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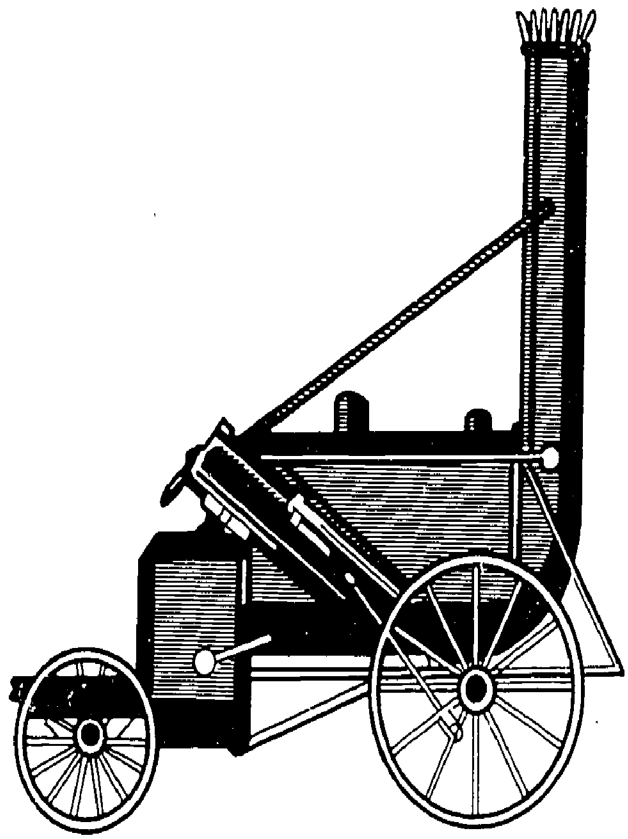
ABSTRACT

Presented are five articles on the history of energy and how it has come to play an important role in people's lives. Designed for the junior high school language arts curriculum, each article is scored for readability according to the Gunning Fog Index. By referring to these ratings, a teacher can provide students with increasingly more challenging reading material. Among these articles are: (1) How Does Energy Contribute to Our Way of Life, and (2) Energy and Doubling Time. Also included are a glossary of energy terms and a list of related readings. This is the second in a series of four books on energy. (WB)



BOOK II

EASY ENERGY READER

HISTORY OF ENERGY

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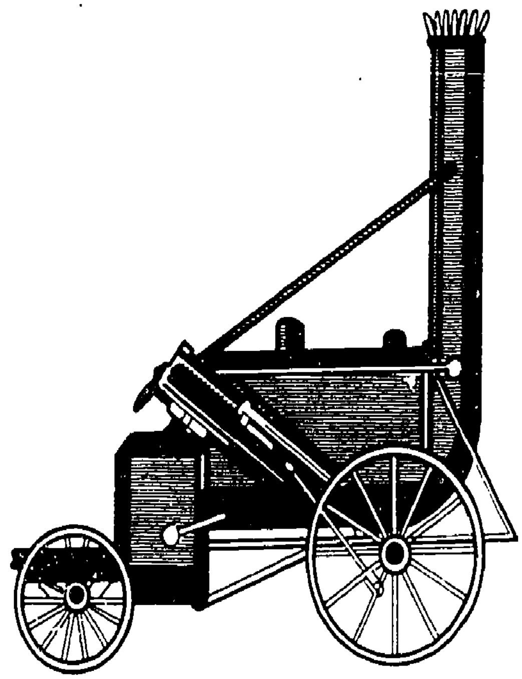


BOOK II
EASY ENERGY READER

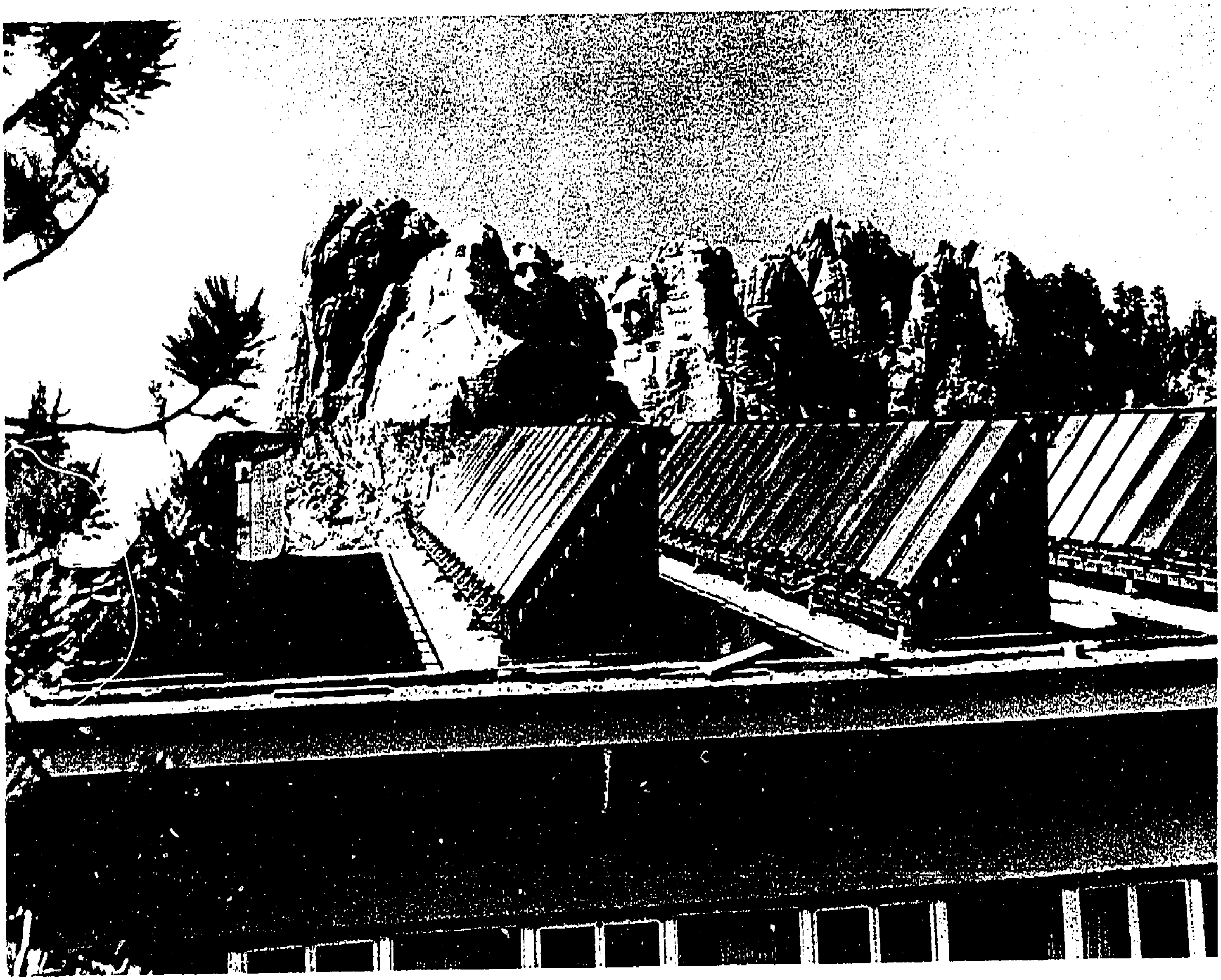
HISTORY OF ENERGY

Prepared by
Information Planning Associates, Inc.
Under Contract No. EU-78-C-01-6497
for
The Department of Energy
Office of Consumer Affairs
The Education Programs Division
Washington, D.C. 20585

ons earliest sources of energy

BOOK 2

THE HISTORY OF ENERGY



Solar collectors on the Visitor's Center roof at Mount Rushmore, South Dakota, provide most of the building's cooling and heating requirements.

PREFACE
TO THE INSTRUCTOR

As current issues have come to play a greater ole in the language arts curriculum, the need for p-to-date materials on the technical and social oundations of these issues has increased. This has een a particular problem for the instructor of unior-high and middle school-students, who may nd that debate manuals and source books do not dequately consider the reading skills of the ounger reader. Nowhere is this more evident than n the area of energy. The *Easy Energy Reader* as therefore been developed to help fill this infor-nation gap as well as to direct instructors and tudents toward other useful materials.

To facilitate reading, the *Reader* has been ivided into four volumes. Book 1 discusses what nergy is, where it comes from, how it is stored, nd how it is transported; Book 2 talks about the istory of energy and how it has come to play such n important role in our daily lives; Book 3 ana-yzes the causes of the nation's current energy-elated problems and offers possible solutions; and ook 4 provides an insightful look at future nergy technologies.

The readings in these books were selected n the basis of their currency, their importance to he student's understanding of energy issues, and heir readability. The articles chosen provide a ide range of readability levels, which will accom-odate the wide range of abilities found in middle hool and junior high classrooms.

The Gunning Fog Index, with slight modifications, proved to be the most useful in scoring entries for the *Reader*. We elected to apply the index to a 300 word sample rather than the 100 word sample cited in the instructions to ensure the accuracy of the results. Also, certain three-or-more syllable words were not counted, as the formula suggests, because of their frequent recurrence and the obvious ease of the word, such as energy, conservation, etc. On occasion, it was necessary for the researcher to use his discretion in adding a point or subtracting a point because of the importance average sentence length plays. If it was noticed that sentences in certain articles were rather short but the text complicated, a point was added in most cases. Whereas if the reverse was true, i.e., long sentences but uncomplicated text, a point was then subtracted, thus producing a more accurate readability level for that article.

The formula that we used works as follows[1]:

1. Select a sample of 300 words.
2. Find the average sentence length.
3. Count the number of words of three syllables or over. (Do not count proper nouns, easy compound words like "bookkeeper," recurring familiar words such as "automobile" or "energy," or verb

[1] Editor's Note: Adapted from *Toward World Literacy*, by Frank C. Laubach and Robert S. Laubach, Copyright © 1960, Syracuse University Press.

forms in which the third syllable is merely the ending, as, for example, "directed.") Divide by 3.

4. Add average sentence length to the number of "hard (three-or-more syllable) words."
5. Multiply the sum by .4 (four-tenths). This gives the Fog Index.

The equation for steps 4 and 5 is:

Number of "hard words" + Average number of words per sentence × .4 = The Fog Index

The table below lists in increasing order of difficulty the articles that are included in Book 2, *The History Of Energy*.

TITLE	FOG INDEX*
Energy and Doubling Time	7.5
"Burning Springs"—Natural Gas	8.5
Current Events—Electricity	8.5
Some Atomic History	8.5
How Does Energy Contribute to Our Way of Life?	9.5

* Rounded to nearest .5

By providing an array of readings in the four books of this series, we hope to make the *Reader* more useful to the teacher who wishes to individualize instruction or to develop a curriculum of increasingly more challenging reading. Students can be encouraged to increase their energy vocabularies by studying the glossary at the back of each book.

Many of the readings lend themselves to problems in distinguishing between fact and opinion, and may be useful as background for mini-debates. Role-playing activities in which students represent the positions of consumer, environmentalist, or electrical utility executive could also be drawn from most of the articles, or current newspaper editorials might be analyzed according to whether the *Reader's* authors would agree or disagree. Students might also be encouraged to write their own letters to the editor in reply.

Simulated news broadcasts and interviews could be prepared using this material, or the readings could be used as preparation for interviewing people from the community, such as representatives of the solar equipment industry, utilities, alternate energy activists and school personnel responsible for reducing energy use.

