaction is used to boil water or some other liquid, creating steam to turn conventional steam generators. The first nuclear fission electric power plant was built at Shippingport, Pennsylvania, and went into operation in 1957.

Government studies have concluded that fission power plants have a favorable net energy yield, although some experts maintain that these calculations may not include all of the energy inputs to the system.

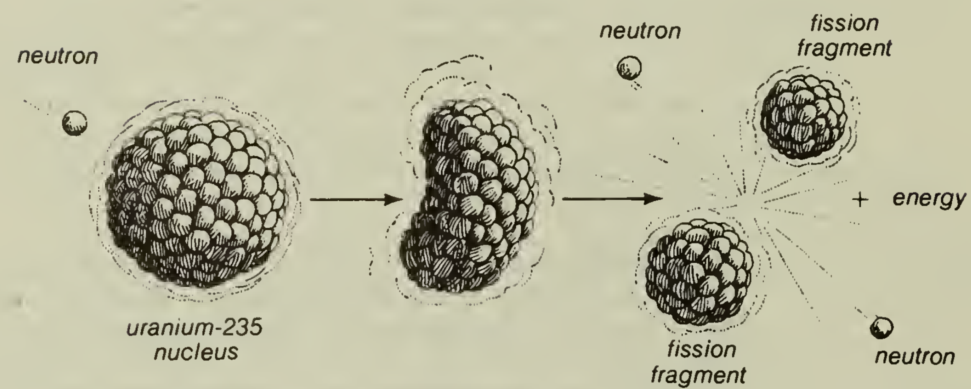
The power of uranium's concentrated energy is immense. According to the Federal Energy Administration, one pound of uranium has as much energy content as nearly three million pounds of coal. In the fission process certain heavy atoms of uranium are split when bombarded with neutrons, releasing energy and more neutrons which then split other atoms (Figure C-3). Wilson Clark provides a good description of how the reactors work:

> Harnessing the energy of fission involves controlling the energy release process so that a "chain reaction" is initiated. A chain reaction occurs when the fissioning of one atom releases neutrons that strike the nucleus of another atom, releasing more neutrons, which strike more atoms, etc. The difference between a nuclear reactor in a power plant and an atomic bomb is measured by the number of neutrons that are released in the fission process. If only one neutron at a time is available for triggering the fission event in the chain of atom-splitting, then the chain reaction is under control. The release of more neutrons accelerates the process rapidly, causing an atomic explosion. Nuclear power plants in operation today are designed so that atomic explosions are not possible. Control rods, made of materials that absorb neutrons, can be inserted or withdrawn in the reactor's core to either start or stop the fission process. In most U.S. nuclear reactors, water is circulated between vertical, pencil-thin rods of uranium fuel to control or "moderate" the speed of traveling neutrons. This is done to increase the chance of neutrons colliding with other atoms since slower-moving neutrons improve the possibilities for fission by 200 or 300 times. For this reason, most U.S. reactors are called "light-water" reactors, to distinguish them from reactors that use deuterium, or "heavy water," as a moderating

agent, and high-temperature gas reactors (HTGR), which use helium gas as a moderating agent....

In a modern nuclear power plant, capable of generating one million kilowatts (1000 megawatts)

Figure C-3



Nuclear fission of a uranium-235 nucleus.

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

of electricity, about 100 tons of uranium fuel in thin rods are loaded into a half-foot-thick, steel-walled reactor vessel containing coolant water and associated pipes for transferring steam to operate turbines for the generation of electricity. As the control rods alongside the fuel elements are withdrawn, fission is initiated and heat builds up within the reactor core, reaching over 4000 degrees Fahrenheit in the center of the uranium fuel elements.

... The over-all operating temperature is kept lower than the operating temperature of a fossil fuel power plant to protect the uranium fuel rods. Consequently, the thermodynamic efficiency is lower than for fossil fuel power plants and almost twice as much waste heat is produced by the operation of nuclear plants. Therefore, nuclear

> power plants are heavier thermal polluters to rivers and waterways than their fossil fuel counterparts.
> (*Energy for Survival,* Anchor Books)

Uranium found on earth is composed of 99.3 percent U-238 and 0.7 percent U-235. Only the latter portion can be used as fuel in our currently operating fission reactors. When high-grade uranium ore is mined from the earth it contains only about 0.25 percent uranium. Because it makes up a small portion of the mined materials, little radioactivity problem exists at this stage. Before the uranium can be used as a fuel it must be concentrated. This work, called uranium enrichment, is done in three huge federal factories built during World War II at Paducah, Kentucky, Oak Ridge, Tennessee, and Portsmouth, Ohio. Enrichment purifies the ore to a substance containing 75 percent or more uranium -- both U-235 and U-238. This enriched uranium is then molded into tiny pellets weighing less than one gram each. About 10 million of these pellets are placed in a group of 12-foot rods that fuel a reactor. Separated from impurities, the uranium is now highly radioactive.

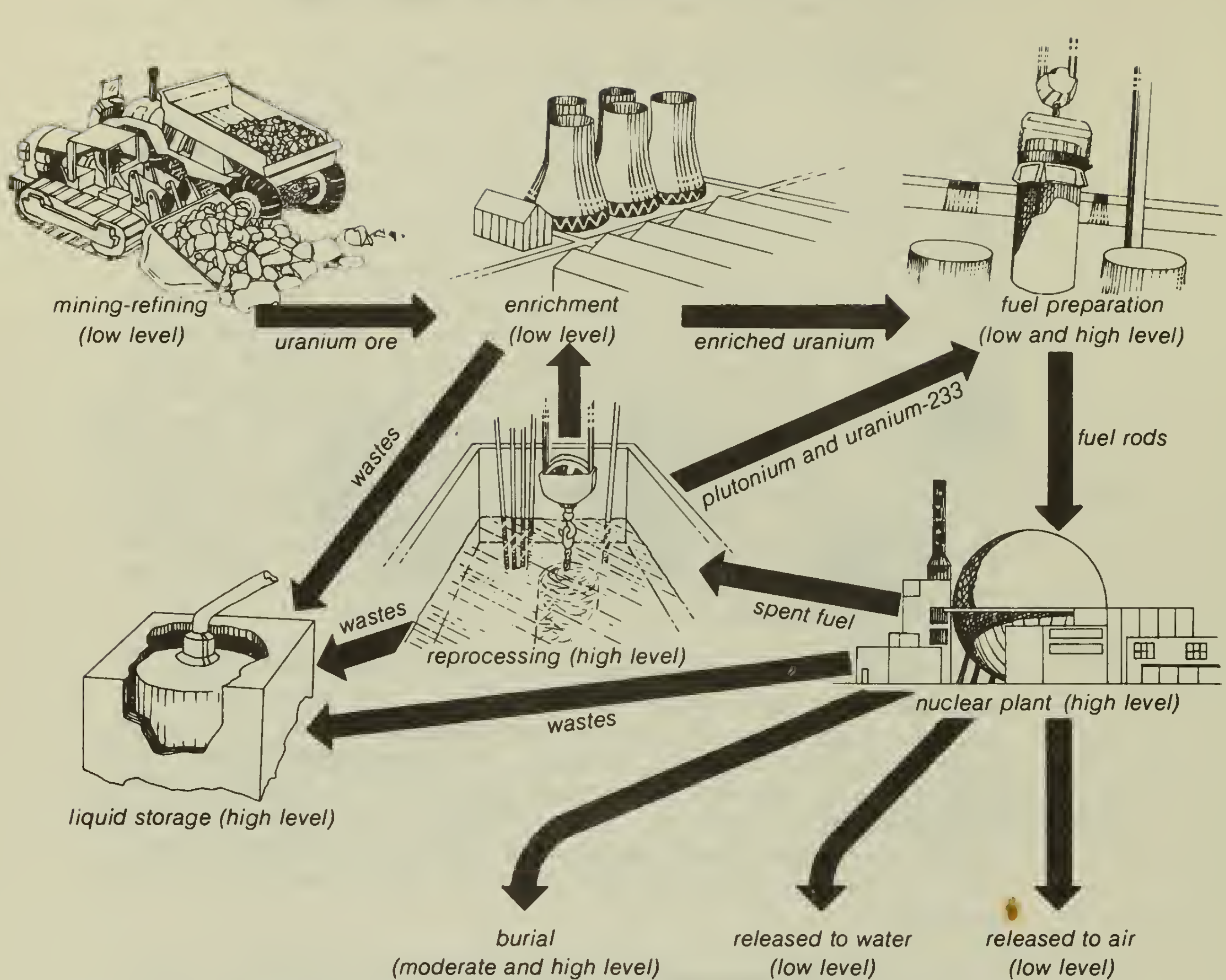
What we have described thus far is only the first stage of the uranium "fuel cycle" (Figure C-4). One such load of processed uranium can fuel a fission reactor for about one year. During that time a number of byproducts of the fission reaction are created in varying quantities and with varying levels of radioactivity. (In addition, the operation of the reactor releases small amounts of low-level radiation into the air around the plant and into the water used for cooling purposes.)

The byproducts and wastes from the reaction, some of which are highly radioactive, must be removed from the plant and buried, stored, or reprocessed into more fuel or low-level radioactive materials. The federal government, which licenses private power companies to operate nuclear reactors, is still searching for a safe method of burying or in some way disposing of nuclear wastes. In the meantime all of the wastes are being stored.

The reprocessing stage of the nuclear fuel cycle is currently undeveloped, causing even more reactor wastes to pile up. Private companies have built reprocessing plants, but these have experienced technical and environmental problems. None are currently operating and the future of this phase of the industry is uncertain.

The transportation of highly radioactive wastes, byproducts, and reprocessed materials is probably the most serious danger

Figure C-4



The nuclear fuel cycle and nuclear wastes, showing the radioactivity level of the materials at each step.

(G. Tyler Miller, Jr., <u>Living in the Environment</u>, <u>Wadsworth Publishing Co.</u>)

of nuclear power. Some of these byproducts are so toxic that they must be isolated from the enviornment for hundreds of thousands of years.

The most dangerous of these substances is the byproduct plutonium, virtually non-existent in nature until produced by humans, and the most toxic material known on earth. The cancer-producing nature of plutonium is so strong that one ten-millionth of an ounce injected under the skin of mice in experiments has resulted in cancer. Plutonium ignites spontaneously when exposed to air and forms tiny, intensely radioactive particles of plutonium dioxide, complicating the safeguard procedures. Once in the air these particles are suspended for long periods of time. Plutonium is also the essential ingredient for constructing atomic bombs. If stolen, the production of nuclear explosives could be easily accomplished.

It should be made clear that fission reactors cannot go out of control and explode. Their fuel is a different type and mixture than that used in nuclear explosives. It is possible that under certain circumstances, such as an earthquake or explosion in the power plant, the reactor chamber could rupture, releasing radioactivity and contaminating the land and people near the site. This would require evacuation of the surrounding area, perhaps for months or years, and would increase the likelihood of cancer among those people exposed.

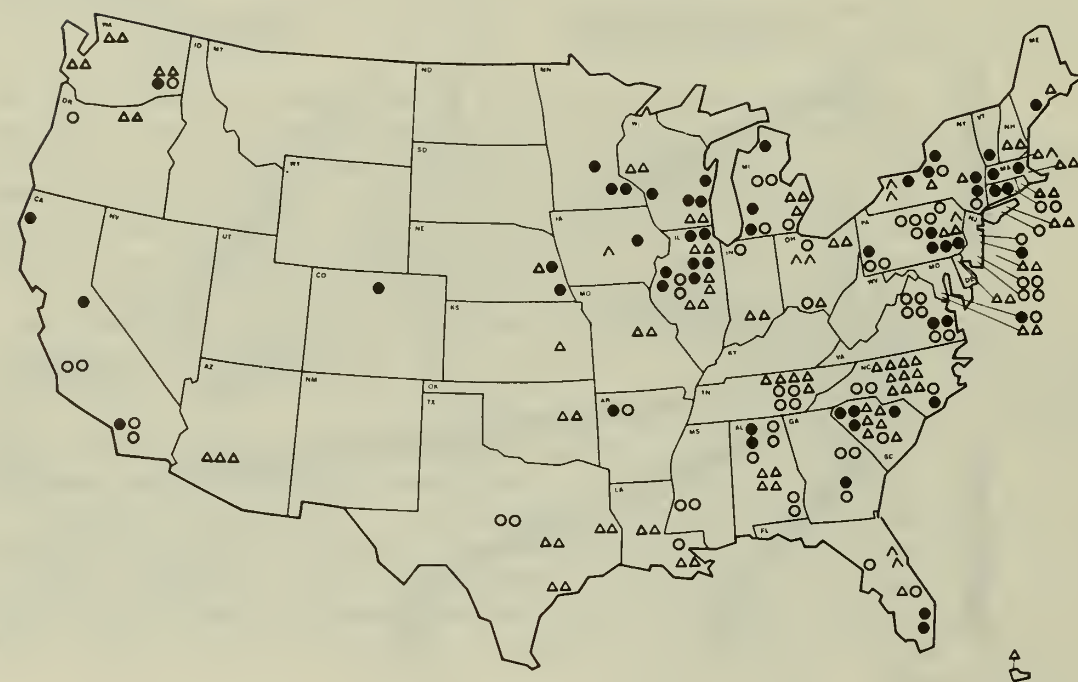
However, in spite of the dangerous materials involved, the safety record of the nuclear power industry, after nearly 20 years of operation, is quite good. There have been some accidents in reactors and some leakage of radioactive materials, but there have been no large-scale accidents. Maintaining this good record as the number of operating nuclear plants grows, is an enormous challenge to the nuclear industry.

Fission power does have financial advantages over other existing methods of producing electricity. Even though nuclear plants cost more to build than their fossil fuel counterparts, the cost of producing electricity over the life of the plant is less -- estimated at 11.93 mills per kilowatt hour (a mill equals one-tenth of a cent) compared to an average of 12 mills per kilowatt hour for all sources of electricity (*Energy Alternatives: A Comparative Analysis*, Council on Environmental Quality).

The U.S. currently has 59 nuclear power plants in operation which supply three percent of our total energy consumption (or eight-and-one-half percent of our electricity), according to the Federal Energy Administration. But these percentages will jump sharply over the remainder of this century if the more than 100 additional plants now under construction and on order are brought into operation. The Federal Energy Administration predicts that nuclear fission will supply 15 percent of our energy demand by 1985 and 30 to 40 percent by the year 2000.

Figure C-5

Central station nuclear power plants in the United States



Key
- ● Operable
- O Under Construction
- Δ On order
- ʌ Letters of intent/options

56	Reactors operable	37,536 Mwe
63	Reactors under construction	64,369 Mwe
100	Reactors on order (including 8 units not sited on map)	112,186 Mwe
17	Letters of intent/options (including 8 units not sited on map)	19,082 Mwe
236	Total	233,173 Mwe

Atomic Industrial Forum, Inc.

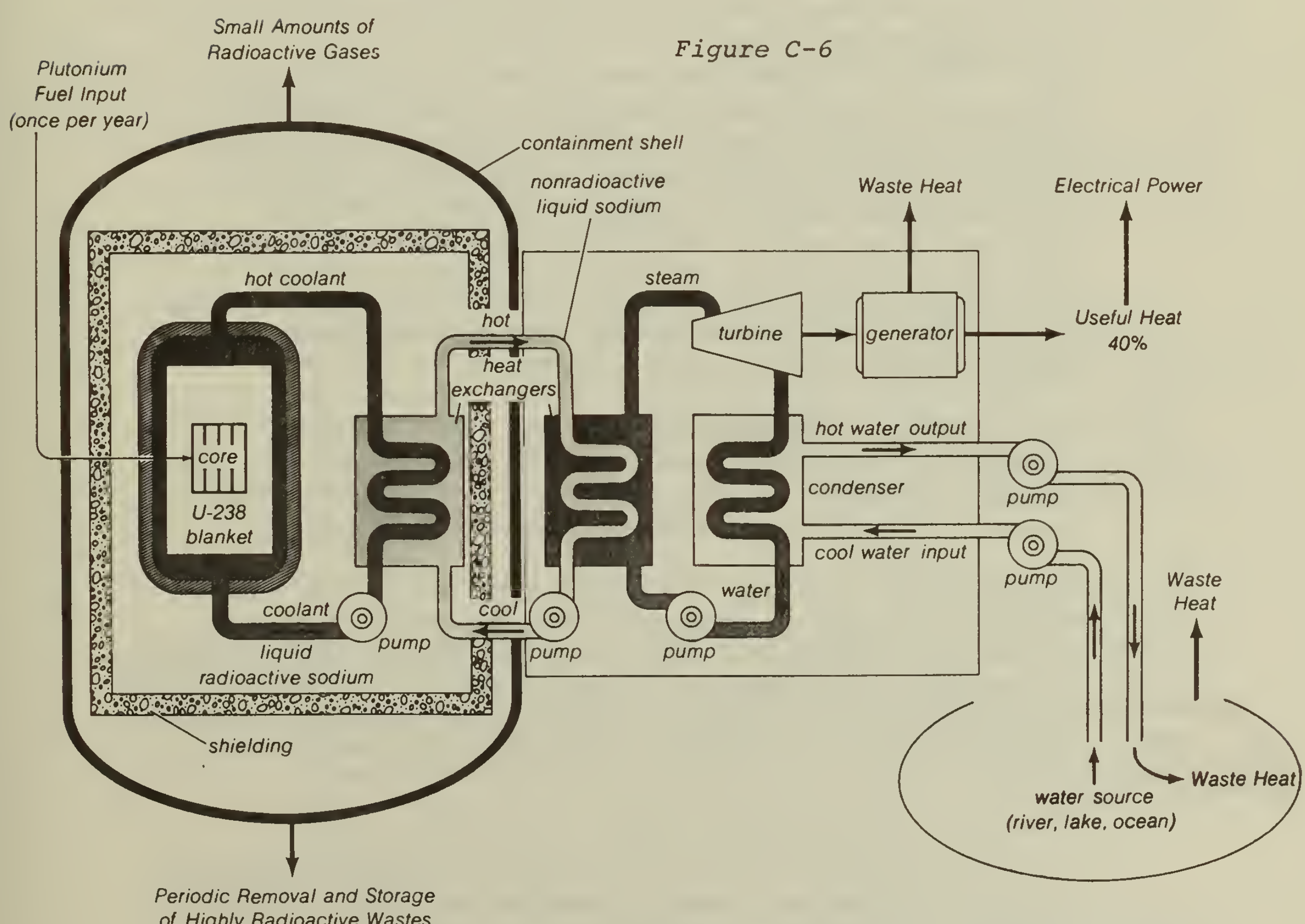
January 1, 1975

Fueling all of these reactors is becoming a problem since uranium is not an abundant mineral. At the increasing rate it is being used, the world's reserves will be virtually depleted by the end of this century. This problem could be partially offset by the use of plutonium, which can be reprocessed and used as a fission fuel. But not enough plutonium is produced in reactors to solve the problem.

The other hope for increasing uranium supplies is the development of the Liquid Metal Fast Breeder Reactor, which would theoretically use uranium fuel more efficiently and produce more plutonium byproduct. Now undergoing advanced federal research and demonstration work, the breeder reactor, if successful, could stretch our usable supply of uranium for decades, or perhaps centuries. The reactor would be fueled by a combination of plutonium and U-238, the more abundant portion of uranium which cannot be used in conventional fission reactors.

However, the breeder reactor also involves increased risk. The expanded use and production of plutonium would increase the likelihood of a mishap involving the dangerous substance. Secondly, current plans for the breeder call for the use of liquid sodium, rather than water, to control the reaction. The use of this highly reactive material, which explodes on contact with air, means that any break in cooling system lines could cause an explosion.

Figure C-6



A liquid metal fast breeder reactor (LMFBR) power plant.

(G. Tyler Miller, Jr., <u>Living in the Environment</u>, Wadsworth Publishing Co.)

The federal government is scheduled to begin construction late this year of a demonstration breeder reactor near Oak Ridge, Tennessee. Scheduled for completion in late 1983, the plant must be tested before any commercial breeders are constructed.

U.S. energy officials believe that these problems can be overcome and that nuclear power and the breeder reactor represent our most promising energy alternative at least through the end of this century. Billions of dollars have already been invested in the program and the Energy Research and Development Administration expects to spend $680 million in fiscal year 1976 on conventional fission, breeder fission, and fuel cycle projects -- more than one-third of the agency's total energy research budget. ERDA's current energy development plan for the U.S. calls for continued "highest priority" commitment to further development of conventional nuclear fission and commercial introduction of the breeder.

NUCLEAR FUSION

Energy from fusion powers the sun, the stars, and the hydrogen bomb, and if the hopes of scientists are realized, it will someday become a nearly unlimited and virtually pollution-free source of power for society. But the problems of harnessing the fusion reaction are so complex that after 20 years of research, scientists have yet to prove that a controlled fusion reaction is feasible. Even if proven, it would take decades before widespread commercial fusion power became a reality.

Thermonuclear fusion occurs when two light (hydrogen) atoms combine at very high temperatures to form a heavier atom, the mass of which is less than the sum of the two original atoms. The additional mass is released as energy.

The basic fuels of the fusion reaction are the so-called "heavy" isotopes of hydrogen -- deuterium and tritium. Deuterium is so plentiful in seawater that it would provide a virtually inexhaustible source of energy. Tritium is bred from lithium, which is also available in enormous quantities from the oceans. Because the fusion reactor would breed its

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* This discussion of fusion is reprinted from the Feb. 2, 1974 issue of *Environmental Action* magazine, with permission. The material is adapted from articles written for *Science* magazine by William Metz, a staff writer for *Science*.

own fuel and immediately burn it, fusion elinimates the fuel transport and disposal hazards of the fission reactor. The only significant radioactive remnant from a fusion reactor would be the inner structure.

A major problem associated with fusion is achieving the enormous temperature required for the reaction -- over 100 million degrees centigrade, hotter than the highest temperature in the sun. Very great pressures are also needed to contain the reaction long enough to produce a useful amount of energy. So far, no system has successfully achieved the required temperature and pressure at the same time.

Two techniques to generate fusion power are under study: magnetic containment and laser fusion. But even if the technological feasibility of either system is proven, commercial sales of fusion reactors would still be years away -- after experimental reactors were extensively tested and a demonstration reactor had been successfully operated. Studies to assess the size, cost, operating characteristics, radioactive hazards and environmental effects of a fusion reactor are in the very early stage for laser fusion and are just becoming available for magnetic fusion. However, it is clear that fusion reactors would have two great advantages: virtually unlimited fuel resources and no conceivable danger of an explosive accident.

Magnetic containment fusion would contain the fusion reaction with a bank of superconducting magnets. These magnets would compress the hot fuel which becomes an ionized gas known as a plasma, the fourth state of matter. Many different systems for the magnetic containment of plasmas have been tried, but thus far all of the machines use more energy than they create. Some scientists think the process can be proven feasible by 1980.

Laser fusion is a newer strategy. An implosion fusion reaction is created within a small pellet of fuel by bombarding it from all sides with laser beams. But this concept has only been tested in computer simulations and it is not clear whether lasers exist which can continually deliver enough energy at the extremely high speed required. Some scientists think the laser concept can be proven in two to four years. The breakthrough may be made in the Soviet Union which has a larger program than the U.S.