There are of course many other uses for the *Reader*, both as part of the regular curriculum and as a resource for independent study. For example, it provides a number of good models of echnical writing, a skill which is usually not aught until the student's senior year or college, if hen. Yet educators have observed that the best ime (the "teachable moment") to help students ommunicate about a subject is while they are dis-overing their interest in it rather than after they ave become immersed in its jargon and short-and. We hope the *Reader* can help achieve that objective. We would appreciate your ideas and comments and those of your students. Please address them to:

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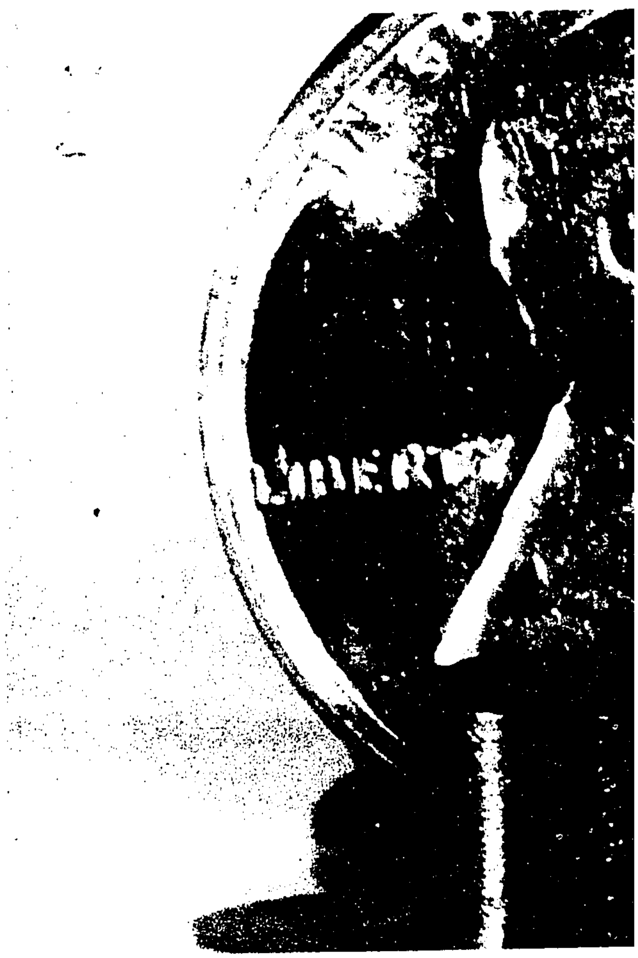
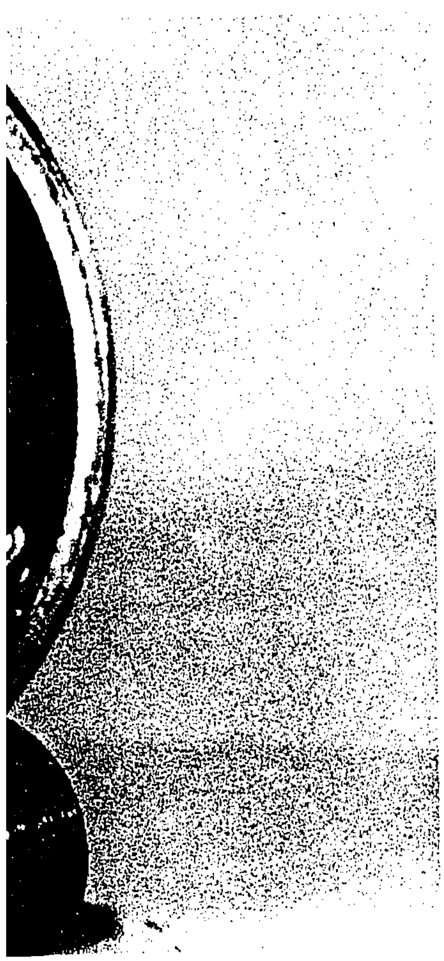
Office of Consumer Affairs
U.S. Department of Energy
Washington, D.C. 20585

A chemical technician examines a "button"

TABLE OF CONTENTS



eighing one-thirtieth of an ounce, this fuel pellet f
ıal.



ılent energy value of 566 pounds of

INTRODUCTION

Just Imagine . . .

Imagine that it is night, and everything around you that runs on electricity has stopped forever. The lights. The heating and air conditioning. The television and radio. The refrigerator. Street lights and stop lights and clothes washers and dryers, stoves and toasters and hair dryers and stereos. What else has stopped? Could you pick up the phone to call someone and find out why everything that uses electricity has stopped?

How would you see? How would you stay warm in winter and cool in summer? How would you send messages and be entertained at home? How would you wash and dry your clothes and cook your food?

You would look for other ways to do these things; you would look for other kinds and sources of energy. You might find that you could get along just fine without many machines. Just because your electric toothbrush wouldn't buzz any more would not mean you had to stop brushing your teeth. And you might discover that you could do without a clothes dryer by letting the sun do the drying.

Try to think of other ways to replace electricity in your daily life.

It Wouldn't Be The First Time

Just about everyone knows that there was a time when we had no electric heat for our homes. It simply didn't exist. Yet people stayed dry and warm by burning oil. Many homes are still heated that way.

What about the days *before* oil? We burned coal. Many homes in the world still do. A lot of factories do, too. And coal, like oil and gas, is now burned to make electricity. And how did we keep warm before coal? We burned wood.

In fact, all through history we have found ways to keep ourselves warm and dry and to cook our food and to make enough light to see by. We have used many, many sources of energy.

This Book Is About Energy

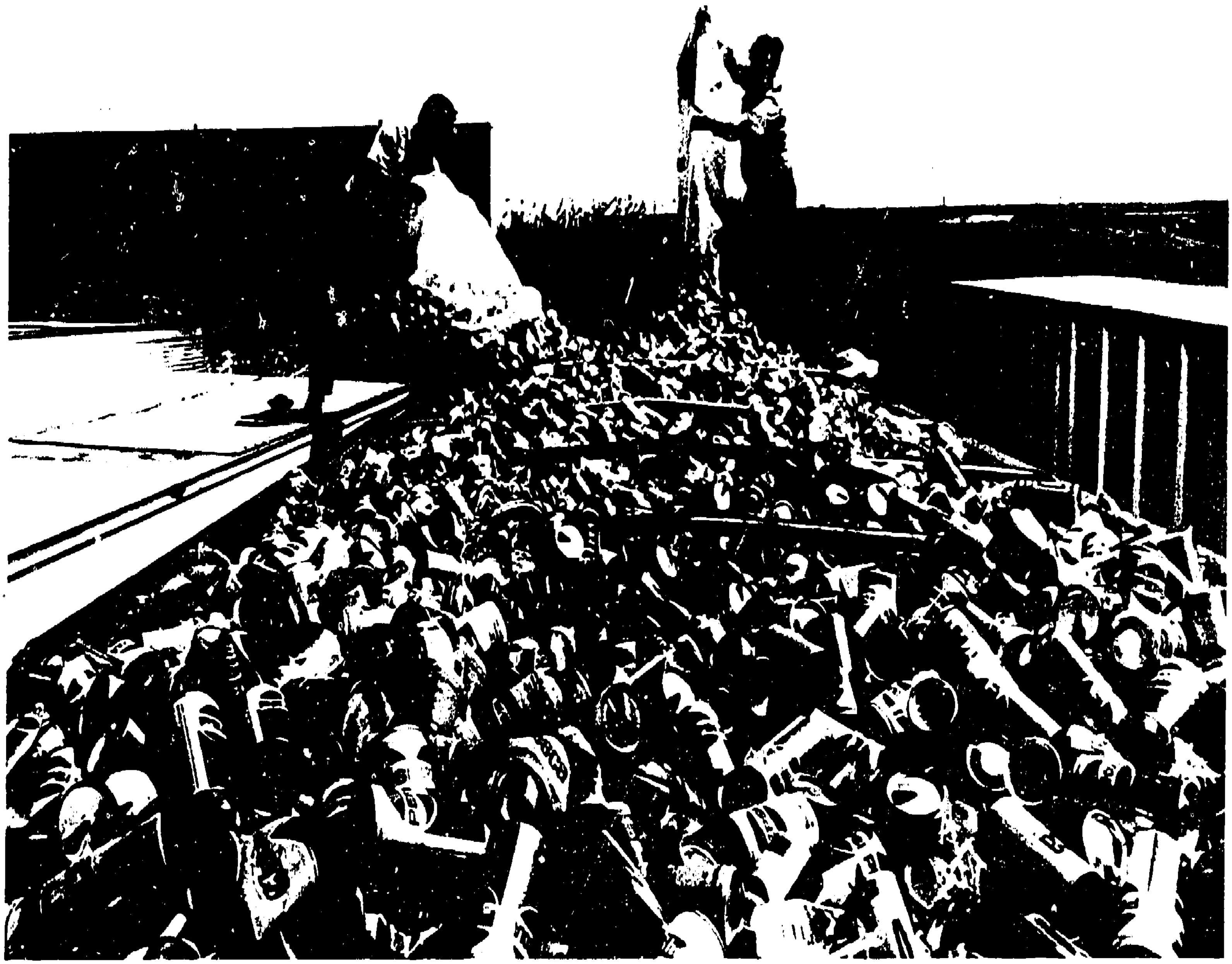
This book is about the energy that runs machines and lights and furnaces and electric blankets and automobiles. It is about how we get energy from many sources, and what we can do when one source or several sources begin to run out. This book will help you understand why it is important not to waste energy, as well as point out some of the things we can do to save it. It will help you think about what *you* want to do to help make sure there will always be plenty of energy for all of us.

This Book Has Many Authors

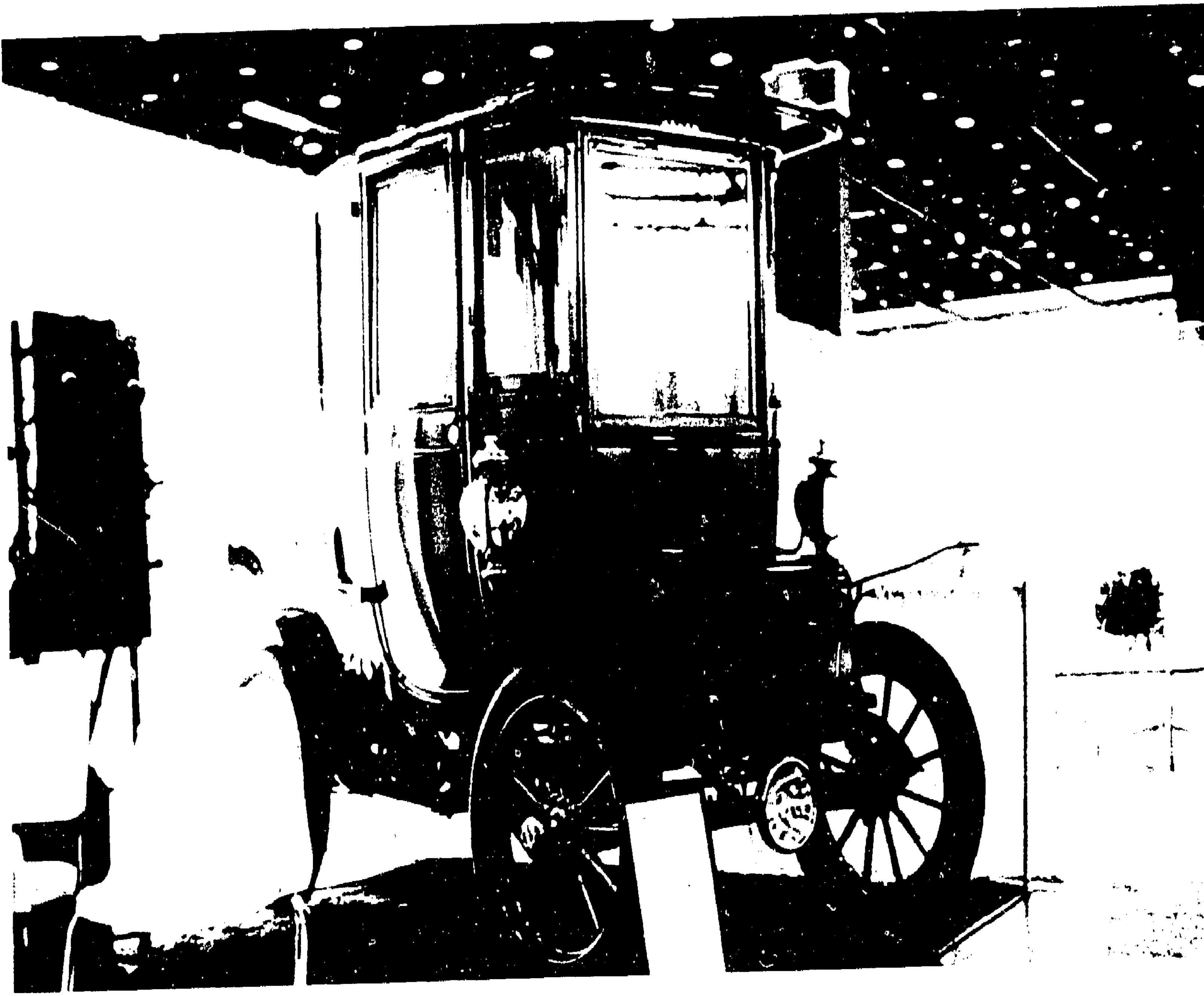
The chapters of this book come from many different books and magazines. Each chapter is about a different part of the subject of energy: what it is, where it comes from, why some kinds becoming very expensive, how different people l about it, and many other topics. Remember, se are not official opinions of the United States partment of Energy. Instead, the chapters will e you an idea of what many different people saying about energy. You will see that people agree about how to make sure there will always enough energy. But everyone agrees that each us will have to make important choices about ergy. That is why we hope you will find this ok useful.

is Book Can Be Used In Many Ways

This book can help you learn to read about ergy. Some chapters are harder than others, and ur teacher can suggest the chapters to start with d the ones to read next. (There is also a list of energy words at the end of this book to help you build your vocabulary.) When you find a chapter you especially like, you may want to read the book from which it came. The first page of each chapter will tell you its source. Then look in the list of suggested reading for information that will help you find the original book or magazine. If it is not in your school library, your librarian may be able to help you get it from another library. Another way to use this book is to close it up every so often and look around you at what energy does. Think about which uses of energy are really necessary and which are not. Think about what you would be willing to give up for a gallon of gasoline or the comfort of an air-conditioned building. Then, when you are finished with this book, pass it on to a friend. By putting our energies together, we can help to assure a bright energy future for everyone.