The greatest hazard of fusion -- whether the magnetic or laser type -- is the danger of radioactive tritium release into the environment. Tritium has a relatively short half-life,* about 12 years, but it spreads rapidly, both because it is a light gas and because it can replace hydrogen in molecules such as water. Although the radioactivity of tritium is relatively benign compared to many fission reactor products, it is still a dangerous substance and is very difficult to contain. The most optimistic estimates agree that at least .03 percent of the total inventory would probably escape from the reactor each year, and it is unclear at the present stage of research whether the tritium hazard would be small enough to permit siting of fusion reactors in cities.

There are several other serious environmental hazards in the operation of a fusion reactor. The first is release of heat from the reactor. Also any accident in the magnet system could release a tremendous quantity of electrical energy. An even greater hazard would be a liquid lithium fire.

As an ultimate resource, the energy available from fusion is surpassed only by the resource of sunlight which, after all, is just fusion power from a far greater reservoir. The bonanza of energy anticipated from fusion reaction prompts the federal government to continue investing ever increasing amounts of money into fusion research, despite lack of success over the last 20 years. In the 1976 fiscal year the Energy Research and Development Administration plans to spend $223 million on fusion research, more than 10 percent of its total energy research budget.

RENEWABLE FORMS

SOLAR - DIRECT USE

The earth's daily ration of constantly renewed energy from the sun comes in a variety of forms, including direct solar rays, wind, falling water, and the thermal gradient of the sea. We often overlook the energy we derive from these forms of solar power for agriculture, hydroelectric power, cooling breezes, or even clothes drying. Still, it is true that most of the power to run industrial society -- power

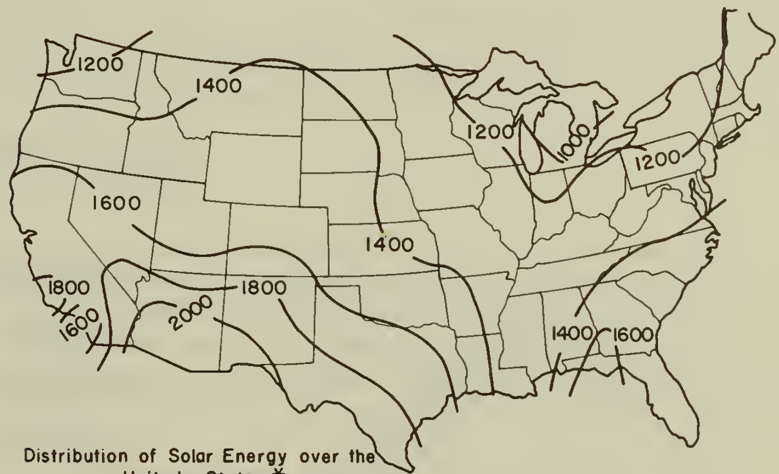
---

* The half-life of a radioactive substance is the time it takes for one half of its atoms to disintegrate.

to make electricity, operate vehicles, run machinery, heat homes and factories -- now comes from fossil fuels, the sun's stored energy. Fortunately, since we are now running out of fossil fuel, solar energy has the potential to provide power for many of these needs.

The main difficulty in harnessing the abundance of solar energy reaching the earth is that the energy is usually insufficiently concentrated to do many of our tasks. Concentrating the energy, of course, requires an investment of energy, reducing the possible net energy yield. The intensity of solar radiation also varies with the season, latitude, and degree of cloud cover (Figures C-7 and C-8). In addition, some method of storing solar energy is usually needed for nighttime and cloudy days.

Figure C-7



Distribution of Solar Energy over the United States *

*Figures give solar heat in Btu/ft^2 per day

Distribution of U.S. Solar Energy

Source: AEC, 1974

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

These are complicated problems which are now receiving research attention from the federal government and private industry in the U.S. Two main advantages of solar energy are causing more and more emphasis to be placed on this research: the supply of fuel -- sunlight -- is essentially unlimited, and solar energy creates less pollution than most other energy forms (*Energy Alternatives: A Comparative Analysis*, Council on Environmental Quality).

The most extensive use of sun-capturing technology in the

Figure C-8

SOLAR RADIATION AT SELECTED LOCATIONS IN THE UNITED STATES DURING 1970

Location	Average Total Daily Insolation (Btu's per square foot per day)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
Seattle-Tacoma, Washington	278	688	1,069	1,354	1,950	2,065	2,105	1,750	1,217	747	370	229	1,152
Fresno, California	710	1,117	1,709	2,205	2,609	2,579	2,576	2,412	2,050	1,425	910	614	1,743
Tucson, Arizona	1,110	1,391	1,750	2,202	2,435	2,449	2,190	1,983	1,735	1,587	1,221	870	1,745
Omaha, Nebraska	777	1,110	1,284	1,576	1,939	2,165	2,002	1,865	1,280	944	581	596	1,351
San Antonio, Texas	862	1,103	1,432	1,506	1,906	2,083	2,176	2,057	1,587	1,388	1,310	784	1,516
Lakeland, Florida	1,029	1,436	1,480	1,983	2,079	2,042	1,883	1,680	1,639	1,436	1,302	1,169	1,597
Atlanta, Georgia	873	1,203	1,288	1,635	1,991	1,854	1,917	1,628	1,591	1,021	955	714	1,389
Burlington, Vermont	581	781	1,088	1,384	1,447	1,758	1,587	1,835	1,195	759	444	448	1,109

Source: Commerce, 1970

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

world today is for cooking and desalination of water. Both are valuable processes although their use is limited to times when the sun is shining. Solar stoves, typically a simple device which uses a concave reflective surface to focus heat on a small area, have been produced by the U.S. for energy-poor nations.

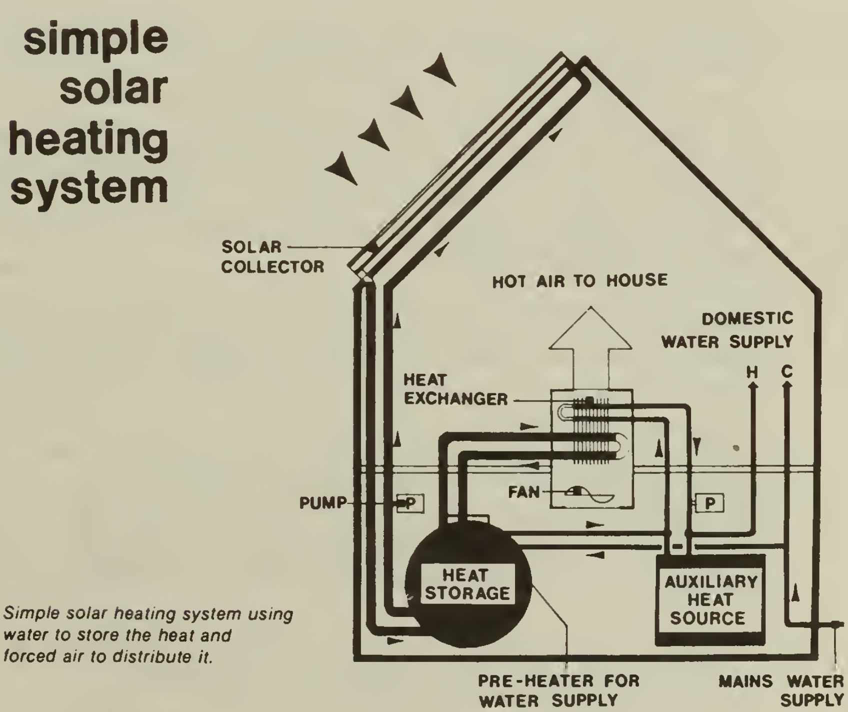
Solar energy has long been used to purify salt water, usually for drinking purposes. Salt water is placed in a shallow container covered by a sloping, transparent roof. Pure water evaporates under the sun's heat, collects on the roof, and flows down into a collecting trough. This process is only practical on a small scale and is not suitable for irrigation.

The most promising "new" uses of solar energy are water heating, the heating and cooling of buildings, and the production of electricity. Solar water heaters, now widely used in Japan, Australia, and Israel, were a common home appliance in California, Florida, and some other south-eastern U.S. states from 1900 to about 1950. Now most systems in the U.S. have been replaced by fossil fuel water heaters. Solar hot water systems are proven and reliable, and can supply all or nearly all of the hot water needed for homes in the southern U.S. and can augment fossil fuel systems in other locations.

The technology to harness solar energy for water heating is simple compared to most other energy systems. A solar collector is mounted on the south-facing roof of the building or on the ground nearby. The typical collector is a flat, dark-colored plate separated by an airspace from a sheet of glass or some other transparent material. Sunlight passes through the glass but is absorbed and converted to heat on the collector. Water is circulated in pipes on either side of the collector plate and then is pumped to an insulated storage tank where a heat exchanger similar to an automobile radiator transfers the heat in the pipes to the water in the tank. Such a system can heat water to about 200 degrees Fahrenheit.

This same equipment can also be used on a larger scale to provide space heat for buildings (Figure C-9). A storage medium, such as crushed rock, enables the system to supply heat through some of the time when the sun is not shining, although backup heating is needed except in very warm climates. Circulating air is often substituted for water in building heating installations.

Figure C-9



Simple solar heating system using water to store the heat and forced air to distribute it.

(Energy for the Home, Garden Way Publishing)

Dozens of solar heated homes have been built in the U.S., primarily by inventors and interested individuals rather than by business or government. However, with the passage of the Solar Energy Research, Development, and Demonstration Act of 1974, the federal government has begun subsidizing the installation of solar hot water and heating systems in hundreds of homes, commercial buildings, and government buildings. Some of these "demonstration" units will include solar cooling, a somewhat more complicated technology which is still undergoing development.

Since there is no fuel cost, solar heating equipment is cheaper to operate than a conventional system, even with backup fossil fuel heat. However solar heating units or a combined system are more expensive to install. Still, in the long run, current home solar heating systems can save money. In addition, recent budget increases for solar research and development by the federal government and private institutions may lead to lower cost systems with wider application. Since 25 percent of the energy consumed in the U.S. is used for heating, cooling and hot water production (Federal Energy Administration) extensive use of solar energy for these purposes could be an important factor in easing fossil fuel demand.

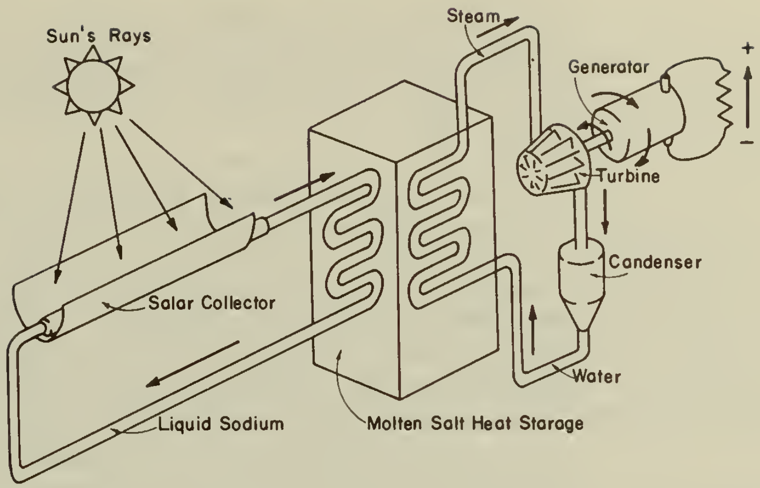
The power of simple solar collectors can be increased by using curved reflective surfaces, such as parabolic mirrors, to concentrate more of the sun's rays on a water-filled pipe. Simple devices of this type have been developed and can heat water to 600 or more degrees Fahrenheit, sufficient for the generation of electricity with steam turbines (Figure C-10). A large number of curved reflectors may be able to create enough steam to operate a standard-size electric power plant.

The federal government's research program is testing this concept but is devoting more attention to a competing system which would use hundreds of mirrors to reflect sunlight onto a boiler mounted on top of a tower. One complication for both of these experimental technologies is the need for collectors or mirrors to rotate to track the sun as it moves across the horizon each day. These tracking systems would probably be motorized and require computer controls, reducing the possible net energy yield of the systems.

Scientists are still looking for an effective way to store the sun's energy for large-scale plants.

These methods for producing electricity from the heat of the sun's rays are still highly speculative. It is not clear if the plants will work efficiently on a large scale and net

Figure C-10



Solar Thermal-Conversion Power System

Source: AEC, 1974

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

energy yields are uncertain. However, the federal government's ambitious program for testing these concepts should reveal their potential within five to 10 years.

A second method for making electricity from the sun's rays is more widely understood by the public since it has been used as a source of power for U.S. space flights. Called photovoltaic conversion, this process was developed by Bell Laboratories in 1954 and was first used in the late 1950's. It uses silicon cells to convert sunlight directly to electricity. Wilson Clark provides a good description of how the cells work:

> The silicon solar cell is able to convert electricity by the unique characteristics of silicon itself, which is a semiconductor material; that is, it is both an electrical insulator and a conductor...
>
> Silicon produced for solar cells is "grown" in large single crystals, and the wafer-like thin strips of silicon that form the basis for the cell are painstakingly cut from the crystal ingots with precision diamond saws. The silicon strips are then coated with other materials, such as boron,

> to produce a positive electrical layer, which interacts with the underlying negatively charged silicon layer. This critical sandwich layer, or "p-n (positive-negative) junction," is the key to the production of electricity and gives the silicon cell its "photovoltaic" property.
>
> ...When the elementary energy particles of sunlight, the photons, strike the silicon cell, they are converted to electrons in the p-n junction. The "p," or positive, layer accepts the electrons, and the "n," or negative, layer rejects them, thus setting into motion a flow of direct-current (DC) electricity. The current is diverted to electrical wires by an electrical conductor imbedded in the surface layer of the cell...
> (*Energy for Survival*, Anchor Books)

The maximum efficiency of this process is currently only about 10 percent. But the chief problem of photovoltaic conversion is cost. Solar cells made for the space program cost $200,000 per kilowatt, five times the cost of nuclear power. The problem is that silicon crystals are difficult to mass-produce, and the process requires so much energy at present that it may not achieve a net energy gain. It is possible that substantial decreases in production costs could result from expanded research programs now underway. Most of this work is being conducted by private companies under contract to the federal government.

Photovoltaic electricity production has the same storage problems as other solar power technologies. The most elaborate scheme to overcome this drawback, and the short production day of solar power plants, is to launch huge panels of photovoltaic collectors into orbit near the equator where the sun would strike them nearly 100 percent of the time. Electricity could be converted to microwave power, beamed to earth antennae, and converted back to electricity.

The environmental impact of solar heating and electricity is almost certainly less than that of competing energy systems, although it is important to remember that the end-use of energy always creates pollution, simply in the process of converting the energy to heat. Other than pollution from fossil fuels or nuclear power used to manufacture or transport equipment, solar energy creates no air or water pollution. Far less heat is released into the environment because no fuel is being burned. Once in place, solar hot water or space heating systems create negligible amounts of pollution.

Solar methods for producing electricity do have some potential problems. Large land areas would be required to deploy solar panels to collect sunlight. Such "solar farms" would likely be a visual eyesore and could affect local weather by reducing the reflectivity of the earth at that location. The most promising area in the U.S. for the development of solar electric plants is the southwestern states which, in some areas, receive more than 300 cloudless days per year. The fact that these areas are sparsely populated and include a hundreds of thousands of acres of desert might indicate that the area is ideal for solar power plant siting. On the other hand, environmentalists may oppose this disruption of the land, even though adjacent lands would suffer little pollution.

The plan clearly needs more study. Desert and semi-arid ecosystems of this region are very fragile and installation of solar power plants would undoubtedly cause damage. Roads would be needed, as well as power lines to transport the electricity to users. Flora and fauna of the region would certainly be affected. However, in spite of these drawbacks, solar electric plants might disturb less land than coal-powered facilities which rely on strip mines.

Until very recently almost no research funds were invested in solar technology. In 1973 the federal government spent only $4 million for solar research. But by 1975 the figure jumped to about $50 million and in the 1976 fiscal year the Energy Research and Development Administration plans to spend $86 million on all aspects of solar energy research. In addition to direct solar conversion, this sum includes research on obtaining energy from wind, sea thermal gradient, and bioconversion. Even though this represents a large expansion, solar energy still receives only about one-sixth as much in federal funds as nuclear fission alone.

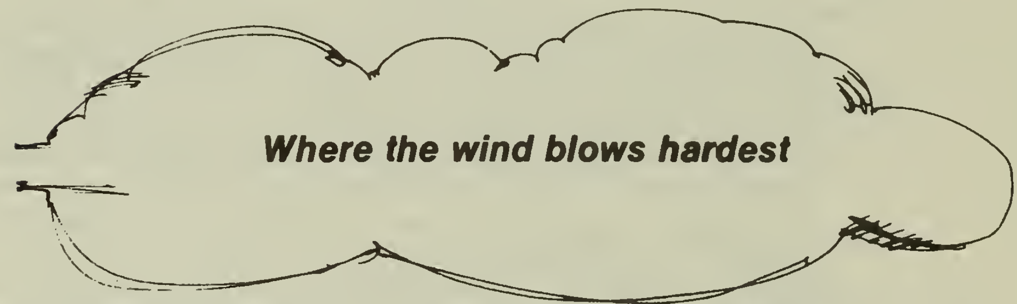
How much energy can be supplied by all forms of solar energy is still uncertain. But an optimistic, 1973 report by a group of scientists from the National Science Foundation and the National Aeronautics and Space Administration predicted that new technological developments will likely reduce solar costs while prices for fossil fuel energy will likely continue to rise. The result: solar energy becomes more competitive. The panel reported that the cost of solar heating for homes and buildings is already competitive with fossil fuels in some areas of the U.S. and that solar heat can provide up to 80 percent of heating needed in sunny climates. The experts predicted that if the nation devoted a research budget of $3.5 billion to solar energy development, by the year 2020 it could supply 35 percent of needed heating and cooling for buildings, 30 percent of our gaseous fuels and 10 percent of liquid fuels (through bioconversion), and 20 percent of our electricity (*Solar Energy as a Natural Resource*, NSF/NASA).

SOLAR - WIND

Wind is actually a form of solar energy because the sun heats the earth's atmosphere and the resulting fluctuations in temperature and pressure cause air movement. Wind is even more variable than sunlight, changing with location, season, and weather of the moment. Wind seldom blows at a constant speed but rather swells and ebbs in an irregular fashion. The flow of wind is also affected by the landscape. Generally, flat, unobstructed terrain, hilltops, or the tops of buildings offer the best wind.

The U.S. wind resource varies widely. Figure C-11 lists average wind readings for some major cities. The Great Plains, northeast coast, and a few other areas have the best

Figure C-11



Based on hourly observations by the National Weather Service over a ten-year period, this chart shows the average mile-per-hour wind speeds for several U.S. metropolitan areas.

Fargo, North Dakota	**14.4**
Wichita, Kansas	**13.7**
Boston, Massachusetts	**13.3**
New York, New York	**12.9**
Ft. Worth, Texas	**12.5**
Des Moines, Iowa	**12.1**
Honolulu, Hawaii	**12.1**
Milwaukee, Wisconsin	**12.1**
Cleveland, Ohio	**11.6**
Chicago, Illinois	**11.2**
Minneapolis, Minnesota	**11.2**
Indianapolis, Indiana	**10.8**
Providence, Rhode Island	**10.7**
Seattle-Tacoma, Washington	**10.7**
San Francisco, California	**10.6**
Baltimore, Maryland	**10.4**
Detroit, Michigan	**10.3**
Denver, Colorado	**10.0**
Kansas City, Missouri	**9.8**
Atlanta, Georgia	**9.7**
Washington, D.C.	**9.7**
Philadelphia, Pennsylvania	**9.6**
Portland, Maine	**9.6**
New Orleans, Louisiana	**9.0**
Miami, Florida	**8.8**
Little Rock, Arkansas	**8.7**
Salt Lake City, Utah	**8.7**
Albuquerque, New Mexico	**8.6**
Tucson, Arizona	**8.1**
Birmingham, Alabama	**7.9**
Anchorage, Alaska	**6.8**
Los Angeles, California	**6.8**

(National Wildlife Magazine)

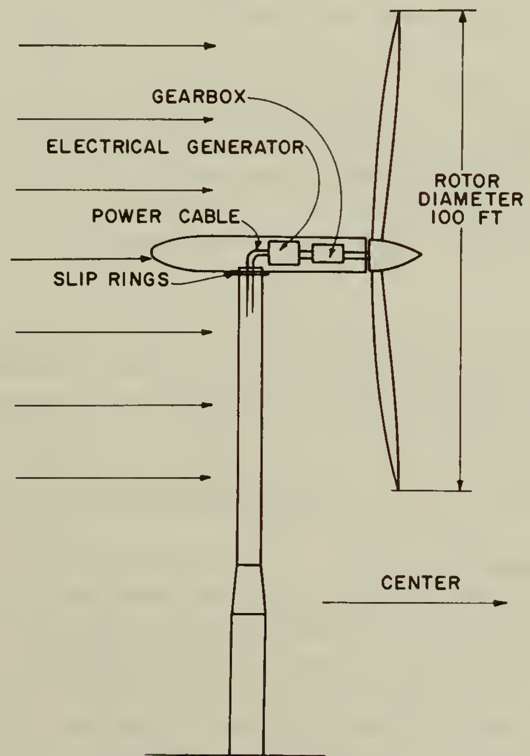
supply in the U.S. for power production purposes, averaging about 12 miles per hour, according to the Federal Energy Administration.

The use of wind goes back several thousand years and was first controlled for sailing by Egyptians 2000 years before Christ. By the 13th century windmills were used widely in Europe, primarily for pumping water, grinding corn, and irrigation.

Windmills were an important source of power in the U.S. in the 1800's, and early 1900's. Early pioneers moving west used windmills for many tasks because steam engines were still not available in the newly settled areas. Wind energy remained a primary source of energy in the western U.S. until the 1930's, when the Rural Electrification Administration was established to provide electricity to the West. The REA did its job well, for very few functioning windmills remain in the U.S. today.

Windmills can easily be adapted for the production of electricity. The rotary action of the blade shaft turns a generator producing a direct current (Figure C-12). Converters

Figure C-12



Typical Wind Rotor System

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

can be attached to make the electricity into alternating current, although most existing home windpower units use direct current so that storage batteries can be used. Most major appliances are available in direct current models.

Numerous proposals have been made for using wind energy on a much larger scale. William Heronemus of the University of Massachusetts has proposed that a group of 300,000 huge wind turbines be constructed from Texas to North Dakota in a favorable wind belt. Heronemus calculates that 189 million kilowatts could be supplied by the massive, 850 foot towers which would each hold 20 turbines.

Other wind power advocates suggest floating giant wind generators off the coast of the U.S. and converting their energy to hydrogen which could then be transported by boat or pipeline to shore.

As is the case with direct solar power, storage of wind energy is a major problem. In home applications, batteries provide reliable, though inefficient, storage. Some experts believe that flywheels could be much more efficient, storing enough momentum to supply energy for a week of windless days (*Energy for Survival,* Wilson Clark). Flywheels are also less expensive than storage batteries. Hydrogen is another promising storage medium for small-scale operations.

If wind energy is produced on a larger scale, storage problems might be minimized by feeding the wind energy directly into electric utility power grids. This would also help to reduce the need for fossil fuel- or nuclear-generated electricity. In times of little or no wind, however, all electricity would still have to come from conventional power plants.

Wind power is a relatively simple technology which appears to have enormous potential for refinement. The NSF/NASA solar energy report concluded that a "major windpower program" could generate 1.5 trillion kilowatt hours of electricity annually by the year 2000 -- a quantity roughly equal to the amount of electricity consumed in the U.S. in 1970.