Recycling aluminum cans consumes less energy than the production of new cans from raw material.



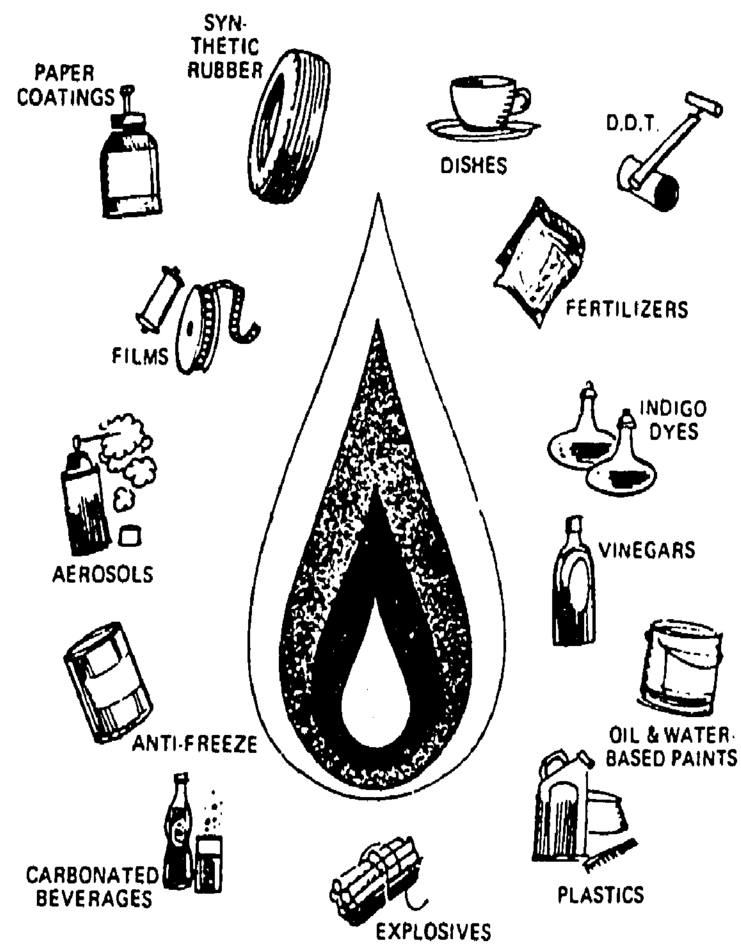
"BURNING SPRINGS"– NATURAL GAS

By Elaine Israel

William Hart, a young gunsmith, was fas-
nated by the bubbles of gas rising from a creek
ar his home in Fredonia, New York. Sometimes
e bubbles seemed to burn. In 1821, Hart built a
nall well above this "burning spring," as his
ighbors called it. Within four years, his well
pplied enough gas to light several nearby shops.
art's curiosity led to the start of the natural gas
dustry.

Natural gas was a late bloomer as far as
ssil fuels are concerned. Although people knew
at it could be used as an energy source, it was
ngerous to transport because it is so highly flam-
able. About fifty-five years ago, a new type of
eel pipe made it possible to better transport the
s. Now natural gas is a major energy source
r heating and cooling homes, as well as for
oking.

Early natural gas deposits, like those in
edonia, were shallow. Over the years, geologists
ve had to search deeper and deeper in the ground
r gas. It is sometimes found together with crude
, but is most often in deposits by itself. In its
ginal state, natural gas is odorless and color-
s. When people say they "smell gas," they are
lly sniffing a man-made smell given the gas so
ks can be found and stopped.



Gas is not only used to cool and heat homes. It has a thousand and one other uses. Here are just a few of them.

Figure 1. Natural Gas Has Many Different Uses

Most of the natural gas in the United States today can be found in five states. They are Texas, Louisiana, Alaska, Oklahoma, and New Mexico.

But the search for natural gas fields still goes on. In the frozen wilderness, 600 miles above the Arctic Circle, teams of scientists are testing ice floes and animal tracks. They are plotting the route of a 3,000-mile gas pipeline[1] to consumers in eastern Canada and the United States. The pipe may go through land so bleak that no people and few animals inhabit it. But it contains one of the largest gas fields ever discovered, so even nature cannot halt the search.

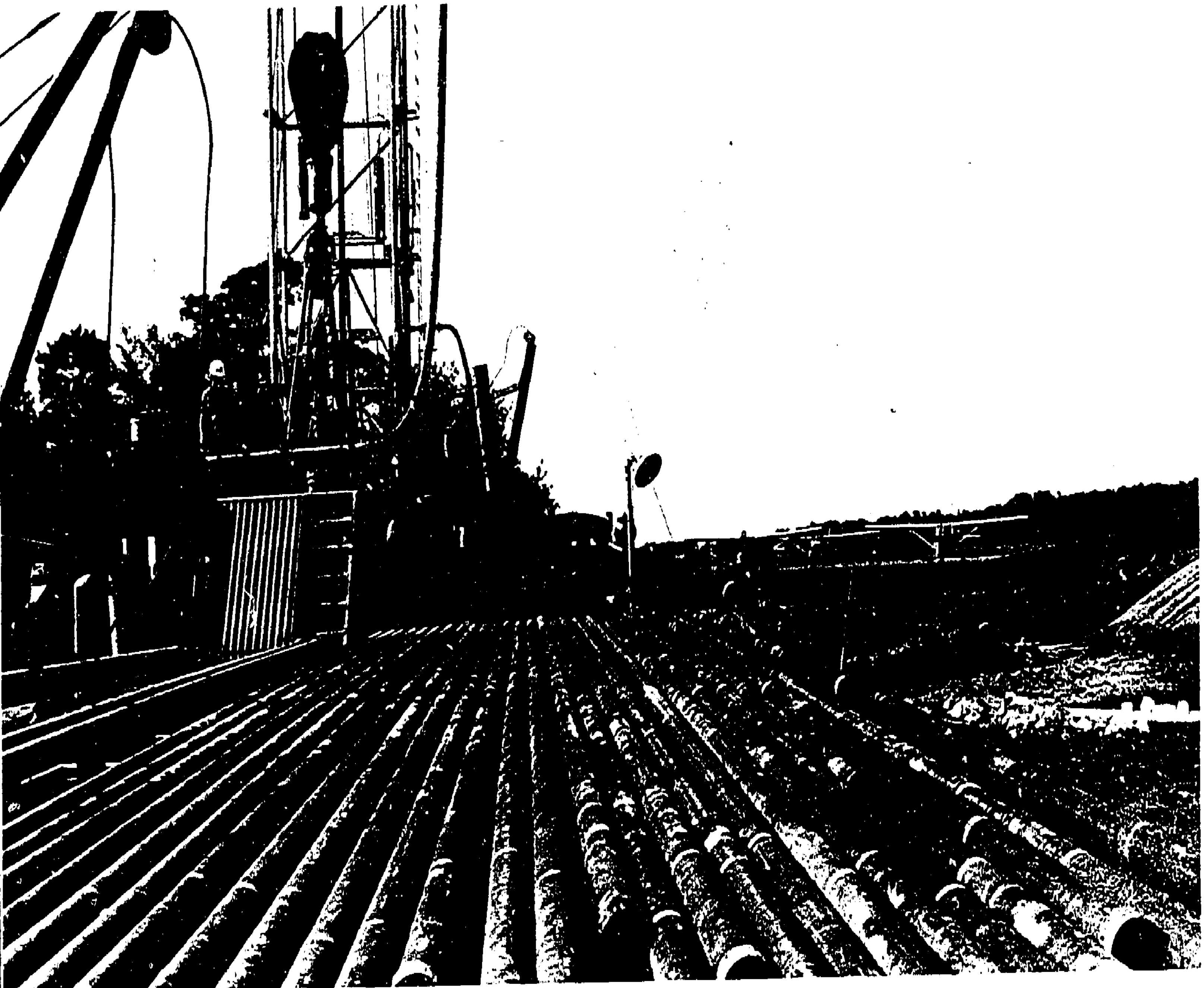
Long-distance pipelines from other areas already carry gas to homes across America. If you live in the western United States, the Southwest, or parts of the Middle West, you are more likely to have a gas-heated home than someone who lives in the Northeast. If you live in Hawaii, you're in the only state without natural gas pipelines. Pipelines are difficult and costly to construct through swamps and over mountains, and especially under oceans.

Natural gas takes care of about one-third of our nation's energy needs. If we keep using it at our present rate, it will last for only another fifty years. It may run out in your lifetime.

Natural gas is clean, convenient to use, and cheap. What would people do without it?

[1] ...s Note: As this article was published in 1974, this number may no longer be accurate.

sured extraction project near Houston, Texas.



CURRENT EVENTS–ELECTRICITY

By Elaine Israel

Just a flick of a switch, and electric current ›es on. Every time we do this, we are using fossil ıels.

Electricity is produced by generators—huge achines which manufacture electric power for se by electric utility customers like you and your mily. The generators are fueled by steam, which made by burning fossil fuels. Originally, coal as burned. But it has been replaced by oil, which cheaper and cleaner.

The night of November 9, 1965, made milons of Americans realize how much they depend electricity and how they take it for granted. ıat night, a power plant failure cut off the elecicity to most of the northeastern United States ıd parts of Canada.

The big blackout was frightening. However, caused few people to change their electricity ıbits. People went right on using—and wastg—as much electricity as they had before.

How did Americans become so dependent on ectricity? In the 1960's, the electric utility comınies had urged consumers to "go electric." The l-electric home, for example, became a symbol of ıccess to some people. Now many of these people e paying high electric bills. Electric appliance anufacturers told us that, to keep up with our iends and neighbors, we "needed" electric ankets, electric shoe shiners, electric this and ectᴇʀɪᴄıt.

How many of these electric appliances do you have at home? Electric companies figure electricity used by a measurement called the kilowatt hour (kwh). In the United States, an average family air conditioner uses up 860 kwh a year. A dishwasher uses 363 kwh; a clock, 17 kwh; and a frostless refrigerator uses up 1,217 kwh.

Figure 1. Electrical Appliances Are Energy Eaters

Some consumer groups charge that utility panies and manufacturers encouraged the use of electricity, though they were aware an gy shortage was ahead.

Now, in the 1970's, the utility companies are prepared for the huge demand on their equip- t. Power lines are overloaded, especially dur- the summer when an increasing number of air itioners are in use. The result is more brown- , which means less power is delivered so that s are dimmed, and blackouts.