Environmental impact from wind systems is slight, although some questions remain to be answered. Virtually no heat and no air, water, or solid waste pollution are created in the process of harnessing the wind. There is some fear of weather modification caused by large numbers of wind generators operating in one area. Hazards to migrating birds should also be considered. Finally, it should be noted that huge towers with windmills on top would be visually unattractive.

Like direct use of sunlight, wind energy has received little attention from government and private research until very recently. The Energy Research and Development Administration plans to spend about $9 million on wind energy research in the 1976 fiscal year. The federal research program deals primarily with large-scale wind electricity-generating systems to supplement electric utility capacity. ERDA is now experimenting with a 100-kilowatt wind turbine and plans to design several larger machines. By 1980 the agency hopes to test several one-megawatt wind generators in existing power grids.

SOLAR - WOOD

Consumption of wood as a fuel reached a peak around 1870 in the U.S., providing about 840 billion kilowatt-hours of energy (*Energy: Sources, Use, and Role in Human Affairs*, Carol and John Steinhart). However, the percentage of our energy supplied by wood began declining by 1850. The U.S. burns today about one-fourth as much wood as was used in 1870, but that amount now supplies only a tiny fraction of our energy.

Wood can be an important source of energy for those who own wooded acreage. Properly harvested it can supply all of the power needed for heating and cooking. However, most Americans do not have this resource at their disposal.

Many other nations still rely on wood for most of their energy, and the rapid worldwide depletion of wood presents a serious crisis for these countries. It has been estimated that more than one-third of the world's population, or about 1.3 billion people, rely on wood as a primary fuel source ("The Other Energy Crisis: Firewood," Erik Eckholm). In addition to the hardship caused by the now insufficient supply of wood, widespread deforestation now occurring to harvest remaining supplies is causing dangerous erosion in many locations, threatening the future productivity of the land.

SOLAR - SEA THERMAL

The biggest collector of solar energy on earth is the oceans. Their waters are constantly heated and billions of gallons are evaporated into the atmosphere, later to become rain. More than two-thirds of the sun's radiation reaching earth is in an area 20 degrees north and south of the equator, and so more than two-thirds of this amount falls on oceans. These tropical ocean waters are heated to an average of about 85 degrees Fahrenheit but are separated by at least 2000 feet from huge quantities of much colder waters at temperatures of 35 to 38 degrees Fahrenheit. This temperature differential represents a constant source of energy.

The potential for capturing this power is largely unproven because little experimentation has been done. The theory is that a tubular device floated in the ocean could take in warmer water from the top to supply a boiler, and colder water from the bottom to cool a condensor. A secondary liquid such as ammonia would be circulated between the boiler and condensor to rotate a turbine.

Some scientists believe this kind of power generation could compete on an economic basis with nuclear plants, although the figures are little more than guesses at this point. Numerous questions remain: Can a design and materials be found that will resist the corrosive power of seawater? What impact on aquatic life or ocean cycles would the mixing of warm and cold water produce? How would the electricity be transmitted to shore? And is a net energy yield possible?

The Energy Research and Development Administration is planning to spend about $3 million in the 1976 fiscal year for research on these and other questions.

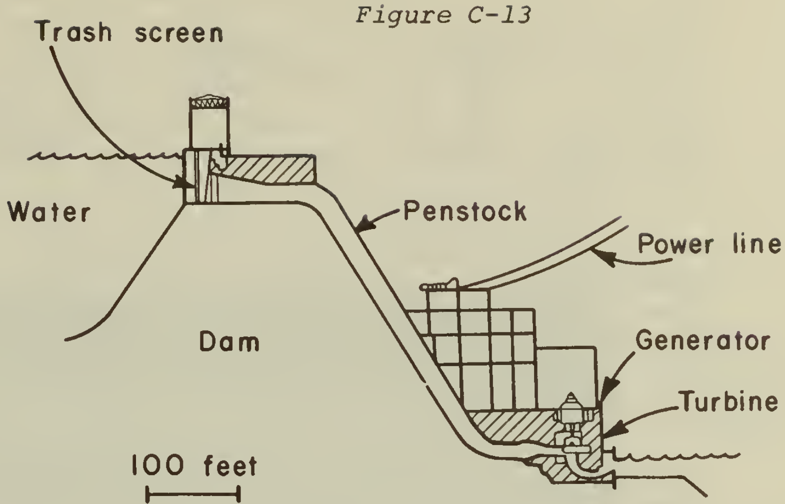
SOLAR - HYDRO

The power of moving water has long been used to supply energy. First used for mechanical energy in mills and factories, water power is now an important source of electricity. The operation of a hydroelectric power plant is quite simple: a river is dammed so that water collected behind the structure is at a higher level than the water in front of the dam. The water is then channeled down a pipe, turning generators which produce electricity (Figure C-13).

Most of the economically attractive hydroelectric sites in the U.S. have already been developed, although the total amount of potential hydroelectric capacity is almost double what is now in use. The U.S. currently has around 50,000 megawatts of hydroelectric generating capacity in operation, supplying about 15 percent of the nation's electricity. Few of the remaining potential hydroelectric sites are likely to be developed because they are too far from population centers, would be too expensive, or would not offer a favorable net energy yield.

Much of the rest of the world, on the other hand, has great water resources that can be easily developed for hydroelectric power. The largest potential exists in Africa, South America, and Southeast Asia.

Figure C-13



Components of a Hydropower System

Source: Creager and Justin, 1950

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

The environmental effects of hydroelectric plants are unique. Once constructed they provide a very clean and (in the case of dams on flowing rivers) efficient form of energy. No pollutants are emitted. However, dams for the projects flood often-valuable agricultural land and can cause serious damage to rivers. Thousands of acres of land are typically flooded above the dam. Below the dams the flow of rivers is often reduced to a small fraction of its original volume, changing the character of the river downstream for many miles. Fish and other aquatic life is often harmed as well, even though passageways for fish are built around many dams.

The absence of economically desirable sites and public pressure to halt any further destruction of rivers makes it unlikely that many more large-scale water power plants will be built in the U.S. There is still considerable opportunity for construction of home mechanical or electricity-producing water power units on streams, although the practicality of these small-scale systems is often diminished by irregular water flow.

SOLAR - TIDES

Another form of energy on earth, created largely by the gravitational force of the moon, is ocean tides. Although it is a very limited energy resource, certain bays or estuaries have a large enough tidal influx so that the water can be captured behind a dam, generating electricity in the same manner as hydroelectric plants. The main difference is that turbines in the unit can be reversed to produce electricity both when the tide enters and leaves. There are only about 15 locations in the world where the right conditions exist for tidal power production; only one of these is in the U.S.

Two major tidal power plants have been built in other countries, one 240 megawatt facility on an estuary of the Rance River on the Brittany coast of France, and the second at Kislaya Guba in the Soviet Union. The only potential U.S. site, on the Passamaquoddy Bay on the coast of Maine, has not been developed.

A number of disadvantages may hinder development of new tidal power sites. The facilities are unattractive, a hindrance to navigation, and may have adverse effects on aquatic life.

GEOTHERMAL POWER

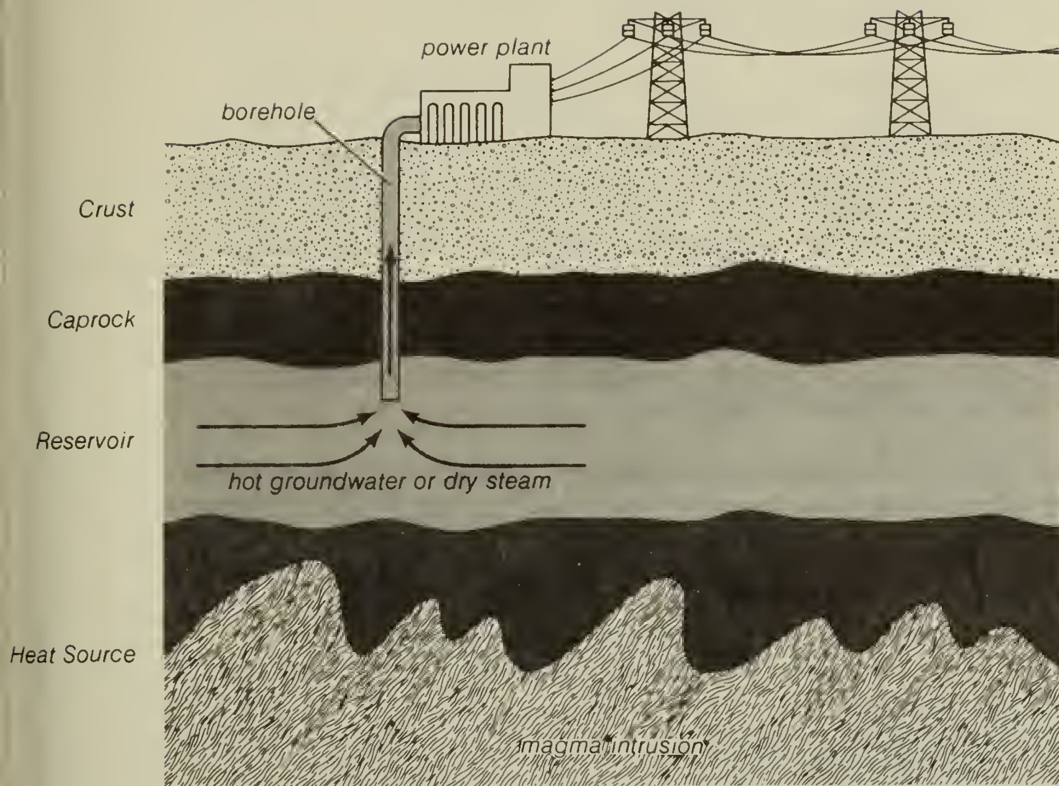
Geothermal energy is provided by the heat of the earth, which reaches 1000 degrees Celsius at the core. This heat is produced primarily by the decay of radioactive materials within the earth which have been inside the planet since it was created.

The principle of harnessing geothermal energy is fairly simple. Steam or hot water occasionally escapes from the earth in a usable form, but more frequently holes must be drilled to release it. Once captured, the heat can be used directly to warm buildings or in industrial processes, or, at its higher temperatures, can be used to generate electricity (Figure C-14).

The tremendous heat in the core of the earth dissipates gradually as it is conducted outward toward the surface. But geologic structure causes some of the heat to collect in pockets under intense pressure within a few thousand feet of the surface. When ground water seeps into these pockets the result is steam or hot water. Tapping the heat in these areas sometimes means the resource is used up, but often the area is reheated and thus represents a renewable energy source. The concentration and quality of geothermal energy varies widely.

This resource has significant energy potential for society but may also have serious drawbacks. Most problematic is the possibility that large-scale development of geothermal energy could alter subsurface geologic structure and prompt earthquakes.

Figure C-14



Schematic view of a dry (steam) or wet (hot water or brine plus steam) geothermal well and power plant.

(G. Tyler Miller, Jr., Living in the Environment, Wadsworth Publishing Co.)

Geothermal energy resources in the U.S. are located primarily in Alaska, Hawaii, and areas west of the Rocky Mountains. Some experts believe geothermal power could supply up to 30 percent of the total U.S. energy needs by the end of this century.

The U.S. has one large, operating, hot steam geothermal electricity plant in northern California, called the Geysers. A private power company, Pacific Gas and Electric, purchases the steam from two other partner companies and can produce about 200 megawatts of power at the facility. Boise, Idaho and Klamath Falls, Oregon have used geothermal energy for building heat since the turn of the century. Other areas in the U.S. are under study to determine their geothermal heat or electricity potential. The Soviet Union, Hungary, Italy, Iceland, New Zealand, and other nations, have used geothermal power extensively.

The concentration and power of geothermal energy varies according to the type of geologic deposit. Thus the net energy yield also varies, depending on the heat in the deposit, whether holes have to be drilled to remove it, whether pumping is necessary, and so forth.

In addition to unanswered questions about earthquakes or possible alteration of the earth's geology from geothermal energy development, there are some other environmental concerns. Some geothermal heat is very clean but steam and hot water resources found in the U.S. are typically laden with salts and dissolved or suspended minerals. Thus discharge of the water and steam can be a problem, although technology exists to control many of these pollutants. In addition, heat release from capturing geothermal energy is substantial, giving this source of energy a handicap when compared to direct solar and wind energy.

One fact that distinguishes geothermal energy from most other alternative sources is the extent that private business has invested money in research and development. A number of electric utility and oil companies are exploring its commercial potential. The federal government has made only a minor commitment; the Energy Research and Development Administration plans to spend $32 million in the 1976 fiscal year on research projects.

POWER FROM WASTES

Each year more than three billion tons of organic (from living matter) and inorganic wastes are produced in the U.S. This staggering quantity of refuse -- city garbage, animal manure, sewage sludge, crop waste, logging waste, and industrial waste -- has, until recently, been considered only a disposal problem.

But this garbage holds a wealth of recoverable minerals and organic products which can be used to produce energy (Figure C-15). As landfill sites to bury the garbage became harder to find, and as energy prices increase, recovering the resources from trash becomes an increasingly attractive way to deal with the disposal problem. Although the emerging technologies to accomplish this are important, it should be remembered that the best way to reduce our solid waste burden is to waste less in the first place.

There are four methods for recovering valuables from our garbage and releasing the energy stored in it: hydrogenation, pyrolysis, bioconversion, and direct burning of wastes in power plants. In all of these processes, the first step is to shred and separate the refuse. Roughly two-thirds of U.S. garbage is organic material and one-third inorganic. By weight, the trash is at least 20 percent water.

COMPOSITION OF MUNICIPAL REFUSE
MATERIALS AND CHEMICALS

Figure C-15

	Weight Percent of Total Refuse
Materials	
Paper	53.0
Food	8.0
Glass	8.0
Ferrous and nonferrous metals	7.0
Miscellaneous--grass clippings, rags, leather, etc.	24.0
Chemicals	
Volatile matter	52.7
Fixed carbon	7.3
Ash and metals	20.0
Moisture	20.0

Source: Anderson, 1972

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

Shredders reduce the refuse to small pieces so that magnets can be used to recover metals and air blowers can separate the lighter organic material from glass and other heavier inorganic material. The quantity of dry, organic material that is easily recoverable to produce energy is about 136 million tons (Figure C-16) which could provide about three percent of the energy consumed yearly in the U.S. (*Energy Alternatives: A Comparative Analysis,* Council on Environmental Quality).

Hydrogenation is the process of resource recovery which has received the most attention to date. Organic wastes are fed into a pressurized container and heated with carbon monoxide and steam at temperatures of 240 to 380 degrees Celsius. About two barrels of synthetic oil is created in the process for each ton of organic material. The fuel is fairly low in sulfur, the major pollutant, and has a heat value only slightly less than standard heating oil.

Pyrolysis is a simpler process in which dry organic material is heated in a vacuum at temperatures of about 500 degrees Celsius. More than one fuel product, typically oil and gas,

Figure C-16

QUANTITIES OF ORGANIC WASTE BY SOURCE
(DRY WEIGHT IN TONS PER YEAR)

Source	Reserve 1971 (Readily collectable)	Resource 1971 (Total amount generated)	Resource 1980 (Total amount expected)
Urban refuse[a]	71.0[b]	129	222
Manure	26.0	200	266
Logging and wood manufacturing	5.0	55	59
Agricultural crops and food wastes	22.6	390	390
Industrial wastes	5.2	44	50
Municipal sewage solids	1.5	12	14
Miscellaneous	5.0	50	60
TOTAL	136.3	880	1,061

Source: Anderson, 1972: 8, 13.

[a]Domestic, municipal, and commercial components of this waste amount to 3.5, 1.2, and 2.3 pounds per capita per day respectively.

[b]Based on the 100 largest population centers in the U.S.

(*Energy Alternatives: A Comparative Analysis*, *Science and Public Policy Program, University of Oklahoma*)

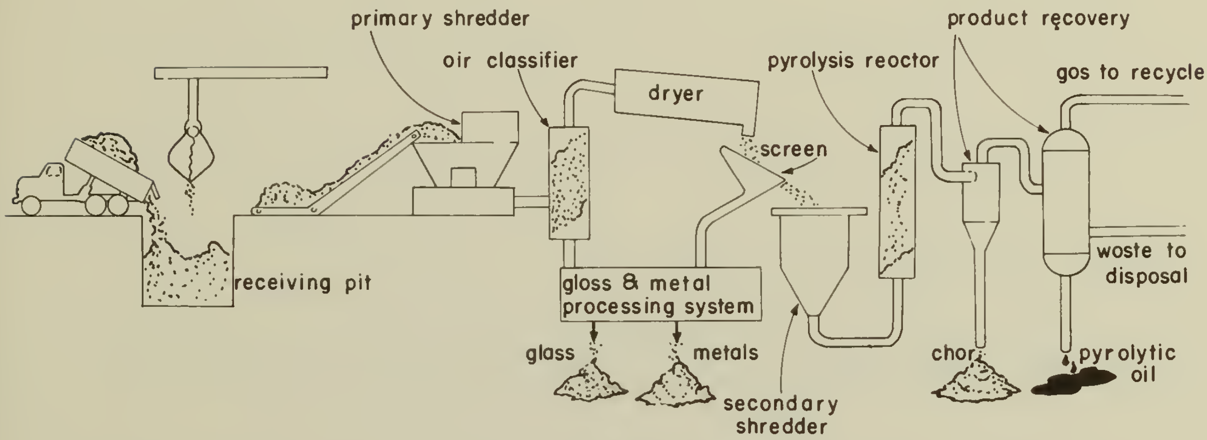
are produced, as well as a number of waste substances (Figure C-17). The synthetic oil and gas is very low in sulfur content but also has a lower heat value than the products of hydrogenation.

Bioconversion uses decomposition processes which occur naturally in the absence of oxygen. Organic material is broken down by microorganisms in a process called anaerobic digestion. Methane, or synthetic natural gas, is released in the process.

Finally, organic material separated from other garbage can be used directly in power plants to supplement oil or coal in the production of electricity. Organic material in U.S. garbage could replace between five and ten percent of yearly coal or oil demand (*Energy Alternatives: A Comparative Analysis*, Council on Environmental Quality).

All of these methods have promise but none is fully developed, and all have drawbacks. The biggest problem is that the garbage is so dispersed that monetary and energy costs of collecting it limit the potential. However, since our garbage must be disposed of in some fashion, these costs represent less of a disadvantage than collection costs for other energy sources.

Figure C-17



Garrett Pyrolysis System

Source: Garrett Research and Development Company, Inc.

(Energy Alternatives: A Comparative Analysis, Science and Public Policy Program, University of Oklahoma)

Similar pollution problems are created in hydrogenation, bioconversion, and pyrolysis. Polluted processing water is the biggest problem and must either be treated at the plant or sent to existing sewage treatment systems. Particulate matter must be removed before exhaust is released into the air. Bioconversion leaves a sludge which constitutes up to 40 percent of its original volume and which must be buried or given further treatment to recover its components. If the sludge is free of toxic materials it could be used as a high grade fertilizer for crops. Burning fuels directly creates about the same level of pollution as burning coal, and slightly more pollutants than are created by burning oil.

The net energy gain, if any, of these processes is still unknown. Hydrogenation plants are now being tested and federal funds have been used to subsidize pyrolysis plants in Baltimore and St. Louis. Bioconversion plants are still in the development stages. A processing plant is scheduled for completion in Wilmington, Delaware by 1977 to separate organic material from garbage to be used directly as a fuel for power plants.

D

APPENDIX

ADDITIONAL RESOURCES

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GROUPS ACTIVE IN ENERGY ISSUES/USEFUL PUBLICATIONS

ALLAGASH ENVIRONMENTAL INSTITUTE, Center for Research and Advanced Study, University of Maine, Portland, Maine 04102, (207) 773-2981, ext. 464. A New England clearinghouse for alternative technology information and land use research.

ALTERNATIVE ENERGY RESOURCES ORGANIZATION (AERO), 435 Stapleton Building, Billings, Mont. 59101, (406) 259-1958. An activist group which disseminates information on renewable energy technologies and publishes Sun Times, a monthly newsletter.

ALTERNATIVE SOURCES OF ENERGY, Route 2, Box 90A, Milaca, Minn. 56353, (612) 983-6892. An excellent source of information on all forms of renewable energy. Has a large borrow-by-mail library and several publications including a quarterly magazine, Alternative Sources of Energy. $5/year.

AMERICAN PETROLEUM INSTITUTE, 2101 L Street, N.W., Washington, D.C. 20037, (202) 457-7000. The trade association for the major oil companies. Has a wealth of free information providing the industry's perspective.

THE ATOMIC INDUSTRIAL FORUM, 1747 Pennsylvania Avenue, N.W., Washington, D.C. 20006, (202) 833-9234. Association representing nuclear power interests. Free publications relate the association's views on nuclear power.

BOSTON WIND, 2 Mason Court, Charlestown, Mass. 02129, (617) 241-7282. An all-volunteer organization offering lectures, classes (at the Cambridge School of Weston), wind information and rebuilt wind-generating units. Publishes a quarterly magazine. $10/year.

COUNCIL ON ECONOMIC PRIORITIES, 84 Fifth Avenue, New York, N.Y. 10003, (212) 691-8550. A non-profit research and publishing organization working on energy and environmental issues, among other things. Detailed environmental studies published on the electric utility and paper industries.

COUNCIL ON ENVIRONMENTAL QUALITY, 722 Jackson Place, N.W., Washington, D.C. 20006, (202) 382-1415. An office established to report to the President on environmental concerns. Publishes an excellent yearly report, Environmental Quality, summarizing significant developments relating to the environment.

EARTH METABOLIC DESIGN, Box 2016, Yale Station, New Haven, Conn. 06520, (203) 776-4921. Associates of Buckminster Fuller specializing in planning and education programs for the environment, human needs and resources.

ECOTOPE GROUP, 747 16th E., Seattle, Wa. 98112, (206) 322-3753, or 329-0922. A research and educational, non-profit organization working on appropriate technology, renewable energy, energy conservation and recycling. Has information on do-it-yourself solar water heater, solar greenhouse, methane digester, composting toilet, and many other energy-related things.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, Washington, D.C. 20545, (202) 376-4000. Federal agency whose primary responsibility is for research on new and traditional sources of energy. Annual reports, plans of action, and lists of other publications available upon request.

ENVIRONMENTAL ACTION, INC., 1346 Connecticut Ave., N.W., Suite 731, Washington, D.C. 20036, (202) 833-1845. A non-profit lobbying group which also works to oust representatives with poor environmental voting records. Publishes Environmental Action, a biweekly magazine with environmental news and trends and good energy coverage. $15/year.

ENVIRONMENTAL DEFENSE FUND, 162 Old Town Road, East Setauket, N.Y. 11733, (516) 751-5191. An important group of lawyers and scientists which specializes in environmental law and works on crucial environmental issues.

THE ENVIRONMENTAL POLICY CENTER, 3117 Pennsylvania Ave., S.E., Washington, D.C. 20003, (202) 547-6500. An effective environmental lobbying organization which stresses energy basics in its works.

FEDERAL ENERGY ADMINISTRATION, 12th and Pennsylvania Ave., N.W., Washington, D.C. 20461, (202) 566-7758. Formulates and implements policies to promote energy conservation, to improve the management of energy resources and to expand energy production. Publishes a free newsletter, Energy Reporter, as well as many brochures and studies.

FRIENDS OF THE EARTH, 529 Commercial Street, San Francisco, Cal. 94111, (415) 391-4270. A membership lobbying group very active in energy and environmental issues. Publishes Not Man Apart, a biweekly newsletter dealing with a wide range of environmental issues. $10/year or $20 membership.