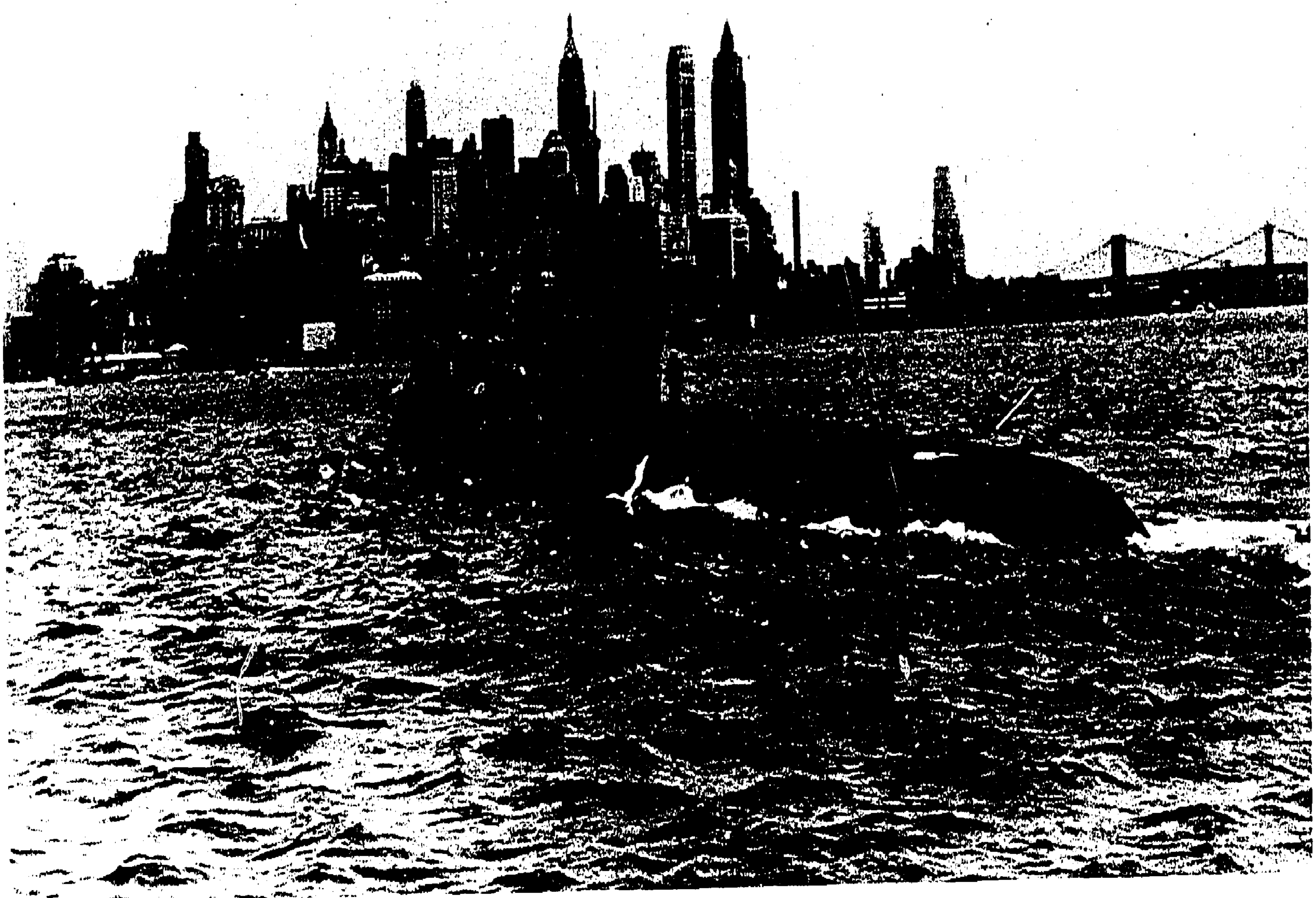
The nation's electric companies say they t to build new plants—but most of these would uclear plants. Many individuals are concerned t the effects on the environment and on people ch plants are built. So there has been a delay uilding.

In addition, the utilities, faced with the fuel shortage and rising fuel prices, have increased their rates. So consumers are getting less electricity for more money!

Some utilities asked city and state governments for permission to burn coal instead of oil. Coal may pollute the environment, but it is less expensive and less scarce than oil.

Government officials replied that they would consider allowing the use of coal, if oil becomes scarce again.

We may not have to return to the widespread use of coal. And we certainly won't be forced to use the old time fuels, like whale oil. But every flick of the switch should remind us that we must seriously look for alternatives to fossil fuels as sources of energy.



The submarine Nautilus, seen here sailing into New York Harbor, was the world's first nuclear ship.

SOME ATOMIC HISTORY

By Boy Scouts of America

If you are to fulfill your pioneer role in this atomic age, you will need to understand atomic energy . . . So, let's see what it's all about, and where it began.

500 BC Greece

Democritus was our first atomic thinker. He figured out that if you take a piece of any particular matter such as copper and cut it in two then divide it again and again and again, you will finally reach the point where the remaining particle of copper is so small that you cannot divide it any more and still have anything. That final particle, Democritus argued, is an atom (*atomos*, meaning something that can't be cut). Everything in the world, he reasoned, must be composed of atoms of one kind or the other.

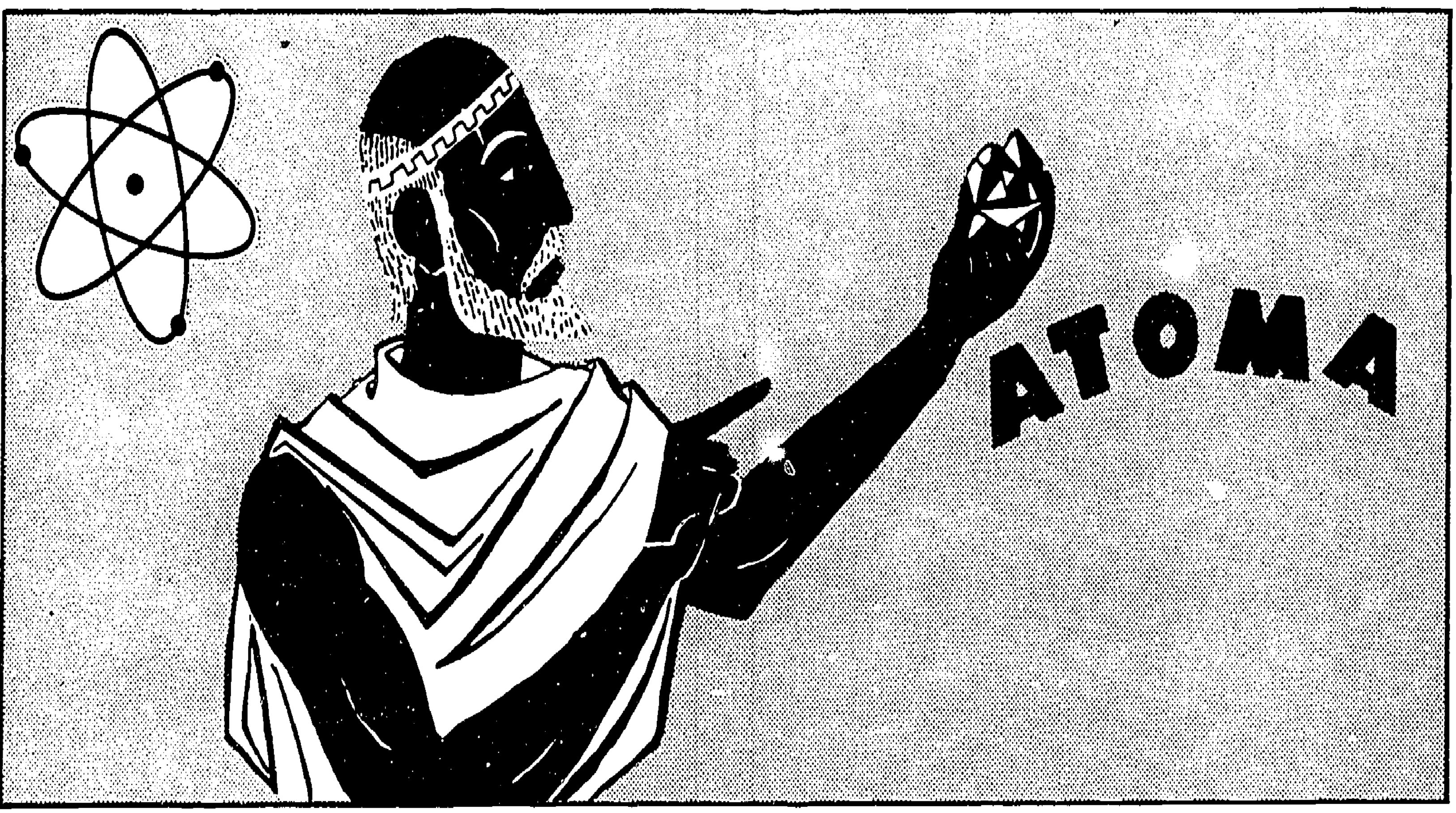
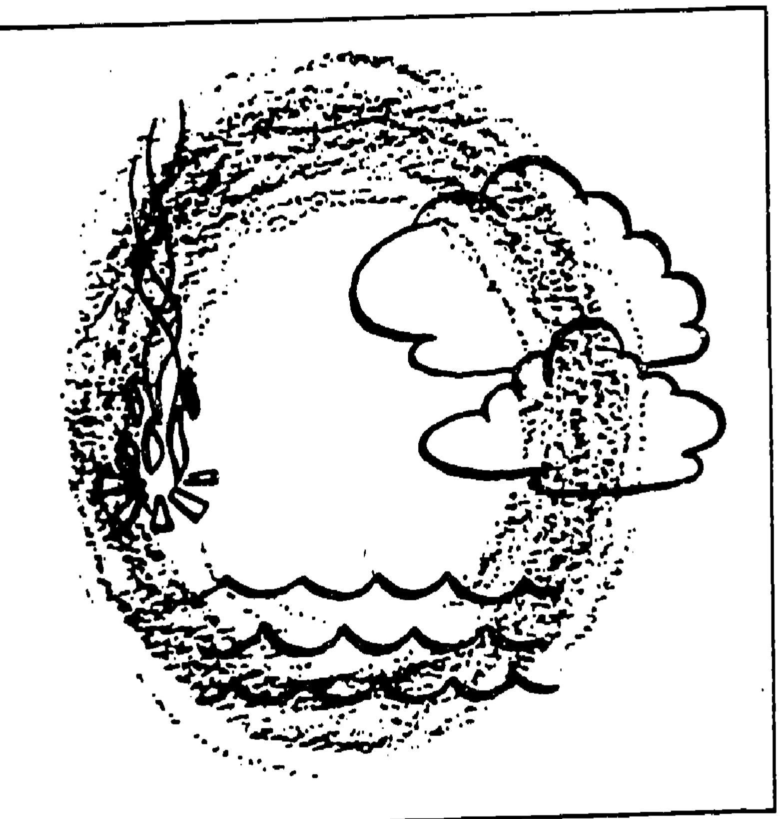


Figure 1. Atomic Theory Was Born in Ancient Greece

50 BC Greece

Aristotle advanced the theory that every-hing is composed of earth, water, air, and fire, ut in various combinations of heat, cold, wetness, nd dryness. Most men seized and held onto this dea for nearly 2,000 years. Democritus' idea was lmost forgotten.

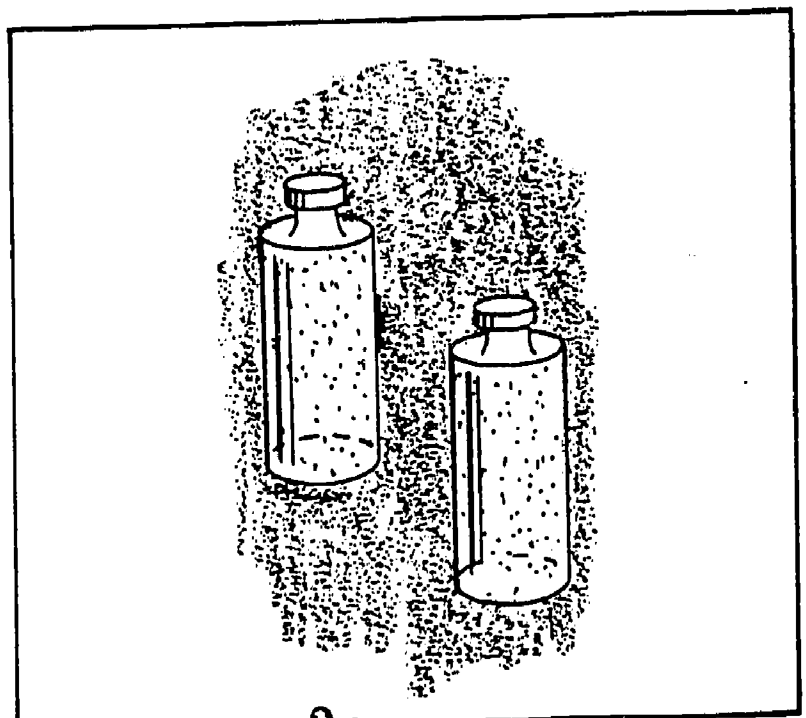


1808 England

John Dalton developed the atomic theory of ma... s a firm principle rather than just a philo-so... guess. He discovered that all atoms in a given element are exactly alike, and that whenever two or more elements are combined to form a compound, they must always be combined in the same proportion.

1811 Italy

Amadeo Avogadro predicted that, if different gases with the same temperature and pressure are placed in bottles of equal size, each bottle will contain an equal number of molecules. This is known as Avogadro's Law. He also found that although a water molecule contains eight times as much oxygen as hydrogen by weight, actually it is a combination of one atom of oxygen with two of hydrogen (H_2O).

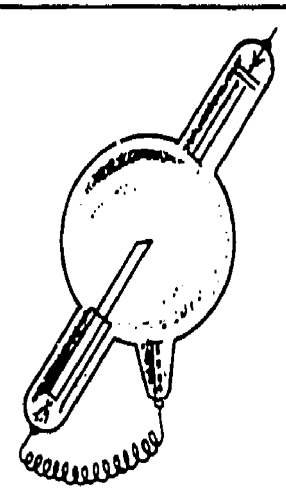


1895 England

Sir Joseph John Thompson used cathode ray experiments to prove the existence of tiny particles or electrons, weighing only 1/1840th as much as an atom of hydrogen. He reasoned that the electric current flowing through a wire is a stream of electrons being transferred successively from atom to atom (like a relay race baton).

1895 Germany

Wilhelm Konrad Roentgen discovered that, when the cathode of a vacuum tube is connected to a high voltage electric current and the tremendous negative charge built up on the cathode is directed across the tube to a positively charged metal plate, the electrons striking the plate cause it to *release energy* in the form of *radiation*. Roentgen did not know exactly how these rays were produced, so he called them X-rays.



1896 France

Antoine Henri Becquerel discovered the effect of radioactive uranium ore on photographic plates. When the ore fogged his plates even on a dark day, he discovered that it was *radioactive*. Although Becquerel did not realize it, the atoms in the uranium ore were actually changing themselves into atoms of other elements by giving off radiation.

1903 France

Pierre and Marie Curie isolated radium by refining huge quantities of pitchblende, an ore of uranium. The radium had more than 900 times the radioactivity of uranium. They, along with Becquerel, received the Nobel Prize that year.

1905 Germany

Albert Einstein discovered his theory of relativity. In part it reads $E=mc^2$ or energy equals mass times the square of the speed of light. The effect of this theory was to show that matter and energy are equivalent. This gave other scientists the tip-off that materials like radium could be an almost endless source of power.

1911 England

Sir Ernest Rutherford discovered the atomic nucleus by firing alpha particles at gold atoms. He was able to measure its infinitely small size and prove it to be positively charged. Scientists had previously separated alpha, beta, and gamma rays by shooting them through a magnetic field at a fluorescent screen. The magnet bent the positively charged alpha rays in one direction, bent the negatively charged beta rays in the opposite direction, and didn't affect the gamma rays at all.

1913 Denmark

Niels Bohr worked out a mathematical explanation for the probable structure of the atom. He reasoned they must be something like miniature solar systems with electrons orbiting the nucleus at speeds that cancel their attraction toward the nucleus. The speeding electrons form *shells* around the atom. His experiments with those of Rutherford showed the relatively great amount of empty space between the nucleus and the nearest shell.

1913 England

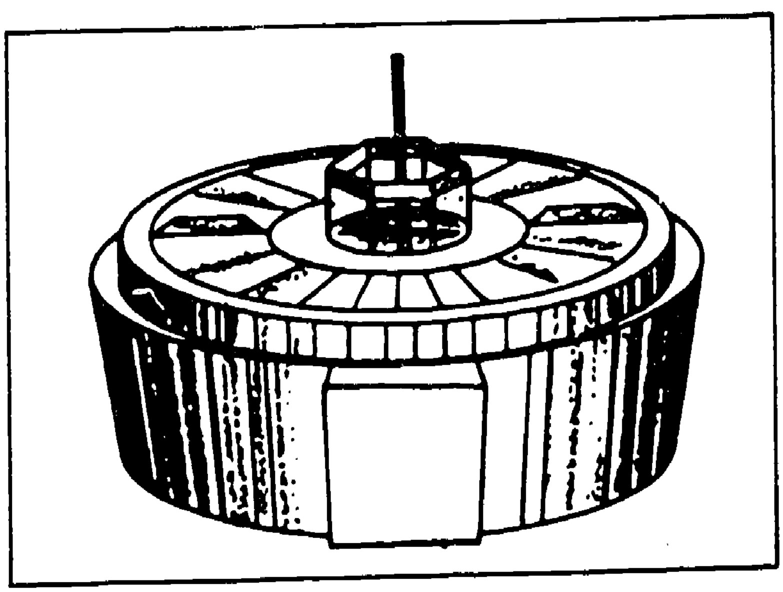
Experiments of Frederick Soddy, Francis William Aston, and Sir Joseph John Thomson resulted in the discovery of *isotopes*, atoms of the same element having different weights. This led to the assignment of mass numbers to each element as a part of its identification, as in uranium^{238}, so that the various isotopes could be identified. For instance, hydrogen occupies three places on the atomic scale with the number 1 for itself, 2 for deuterium, and 3 for tritium (its isotopes).

1930 England

Sir James Chadwick studied a new type of radiation and decided that it must consist of a stream of particles coming from the nucleus of atoms, with each particle weighing about the same as a single proton, but having no electric charge. These neutrally charged particles he named *neutrons*.

1930 United States

Ernest Orlando Lawrence developed the *cyclotron* to control and speed up atomic particles. He also perfected the means of aiming the particles. His development opened up the new field of high-energy physics.



1932 Italy—United States

Enrico Fermi used neutrons as bullets to pierce the atomic nucleus. Having no charge, they are not repelled or attracted by protons or electrons.

1938 Germany

Otto Hahn and Fritz Strassmann split the uranium atom but did not understand that this had taken place.

1939 Germany

Lise Meitner and Otto Frisch announced the theory of nuclear fission and thus explained the Hahn-Strassmann experiment.

1940 United States

Neptunium and plutonium discovered by Glenn T. Seaborg and associates.

1942 United States

The first atomic chain reaction, directed by Enrico Fermi and associates, occurred in a controlled reactor at the University of Chicago.

1945 United States

The first atomic bomb was exploded in New Mexico on July 15, and the first atomic bomb used in warfare fell on Hiroshima, Japan, on August 6.

1946 United States

The Atomic Energy Commission was established by Congress.

1951 United States

The first significant amount of electricity was produced from atomic energy at a testing station in Idaho.

1952 United States

First detonation of a thermonuclear bomb, at Eniwetok Atoll in the Pacific Ocean.

1953 United States

President Eisenhower announced the U.S. Atoms for Peace program.

1954 United States

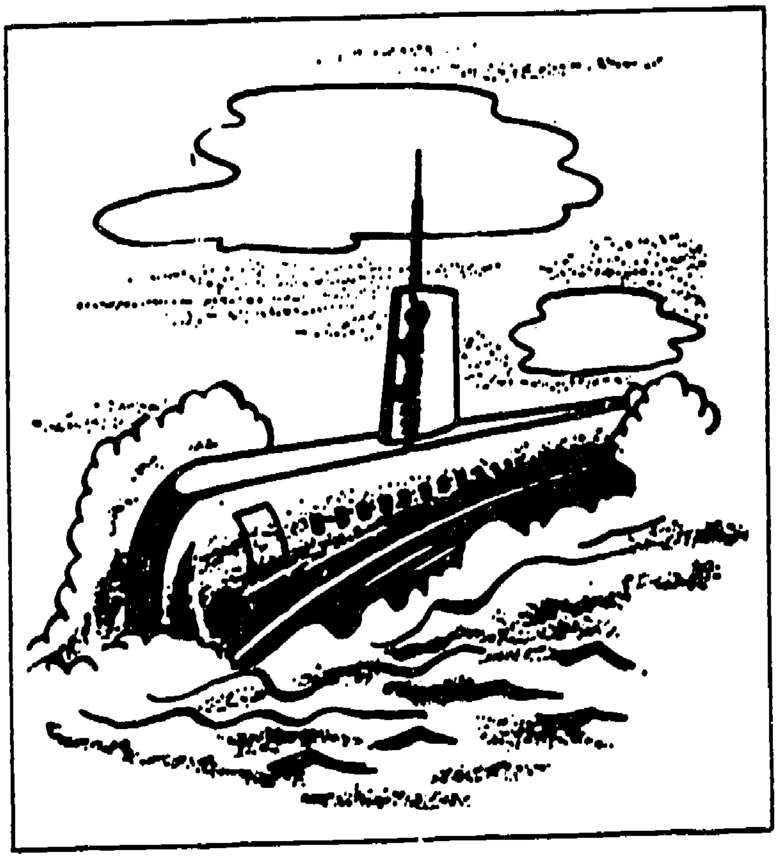
The first nuclear-powered submarine, the *Nautilus*, was commissioned.

1957 United States

First full-scale centralized civilian nuclear power plant began operation at Shippingport, Pa.

1959 United States

First nuclear-powered cargo vessel, the NS *Savannah*, was built at Camden, N.J.



1961 United States

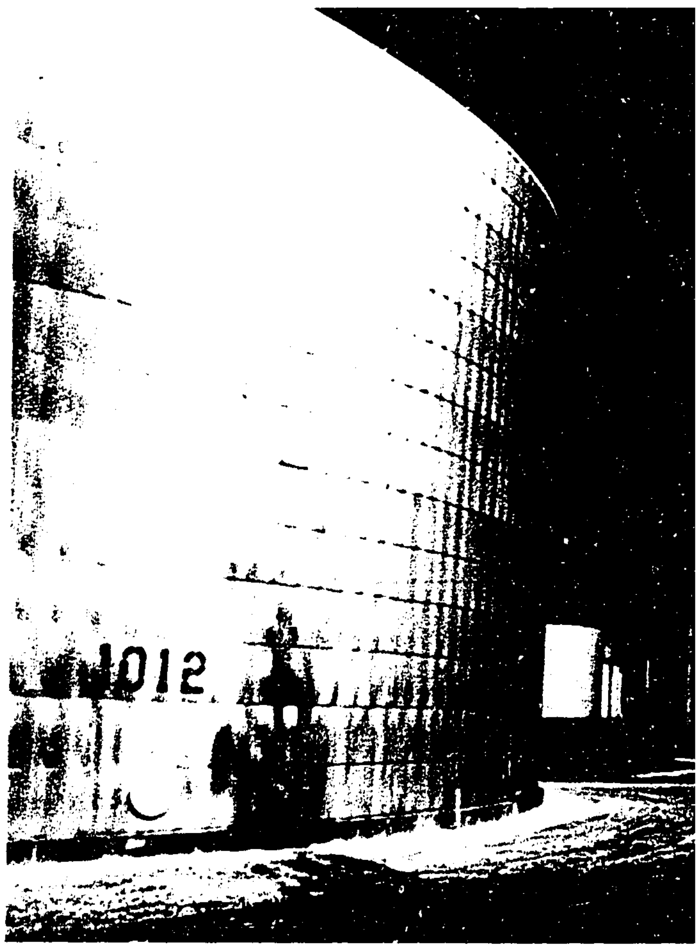
A radioisotope-powered, electric-power generator was placed in orbit, the first use of nuclear power in space.