INFORM, 25 Broad Street, New York, N.Y. 10004, (212) 425-3550. A non-profit research and publishing group involved in research on energy and environmental issues, among other topics. Has published several very good books. Will send a publications list upon request.

INSTITUTE FOR LOCAL SELF RELIANCE, 1717 18th Street, N.W., Washington, D.C. 20009, (202) 232-4108. A non-profit research organization working to counter over-centralization and unnecessarily large production systems. Has published several good books and will send a full publications list upon request. Publishes a monthly newsletter, Self-Reliance. $6/year.

LEAGUE OF WOMEN VOTERS OF THE UNITED STATES, 1730 M Street, N.W., Washington, D.C. 20036, (202) 296-1770. A very active women's membership organization which lobbies Congress and offers to the public a wide range of educational materials on energy and environmental matters, as well as other subjects.

MOTHER EARTH NEWS, P.O. Box 70, Hendersonville, N.C. 28739, (704) 692-4256. An informative bimonthly magazine which provides do-it-yourself information on alternative energy systems, gardening, and other ways to increase self-sufficiency. 6 issues/year. $10/year.

NATIONAL CENTER FOR APPROPRIATE TECHNOLOGY, P.O. Box 3838, Butte, Mont. 59701, (406) 723-6533. A non-profit corporation operating on an initial grant from the Community Services Administration to provide technical assistance and grants to low income projects. Provides small grants to potential developers of appropriate technology projects, as well as access to good information, outreach services, and research.

NATIONAL COAL ASSOCIATION, 1130 17th Street, N.W., Washington, D.C. 20036, (202) 628-4322. The trade association for the major coal companies. Offers free information from the industry's perspective.

NATIONAL RECREATION AND PARK ASSOCIATION, 1601 N. Kent Street, Arlington, Va. 22209 (703) 525-0606. A non-profit membership organization devoted to improving and expanding the nation's park, recreation and leisure services and resources. Conducts the Park Project on Energy Interpretation.

NATURAL RESOURCES DEFENSE COUNCIL, 917 15th Street, N.W., Washington, D.C. 20005, (202) 737-5000. A non-profit, environmental organization with extensive involvement in nuclear power and other energy issues. Has won numerous key environmental cases. Publishes a newsletter quarterly.

NEW ALCHEMY INSTITUTE, P.O. Box 432, Woods Hole, Mass. 02543, (617) 563-2655. A private research organization working on ways to make available low-cost alternative energy technologies. Offers a bibliography of material relating to its work and conducts workshops on Saturdays during the summer.

NEW ENGLAND SOLAR ENERGY ASSOCIATION, P.O. Box 121, Townshend, Vt. 05353, (802) 365-4084. A clearinghouse for information on solar power in New England, composed of 14,000 members from the manufacturing, building, and consuming communities.

NEW MEXICO SOLAR ENERGY ASSOCIATION, c/o Aubrey Owen, Ghost Ranch Conference Center, Abiquiu, N.M. 87510, (505) 685-4436. A clearinghouse for information on solar energy in the southwest.

RAIN, 2270 N.W. Irving, Portland, Ore. 97210, (503) 227-5110. An information access and referral center for people interested in all aspects of appropriate technologies. Publishes _Rain_, a newsletter giving information resources plus interesting comments and ideas. $10/year (ten issues).

REDE CORP, Box 212, Providence, R.I. 02901, (401) 751-7333. A profit-making company working under contract and selling intermediate technology energy devices and systems. Sells a Darrieus wind generator, a novel thermal-syphoning solar shower, and efficient design ideas.

RESOURCES FOR THE FUTURE, 1755 Massachusetts Avenue, N.W., Washington, D.C. 20036, (202) 462-4400. A non-profit research organization which specializes in independent studies on resources, supplies and options. Publishes _Resources_ three times yearly, a newsletter summarizing its research. Free.

SCIENCE, 1515 Massachusetts Avenue, N.W., Washington, D.C. 20036, (202) 467-4418. Published weekly by the American Association for the Advancement of Science. Technical but very readable journal which focuses on environmental problems. $20/year for non members.

SCIENTIFIC AMERICAN, 415 Madison Avenue, New York, N.Y. 10017, (212) 754-0550. Excellent monthly magazine for citizens who want to keep abreast of science news. $10/year.

SCIENTISTS' INSTITUTE FOR PUBLIC INFORMATION, 560 Trinity Avenue, St. Louis, Mo. 63130, (314) 863-6560. Especially concerned with the question of the relationship between energy and employment and places new emphasis on the economic implications of environmental issues. Publishes an excellent environmental magazine ten times yearly, Environment. $12.75/year.

SOLAR AGE, Box 2245, Grand Central Station, New York, N.Y. 10017, (212) 873-1153. A monthly magazine presenting clearly-written technical information and stories about owner-built homes and equipment from a solar perspective (including such indirect solar sources as wind, wood and water). $20/year.

TOTAL ENVIRONMENTAL ACTION, INC., 12 Church Hill, Harrisville, N.H. 03450, (603) 827-3374. A profit making professional group involved in alternative energy architectural design, workshops, consultation and publications. A full publications list, slide kits, workshops and reprints available upon request.

UPLAND HILLS ECOLOGICAL AWARENESS CENTER, 2575 Indian Lake Road, Oxford, Mich. 48051, (313) 628-5116. Provides hands-on opportunities for people to learn about possible alternative solutions for the future by seeing alternative, non-polluting sources of energy in operation. Publishes a bulletin periodically as well as publications on energy-related topics.

VOLUNTEERS IN TECHNICAL ASSISTANCE (VITA), 3706 Rhode Island Avenue, Mt. Ranier, Md. 20822, (they prefer that you write). An active, internationally-oriented appropriate technology organization. Has a wealth of resources on alternative energy topics and self-sufficient lifestyles, including bibliographies, books and how-to designs.

ZERO POPULATION GROWTH, 1346 Connecticut Ave., N.W., Washington, D.C. 20036, (202) 785-0100. Dedicated to reducing population in the U.S. and the world. Is a strong lobbying force and publishes a newsletter, National Reporter, ten times yearly. $5.50.

ZOMEWORKS, P.O. Box 712, Albuquerque, N.M. 87103, (505) 242-5354. A place where active and resourceful people are at work on design, drafting, consulting, fabrication, research and development in solar energy and structural systems, with emphasis on passive solar design. A list of publications, including plans for devices, available upon request.

FILMS

Ark, 1971, Barr Films, P.O. Box 5667, Pasadena, Ca. 91107, (213) 793-6153. Drama about what the future may hold for mankind if the implications of environmental problems are not faced. Grades 5-12. 20 min. Color. $275 (contact Barr Films about possible loan or rental).

Challenge of the Future, 1975, Energy Research and Development Administration, ERDA Technical Information Center Film Library, P.O. Box 62, Oak Ridge, Tenn. 37830, (615) 483-8611, ext. 34161. Presents the energy supply/demand problems facing our society and discusses future options. Good photography. Reflects traditional approach but also covers alternatives. Adults. 28½ min. Color. Free on loan.

An Ecosystem: A Struggle for Survival, 1975, National Geographic Films, c/o Modern Film Rentals, 315 Springfield Avenue, Summit, N.J. 07901, (201) 277-6303. Includes a curriculum package and provides understanding of the dynamics of the Gir Forest ecosystem in India. All ages. 22 min. Color. $310 ($20 rental).

Energy -- Critical Choices Ahead, 1974 - revised 1977, Department of Commerce, Room 2203, 14th and Constitution, N.W., Washington, D.C. 20320, (202) 377-3040. Technical film which gives an excellent presentation of growth in demand for energy during the remainder of the 20th century. Adults. 26 min. $125 (available on short-term free loan from DOC satellite field offices).

Energy for the Future, 1974, Encyclopaedia Britannica Educational Corp., 1925 N. Lynn Street, Arlington, Va. 22209, (703) 528-0667. Energy supply efforts ranging from finding cleaner ways of burning coal to utilizing the tremendous heat buried below the earth are covered. Well done presentation of industry's approach to finding solutions. Adults. 17 min. Color. $220 ($14 rental).

Energy and Life, 1974, Modern Learning Aids, Division of Wards Natural Science, P.O. Box 1712, Rochester, N.Y. 14603, (716) 467-8400. Introduces basic physical laws, energy transfer among organisms, and nicely ties together the concepts of energy and environment. Grades 8-college. 20 min. Color. $225.

Energy and Matter, 1967, National Film Board of Canada, McGraw-Hill Book Company, Film Division, 1221 Avenue of the Americas, New York, N.Y. 10020, (212) 997-1221. Introduces important energy concepts, primarily the "sun as source of it all" concept. Film is in bad condition. Grades 4-8. 9 min. Color. $120 ($10 rental).

Farming is Farming, The Small Farm in America, 1976, Douglas Miller and Carol Ramsey, Ram Films, 200 Lovers Lane, Steubenville, Ohio, 43952, (no phone listed). Portrays a story about small farm alternatives and is told by farmers of all ages. Designed as a tribute to Miller's grandfather, a small farm owner and professor of agriculture at Ohio State, this is an upbeat film contrasting currently popular large-scale and energy-intensive farming methods to old, small-scale animal and labor intensive farming methods now being reapplied experimentally in small farms from Iowa to Vermont and West Virginia. All ages. 45 min. Color. $450 ($45 rental).

Man: The Incredible Machine, 1975, National Geographic Films, c/o Modern Film Rentals, 315 Springfield Avenue, Summit, N.J. 07901, (201) 277-6303. Reveals the human body to be a wonderfully complex, efficient machine for living. Is accompanied by a teacher's guide. All ages. 28 min. Color. $390 ($20 rental).

Mzima: A Portrait of a Spring, 1973, McGraw Hill Book Company, Film Division, 1221 Avenue of the Americas, New York, N.Y. 10020, (212) 997-1221. A beautiful film presenting a unique opportunity to observe closely the intricacies of abundant life in this jungle spring. Hippopotamus, crustaceans, fish, birds, otters and crocodiles are all parts of this story. All ages. 53 min. (two part-film). Color (excellent photography). $700 ($35 rental).

The New Alchemists, 1974, Canadian Film Board, Benchmark Films, Inc., 145 Scarsborough Road, Briarcliff Manor, N.Y. 10510, (914) 762-3838. Regrettably dated, an interesting film about the ventures of a pioneering group in Massachusetts' Cape Cod area, working with energy-saving, intensive agriculture and integrated systems. All ages. 29 min. Color. $395 (ask Benchmark about rental or loan).

The Other Way, 1975, Time-Life Multimedia, 100 Eisenhower Drive, Paramus, N.J. 07652, (201) 843-4545. Author and economist, E.F. Schumacher ("Small is Beautiful") explains how the concept of intermediate technology developed. A good introduction to ideas for less energy-intensive ways of using energy. All ages. 26 min. Color. $335 ($35 rental).

Plankton, 1976, National Geographic Films, c/o Modern Film Rentals, 315 Springfield Avenue, Summit, N.J. 07901, (201) 277-6303. Shows how planktonic plants and animals fit into complex food chains and displays their incredible variety. Accompanied by a teacher's guide. All ages. 12 min. Color. $150 ($12 rental).

Pond-Life Food Web, 1976, National Geographic Films, c/o Modern Film Rentals, 315 Springfield Avenue, Summit, N.J. 07901, (201) 277-6303. Protists, tadpoles, snails, dragonflies, and fish illustrate food webs (numerous food chains exist and overlap creating a web) in a pond. Accompanied by a teacher's guide. All ages. 10 min. Color. $150 ($12 rental).

Powers of Ten, 1968, Charles Eames, Pyramid Films, P.O. Box 1048, Santa Monica, Ca. 90406, (213) 828-7577. Presents a linear view of our universe from the human scale to the sea of galaxies, then directly down to the nucleus of a carbon atom. All ages. 8 min. Black and white (produced as a "sketch film"). $150 ($20 rental).