1962 United States

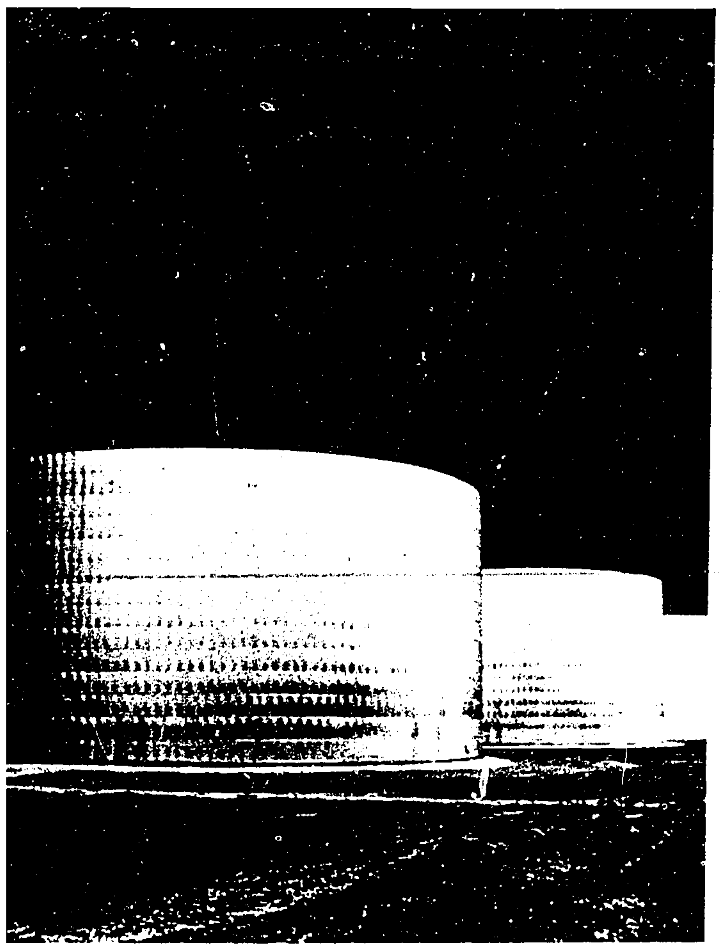
Nuclear power plant in the Antarctic became operational.

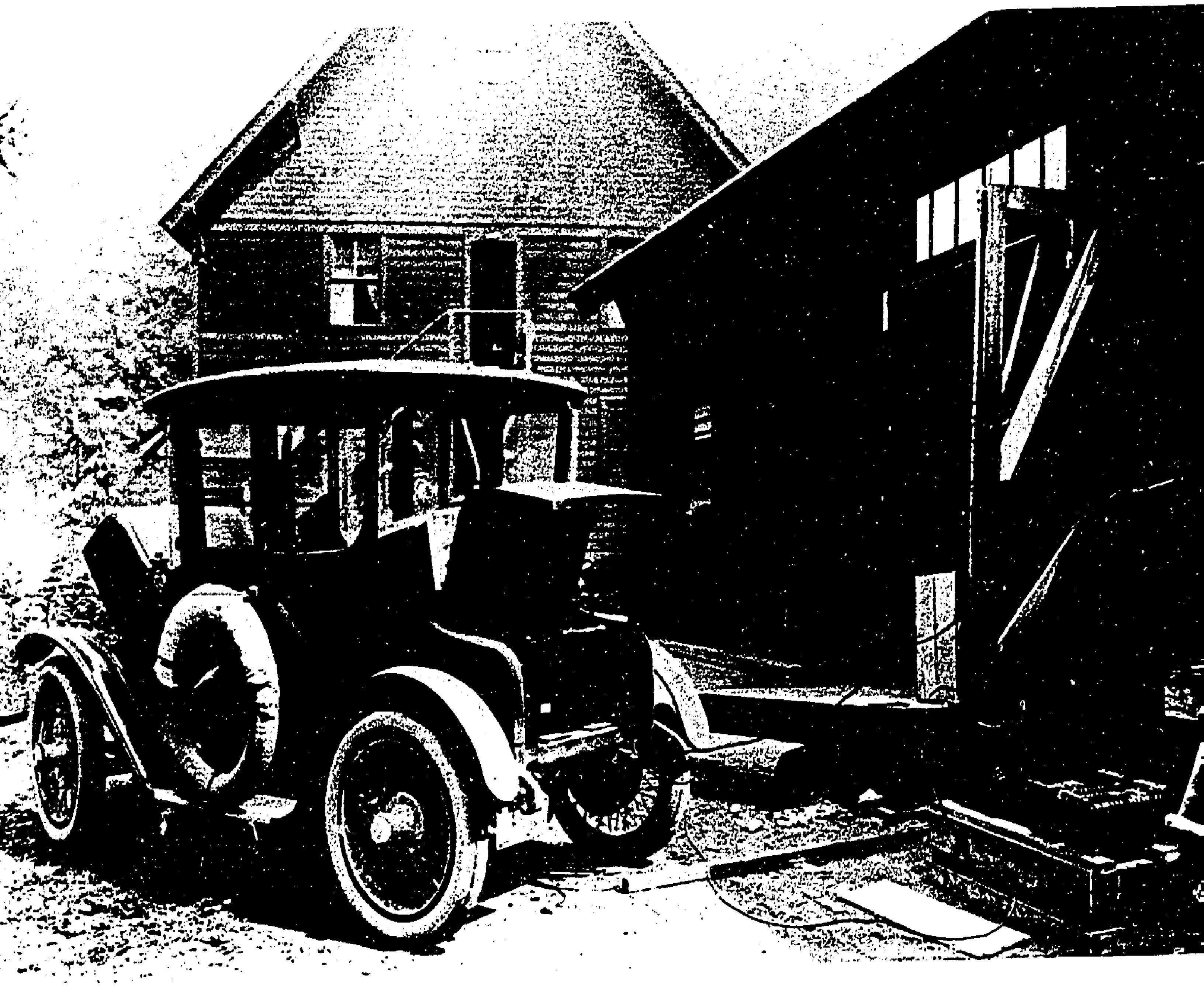
1965 United States

The 16th U.S. civilian power plant began operation. First ion-power reactor orbited in space.



Oil storage tanks like these are common along the U.S. C





ENERGY AND DOUBLING TIME

By Richard McLeod, Professor
Science and Mathematics Teaching Center
Michigan State University
Artwork by Lisa Hertherington and William Draper

Conflicting Statements

Since the 1973 oil embargo, we have heard some "experts" say that there *is* an energy crisis while others say there is *not*. For example, in May of 1978, a World Bank official claimed that we have enough oil to last hundreds of years—at current consumption rates.[1] Just one month later, President Carter's Chief Science Advisor made an estimate for the United States' oil reserves that was much closer to a 10 year remaining supply.[2] These, of course, are vastly different estimates. Yet they are both made by important people. Who is right? Is there really an energy crisis that may change our way of life?

Recipe for Disaster: Finite Reserves and Doubling

In order to better understand the problem, let's look at a graph showing the history of energy use in the United States. The amount of energy use increases toward the top of the graph while time moves from left to right.

As you can see, our use of energy has increased rapidly during this time and is still increasing.

It's easy to explain our changing patterns of energy use. In earlier times, our energy needs were

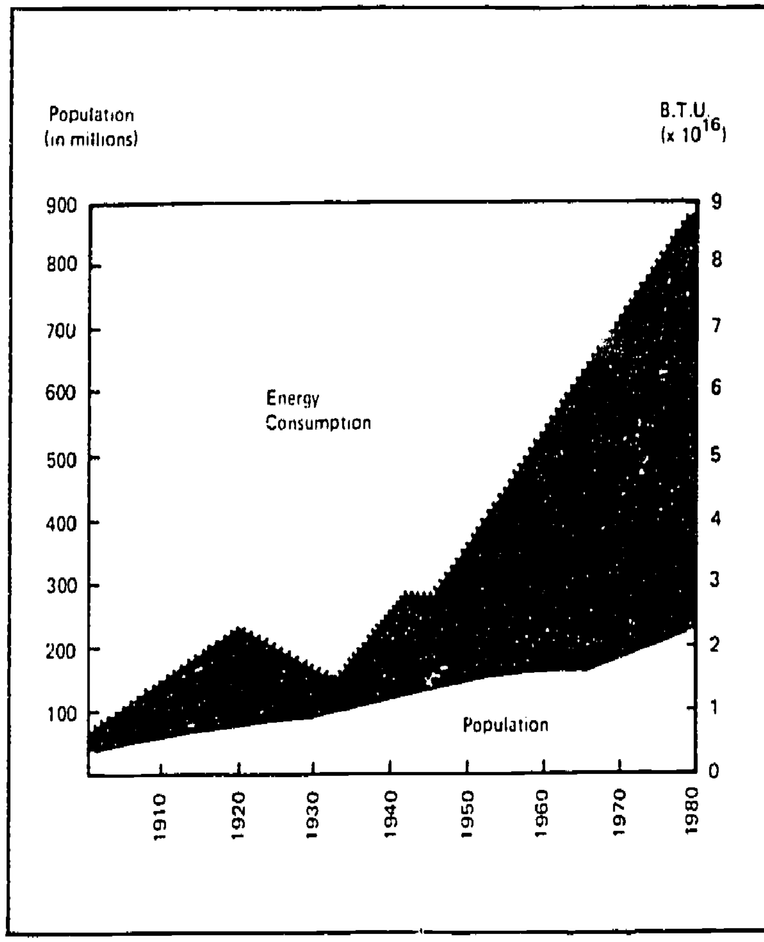


Figure 1. History of Energy Consumption in the United States

The Youth Energy Project is funded by the Michigan Department of Commerce and the Michigan Energy Extension Service on a pilot basis. Michigan State University's Cooperative Extension Service (4-H—Youth Programs) and Science and Mathematics Teaching Center are the project contractors. This material was prepared with the support of the U.S. Department of Energy (DOE) Grant No. EC-77-6-01-5092. However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE.

Note: The author is grateful for the research assistance of Mr. David

primarily confined to heating our homes and firing the cook stove. This energy was supplied by wood and coal. In fact, until 1950 coal was actually our most important fossil fuel. That was the first year in which we used more oil and natural gas than coal. During the first half of the 20th century, our way of life changed. We became an industrial, highly mobile, and throwaway society. Oil with its versatility has become our primary energy source.

We have now reached a point where each of us, on the average, uses more energy than our parents and grandparents combined. In fact, the United States, with only 6% of the world's population, accounts for over 30% of the world's energy consumption.

But there are distressing signs that the "sweet" ride is coming to an end—and that we will soon be forced to change our lifestyle whether we like it or not. In order to understand what the future holds, we must explore two important ideas.

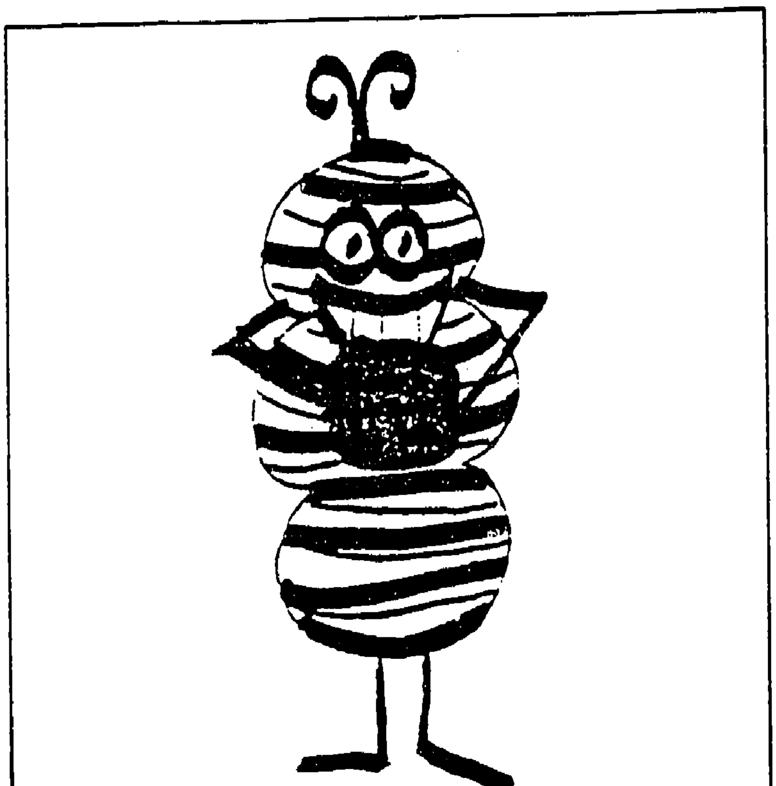
First, we must understand the phenomenon of exponential growth, or doubling time. Second, because we are the most energy hungry society on earth, we must also understand the effect doubling has on the use of limited energy sources such as oil and coal. Since oil is the main contributor to our energy needs, we will initially focus on our oil supplies.