Protists: Threshold of Life, 1974, National Geographic Films, c/o Modern Film Rentals, 315 Springfield Avenue, Summit, N.J. 07901, (201) 277-6303. Fascinating look into the world of tiny organisms called protists. Accompanied by a teacher's guide. All ages. 12 min. Color. $150 ($12 rental).

The Solar Generation, 1976, Stuart Finley, Inc., 3428 Mansfield Road, Falls Church, Va. 22041, (703) 820-7700. A good, comprehensive introduction to the possibilities of solar energy technologies for current and future applications. Tends to neglect potential of low-technology approaches. Accompanied by a teacher's guide. All ages. 21 min. Color. $350 ($35 rental).

The Sun Watchers, 1969, McGraw Hill Book Company, Film Division, 1221 Avenue of the Americas, New York, N.Y. 10020, (212) 997-1221. A good film which aptly demonstrates the power of the sun and its influence on past, present and future civilizations. Also covers methodologies and instruments used to learn more about our solar system. Adults. 30 min. Color. $425 ($20 rental).

A Thousand Suns, 1974, Gilbert Film Associates, Seattle, Wa. 98105 (no phone listed). A visual statement about the concept of an energy ethic. Discusses various ways we invest energy and questions waste resulting from those investments. All ages. 9 min. Color. Price unknown.

Toast, 1975, Daniel Hoffman, Earth Chronicles, 811 N.W. 20th, Portland, Ore. 97209, (503) 224-3807. Nicknamed "Burnt Toast," this film reflects the concept of net energy. Tracks the materials and energy invested in the production and disposal of one piece of burnt toast. Accompanied by a teacher's guide. All ages. 13 min. Color. $175 (no rental but preview for purchase is possible).

When the Circuit Breaks, 1975, Federal Energy Administration, Film Scheduling Center, 2323 New Hyde Park Road, New Hyde Park, N.Y. 11040, (516) 488-3810. Explains how America's energy problems developed and how to resolve them. Investigates both additional resource development and alternative energy sources. All ages. 21 min. Color. Free on loan.

Which Energy, 1976, Stuart Finley, Inc., 3428 Mansfield Road, Falls Church, Va. 22041, (703) 820-7700. Shows aspects of the multi-billion dollar breeder development program, previews coal's future, explains the current research into fusion energy, and also covers alternatives to these high-technology approaches, including energy conservation. Accompanied by a teacher's guide. Not good for young ages. 23 min. Color. $350 ($35 rental).

ACTIVITIES PACKETS AND TEACHING AIDS

Create Tomorrow ... Today, An Energy Awareness Program of the Washington State Superintendent of Public Instruction,1974 Available from ERIC Document Reproduction Service, P.O. Box 190, Arlington, Virginia 22210.

Guidelines, activities, and instructional tools offered for use by teachers and administrators. Stock number ED-089-993. $3.32/copy or 76¢ for microfiche.

Energy-Environment Materials Guide, Kathryn E. Marvine and Rebecca E. Cawley, National Science Teachers Association, 1742 Connecticut Ave., N.W., Washington, D.C. 20009, 1975. Part of a set, including the Energy-Environment Mini-Unit Guide and the Energy-Environment Source Book (below).

Readings representing a sampling of current energy literature. References divided into four separate bibliographies: Readings for Teachers, Readings for Students (grades 8-12), Readings for Students (grades 5-9), and Readings for Students (grades K-6). $2 each of $9/set of all 3 NSTA books, plus postage.

Energy-Environment Mini-Unit Guide, Steve Smith, Editor, Julianne Crocker and James V. DeRose, National Science Teachers Association, 1742 Connecticut Ave., N.W., Washington, D.C. 20009, 1975. Part of a set, including the Energy-Environment Materials Guide (above) and the Energy-Environment Source Book (below).

Collection of seven series of plans for lessons which focus on several related energy-environment concepts, relationships and student objectives aimed at teachers in grades K-12. $3 each or $9/set of all 3 NSTA books, plus postage.

Energy-Environment Source Book, Volume 1 - Energy, Society, and the Environment. Volume 2 - Energy, its Extraction, Conversion, and Use. John Fowler, National Science Teachers Association, Washington, D.C. 20009, 1975. Part of a set, including the Energy-Environment Materials Guide and the Energy-Environment Mini-Unit Guide (above).

Information on energy and on its interaction with society and the environment, written for teachers who wish to incorporate such material into their teaching. $4 each or $9/set of all 3 NSTA books, plus postage.

The Energy and Environment Glossary, Energy and Man's Environment, Inc., 0224 S.W. Hamilton, Suite 301, Portland, Ore. 97201, 1975. Part of a set, including Energy and Man's Environment Activity Guide (below).

An organized collection of many of the energy and environmental terms that are of increasing importance in our lives. $16/set. Limit of 100 outside of Northwest service area.

Energy and Man's Environment Activity Guide, Energy and Man's Environment, Inc., 0224 S.W. Hamilton, Suite 301, Portland, Oregon 97201, 1975. Part of a set, including The Energy and Environment Glossary (above).

An organized collection of many of the energy and environmental terms that are of increasing importance in our lives. $16/set. Limit of 100 outside of Northwest service area.

Energy Quotient Index, Honeywell, Inc., Honeywell Plaza, Minneapolis, Minnesota, 55408, 1975.

A short energy conservation test. Free.

The Household Energy Game, University of Wisconsin, Sea Grant College Program, 1800 University Ave., Madison, Wisc. 53706, 1974.

A 20-page booklet designed to show how much energy your household uses and how you can conserve energy and save money. Free.

Kilowatt Counter, Alternative Sources of Energy, Route 2, Box 90A, Milaca, Minn. 56353, 1975.

A consumer's guide to energy concepts, quantities, and uses, designed as a basic tool to help in the understanding of the broad concept of "energy". $5/4 issues, or $2/1 issue.

The Lifestyle Index, Center for Science in the Public Interest, 1779 Church Street, Washington, D.C. 20036, 1974.

Tells how individuals can calculate their energy expenditures and compare them with energy and materials consumed by average citizens in other countries. $1.50 prepaid.

Miniature Environments, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, 1973 revised edition.

Tells how to build miniature environments for living things, using low-cost materials and equipment so as to discover by personal contact the workings of diverse environments. 80¢. Stock Number 2416-00069.

Ten-Minute Field Trips - A Teacher's Guide, Using the School Grounds for Environmental Studies, Helen Ross Russell, J.G. Ferguson Publishing Company, 111 East Wacker Drive, Chicago, Ill. 60611, 1973.

Written about environmental study. Excellent collection of activities designed to help teachers learn along with their pupils, even in urban settings. Most suitable for upper elementary grades, but adaptable to all ages. $5.35.

Tips for Energy Savers, Federal Energy Administration, Consumer Information, Public Docuemnts Center, Pueblo, Colorado 81009, 1975.

Useful suggestions on how to save energy in the home, on the road, and in the marketplace. Free.

STATE ENERGY OFFICES

Alabama Energy Management Board
Executive Building, Suite 203
312 Montgomery Street
Montgomery, Alabama 36104

Alaska State Energy Office
Mackay Building
338 Denali Street
Anchorage, Alaska 99501

Fuel Allocations Section
Office of Economic Planning and Development
1645 West Jefferson
Room 428
Phoenix, Arizona 85007

State Energy Office
325 National Old Line Building
Little Rock, Arkansas 72201

Energy Resources Conservation and Development Commission
1111 Howe Avenue
Sacramento, California 95825

Office of the Governor
State Capitol
Denver, Colorado 80203

Department of Planning and Energy Policy
20 Grand Street
Hartford, Connecticut 06115

Division of Emergency Planning and Operations
Department of Public Safety
P.O. Box C
Delaware City, Delaware 19706

State Energy Office
108 Collins Building
Tallahassee, Florida 32304

State Energy Office
7 Hunter Street
Room 145
Atlanta, Georgia 30334

Department of Planning and Economic Development
P.O. Box 2359
Honolulu, Hawaii 96804

Office of Energy
300 North 6th Street
Boise, Idaho 83720

Division of Energy
Department of Business and Economic Development
222 South College
Floor 1
Springfield, Illinois 62706

Indiana Energy Office
803 State Office Building
Indianapolis, Indiana 46204

Energy Policy Council
300 Fourth Street
Des Moines, Iowa 50309

Kansas Energy Office
503 Kansas Avenue
Room 241
Topeka, Kansas 66603

Kentucky Department of Energy
Capital Plaza Tower
Frankfort, Kentucky 40601

Division of Natural Resources and Energy
Department of Conservation
P.O. Box 44275
Baton Rouge, Louisiana 70804

State Fuel Allocation and Conservation Office
State House
Augusta, Maine 04330

Maryland Energy Policy Office
301 West Preston Street
Baltimore, Maryland 21201

Energy Policy Office
One Ashburton Place
Room 1413
Boston, Massachusetts 02108

Michigan Energy Office
Public Service Commission
Department of Commerce
5th Floor, Law Building
Lansing, Michigan 48913

Minnesota Energy Agency
740 American Center Building
160 East Kellogg Boulevard
St. Paul, Minnesota 55101

Fuel and Energy Management Commission
1307 Woolfolk State Office Building
Jackson, Mississippi 39205

Missouri Energy Agency
P.O. Box 1309
Jefferson City, Missouri 65101

Energy Advisory Council
c/o Lt. Governor's Office
Capitol Building
Helena, Montana 59601

State Office of Petroleum Allocations
Department of Revenue
P.O. Box 94841
Lincoln, Nebraska 68509

Public Service Commission
198 South Carson
Carson City, Nevada 89701

Governor's Council on Energy
3 Capitol Street
Concord, New Hampshire 03301

State Energy Office
101 Commerce Street
Newark, New Jersey 07102

Energy Resources Board
P.O. Box 2770
Santa Fe, New Mexico 87501

Emergency Fuel Office
Tower Building
Empire State Plaza
Albany, New York 12223

Energy Division
Department of Military and Veterans Affairs
215 East Lane Street
Raleigh, North Carolina 27611

Office of Energy Management
P.O. Box 1817
Bismarck, North Dakota 58501

Energy Emergency Commission
30 East Broad Street
25th Floor
Columbus, Ohio 43215

Department of Energy
4400 North Lincoln Boulevard
Suite 251
Oklahoma City, Oklahoma 73105

Department of Energy
528 Cottage, N.E.
Salem, Oregon 97310

Governor's Energy Council
Capitol Building
Harrisburg, Pennsylvania 17120

State Energy Office
State House
Providence, Rhode Island 02903

Energy Management Office
1429 Senate Street
Columbia, South Carolina 29201

Office of Energy Policy
State Capitol
Pierre, South Dakota 57501

State Energy Office
250 Capitol Hill Building
Nashville, Tennessee 37219

Governor's Energy Advisory Council
c/o Division of Planning Coordination
411 W. 13th Street
Austin, Texas 78701

Department of Natural Resources
538 Capitol
Salt Lake City, Utah 84114

State Energy Office
State Office Building
110 State Street
Montpelier, Vermont 05602

Virginia Energy Office
823 East Main Street
Room 300
Richmond, Virginia 23219

Conservation Information Center
Department of Emergency Services
4220 East Martin Way
Olympia, Washington 98504

Fuel and Energy Office
1262½ Greenbrier Street
Charleston, West Virginia 25305

Office of Emergency Energy Assistance
4510 Regent Street
P.O. Box 5368
Madison, Wisconsin 53705

Mineral Development Division
Department of Economic Planning and Development
720 West 18th Street
Cheyenne, Wyoming 82002

Oil and Gas Conservation Commission
P.O. Box 2640
Casper, Wyoming 82601

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NATIONAL RECREATION AND PARK ASSOCIATION