The demand for oil is growing rapidly. Some say this means that we will soon run out of oil. C[illegible] point to estimates indicating that fully one-half of our entire original oil reserves are still in the ground. But that means that we have already used one-half of our reserves in 125 years. How long will the remaining one-half last? Doubling time holds the key.

The Ortep-Eating Snarf

Doubling Time

In order to explain doubling and its effect on a finite reserve, let me introduce the red-banded snarf.

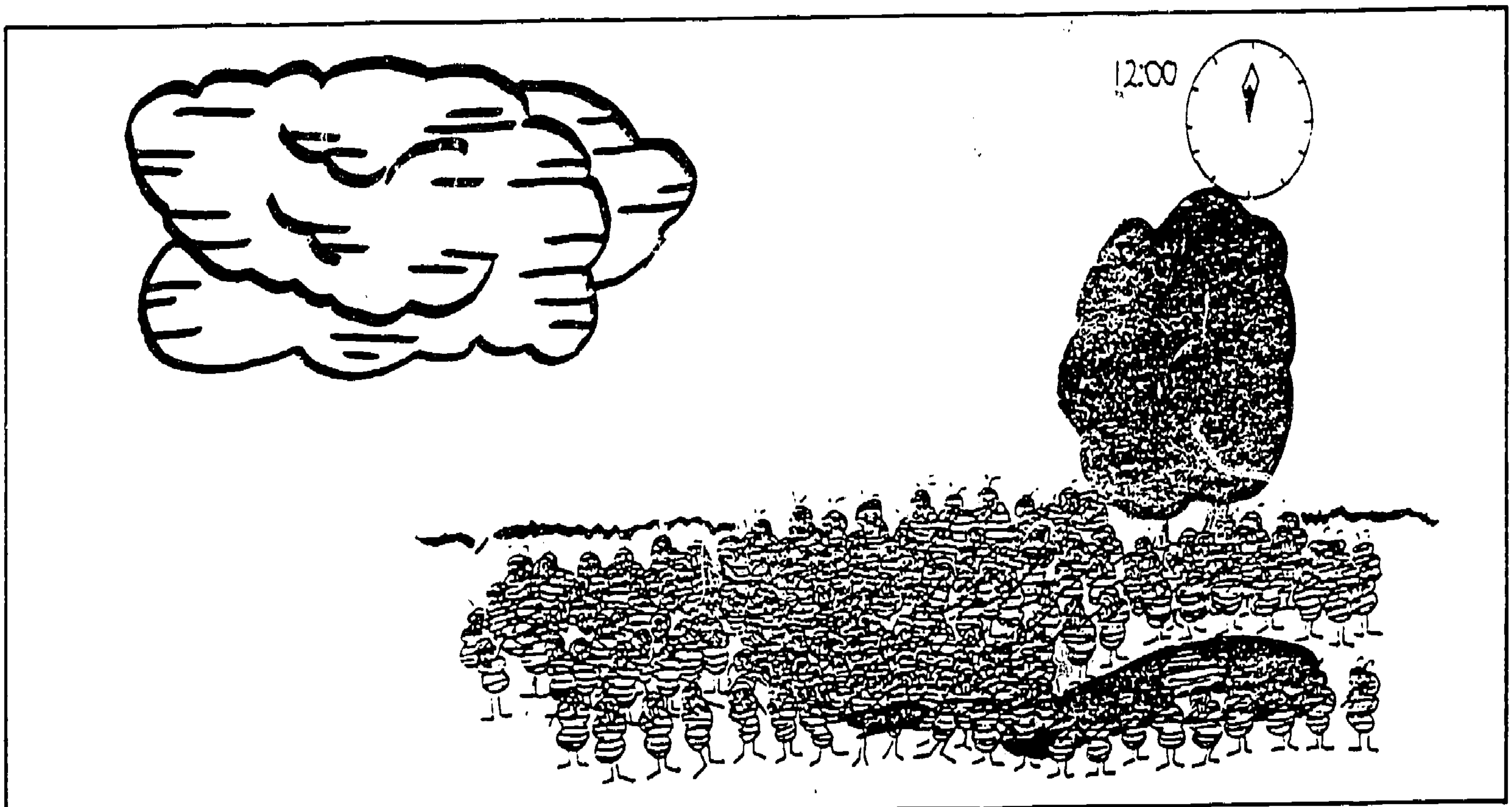


Now, this ridiculous mythical beast reproduces very quickly. Under ideal conditions, a snarf can reproduce once every minute. In other words, the snarf's doubling time is one minute. Each and every minute, there are twice as many snarfs as there were the preceding minute.

Imagine that the snarf eats nothing but a rare material called ortep, which usually is quite hard to find. Now, suppose we were able to gather in one place all of the world's known reserves of ortep and place one snarf on this huge mountain of food at 11:00 a.m.

Because the snarf reproduces every minute, at 11:01 there would be two snarfs munching happily away on a seemingly endless supply of ortep. They could truly last hundreds of years at their present consumption rate. However, at 11:02 four snarfs are on ortep mountain. Note that the number is *doubling* with each passing minute and their need for food doubles also.

At 11:03, we count eight snarfs happily eating ortep and so on. But at 12:00, we can't believe our eyes!



The number of red-banded snarfs has grown tremendously and they have completely exhausted their food supply. How could this happen in only one hour? Let me give you a clue—one hour contains 60 doubling times.

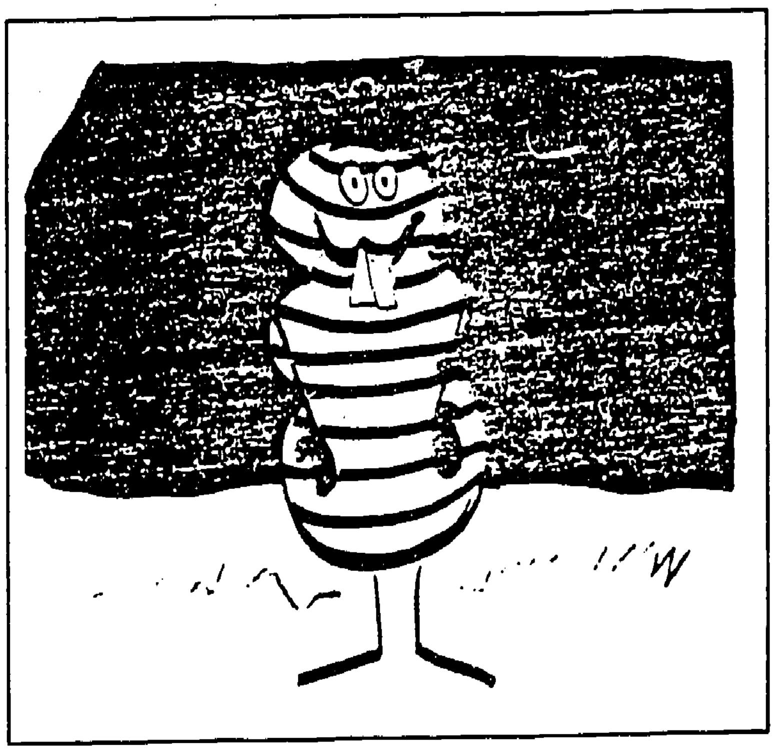
Now, consider two questions:

(1) When was the ortep half gone?
(2) When would the normal, average-IQ, red-banded snarf first notice the danger of running out of ortep?

Well, at 11:59, (one minute before noon) one-half of the entire mountain of ortep was gone—or put another way, one-half of the known world's supply of ortep still remained. *But the number of red-banded snarfs was in the process of doubling again so that their need for ortep also doubled. In the next minute, by 12:00 noon, they used the remaining one-half of the world's supply of ortep.*

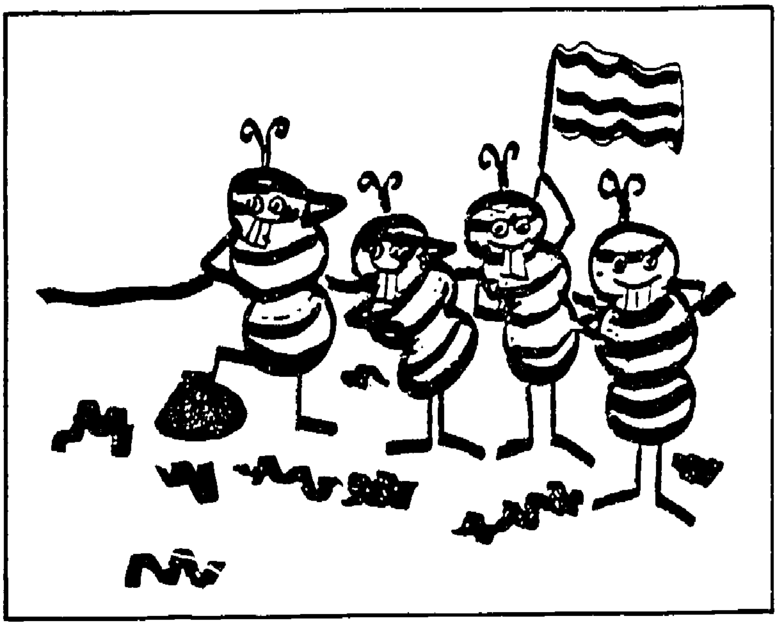
Doubling Versus "Fantastic New Discoveries"

The answer to the second question is less clear. It's hard to tell when the average, reasonably alert, red-banded snarf would begin to worry. But let's imagine that they do something about their problem, and give the story a different ending. Let's look at the situation at 11:55. Maybe, at that time, one or two snarfs began to worry about the problem and tried to alert their neighbors with no success. After all, at 11:55 only 3% of the ortep supply was gone, while 97% still remained. Who could possibly believe that there would be an ortep problem?



Finally, at 11:58, snarf leaders send out a team of very fast explorer-type snarfs to find more ortep. Now remember, the ortep is a non-renewable resource just like coal, oil, and natural gas. The only hope lies in finding previously unknown reserves.

But joy is heaped on joy when, at 11:59, they return with good news. Fantastic new reserves of ortep have been found in Alaska and along the eastern shores of the United States. These new finds are equal to three times the entire previously known world's supply of ortep. How long will this new supply of ortep last?



The picture is just as grim as it was before. The new ortep will again melt in the face of ever-increasing demands of a growing ortep-hungry population. *By 12:01, the snarfs will consume one mountain of ortep, an amount equal to all that has been consumed in the previous hour. In the next minute, by 12:02, they will consume the next two mountains of ortep and will again be facing starvation.* With these fantastic new finds the snarfs have only held on to the "good life" for a matter of two more minutes—two doubling periods.

Here, we must make a very important point: *EVEN FANTASTIC NEW DISCOVERIES ARE USED UP QUICKLY WHEN DOUBLING TA[illegible] PLACE.*

Doubling and the History of a Resource

Let's look back again at the snarf's consumption of ortep and assume that each snarf consumes one bite of ortep per minute.

Table 1 shows that at 11:00 there was only one snarf who consumed one bite of ortep. At 11:01, there were two snarfs eating two bites per minute, but the total taken from ortep mountain was three. At 11:02, there were four snarfs gobbling four bites per minute and the total removed from ortep mountain was seven. It is very easy to continue this table for as long as you like. However, let's take a closer look at it.

TABLE 1. Principle of Doubling Over Time

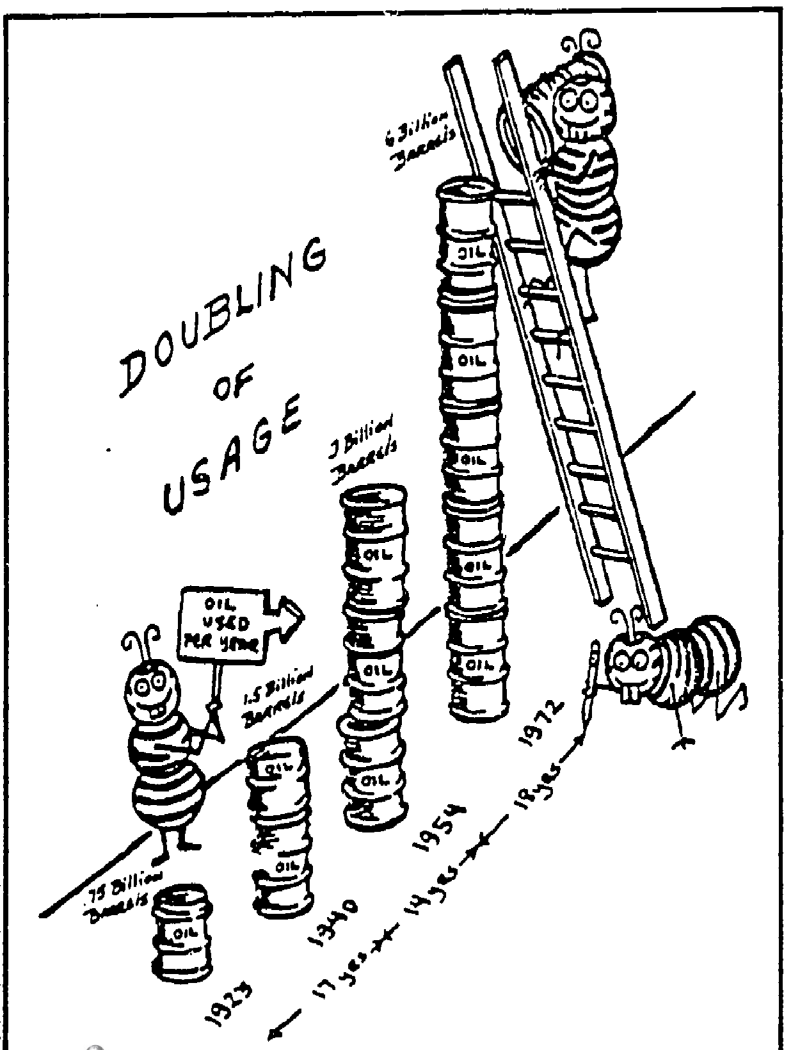
Time	No. of Snarfs	No. of Bites	Total No. of Bites
11:00	1	1	1
11:01	2	2	3
11:02	4	4	7
11:03	8	8	15
11:04	16	16	31

Between 11:01 and 11:02, there were four bites consumed, while in all previous history only three had been consumed. Between 11:02 and 11:03, eight bites were used, while only 7 had been used in all previous history. Between 11:03 and 11:04, sixteen bites were devoured, compared

to the 15 consumed in all previous history. *THE SECOND IMPORTANT POINT ABOUT DOUBLING IS: IN ANY ONE DOUBLING PERIOD, MORE RESERVES ARE CONSUMED THAN IN ALL PRECEDING HISTORY.*

From Ortep to Petro

The snarf's ortep problem is directly related to our energy crisis. Our demand for oil has been doubling just like the snarf's demand for ortep. For example, Table 2 shows that during the year 1923, we used only ¾ of one billion barrels of oil. Just 17 years later, our use doubled to 1½ billion barrels. By 1972, we were using 6 billion barrels per year. Our oil doubling periods have been 14 to 18 years.



Now let's look at the total amount of oil we have used. In all history prior to 1923, we had used approximately 6.4 billion barrels of oil. In the next doubling period from 1923 to 1940, we used 16.6 billion barrels—more than had been used in all previous history.

Our demand for oil has followed the same pattern of doubling as the snarf's use of ortep. In each doubling period, we used more oil than was used in all preceding history! We don't know how long the next doubling period will be. History shows it could be less than twenty years. What we do know, however, is that during that doubling period, we will use more oil than the 124.6 billion barrels that were used prior to 1972. But various estimates indicate that we have already used approximately one-half of our oil reserves. The time for our oil supply is clearly 11:59. Further, there is much reason to believe that U.S. oil production has passed its peak. We are now in a period of decline. Since 1970, we have been producing less each year while at the same time we have been using more. And, we must go further and drill

TABLE 2. United States Oil Use

Time	Doubling Time	No. of Barrels Used Per Year (in Billions)	No. of Barrels Used During Doubling Time (in Billions)	Total No. of Barrels Used (in Billions)
1923		.75		6.4
	17 yrs.		16.6	
1940		1.5		23.0
	14 yrs.		29.7	
1954		3.0		52.7
	18 yrs.		71.9	
1972		6.0		124.6
	??		??	
19??		12.0		

deeper for new discoveries. Now it costs more and more to get the same amounts!

The Alaskan, North Sea, and Gulf of Mexico deposits are impressive. They are greeted with great fanfare, as well they should be. But the very large Alaskan deposits, for example, *are equivalent to less than two years use at present U.S. consumption rates*. In order for U.S. oil to last one additional doubling period, (until 12:01) be it ten years or thirty years, we must find approximately twenty Alaskan-sized deposits. That is as much more oil as all of our known deposits, both past and present. But the declining production clearly makes this unlikely.

Will the Oil Run Out?

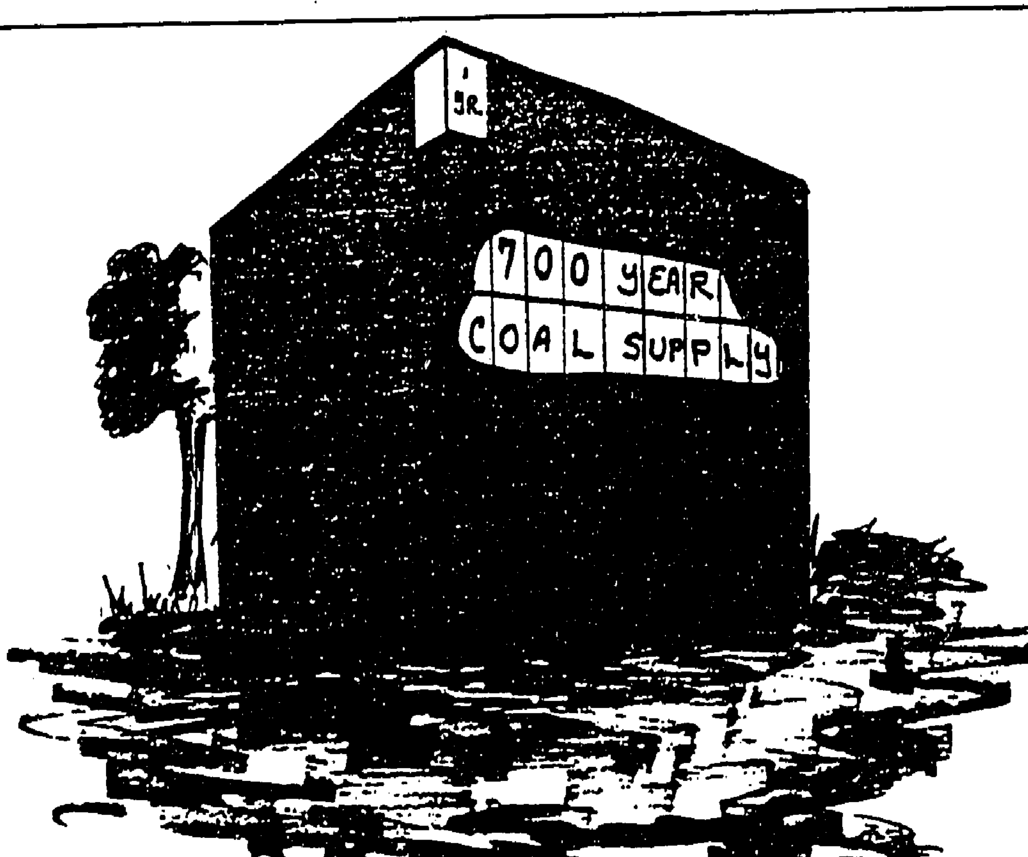
Are we really going to run out of oil? Probably not. It is likely that there will always be some oil pumped from the ground, but it will become very expensive and the competition for it will be so severe that it will no longer be the popular fuel that it is today.

Where then do we go for new energy sources? Coal has been extolled as our most abundant energy source—and indeed it is. It has been estimated that we have somewhere between 700 and 2800 years of coal in the United States at *present consumption rates*. Either estimate is sufficient to take care of our needs for many generations to come—if we don't continue to increase our consumption.

However, an 8% increase in coal production has been advocated to meet our increased energy needs and make up for short-falls in the areas of domestic oil and natural gas production. When an 8% annual growth rate is considered, we have a doubling period of less than nine years for coal.

Let this block of 700 small cubes represent a 700 year coal supply if we use one small cube each year. But let's look at what happens if we double our use each 9 years.

For ease in calculating, let's imagine that the growth is *not* gradual, but remains constant dur-



ing each 9 year period and then doubles abruptly. Thus during the first nine years, we would use one cube each year for a total of 9 cubes. During the second nine years, our use each year would double and we would consume a total of eighteen cubes. Table 3 shows that the entire 700 cube block would be exhausted in less than 60 years. Remember that at our present rate of consumption it would have lasted 700 years! Actually, if we had computed this accurately using a gradual increase each year, we would have found that the supply would last only 50 years. For our purposes, however, the ease of calculation justifies the small error.

TABLE 3. Exhaustion of a Limited Resource Over Time With Doubling Principle Applied.

Years	Number of Cubes Used Per Year	Number of Cubes Used in 9 Year Doubling Period	Total Number of Cubes Removed from 700 Cube Block
1–9	1	9	9
10–18	2	18	27
19–27	4	36	63
28–35	8	72	135
36–45	16	144	279
46–54	32	288	567
55–63	64	576	1143

QUESTIONS JUST FOR FUN

1. How long will the 2800 year supply last?
2. How long would either supply last with a growth rate of only 4% (doubling time of 17.5 years) or 2% (doubling time of 35 years)?

Now let me summarize four important ideas.

First—Our energy use has been, and still is, following the rules of doubling time—just like the snarf and its use of ortep.

Second—95% of our energy comes from fossil fuels—oil, coal, and natural gas. *These supplies are limited and non-renewable.*

Third—In each doubling period we will use more of these fuels than has been used in all preceding history.

Fourth—Even very large new discoveries will be devoured in unbelievably short time periods.

The situation may sound hopeless. However, it's hopeless only if we fail to act now. We must reduce our use of energy in every way possible. But at the same time, we can look with hope to the many alternative energy sources that may supply our future energy needs such as nuclear, solar, hydrogen fusion, and wind power. While there are major problems with each of them, we should not become discouraged. We must make every effort to develop all reasonable alternatives.

In the meantime, reduction in energy use is extremely important because it will help buy the time needed to develop other energy sources. If we continue to increase our energy use, the time-line for development of alternative sources is very short.

Remember, Table 1 showed that our growth in energy use has been much greater than our growth in population. Since 1940, our population has *doubled* while our use of oil has *quadrupled*. We obviously cannot continue that kind of growth rate. Holding our energy growth to the same rate as our population would indeed, help us, but we did not start soon enough. If we had started to conserve in 1940, and increased our energy use only as our population grew, we would now be using approximately 3 billion barrels of oil per year instead of nearly 7! We would, even now, be energy self-sufficient and have the time needed to adequately develop alternative energy sources.

We must now, therefore, actually *reduce* our present levels of consumption per person and then maintain it such that our total energy use grows only as our population grows. Many things are in our favor. We already enjoy an energy-abundant way of life. Modest conservation measures will hardly reduce our standard of living. Further, the United States population growth has recently slowed to a doubling period of approximately 90 years. Therefore, if our energy grows only with our population, the next doubling period for energy use would also be 90 years rather than the expected 20 years. This extended doubling period together with actual reductions in our use of energy, will buy the time we need to help us maintain a high quality of life.

[1] Washington (AP). "Oil Could Last for Centuries." In *The State Journal*, Lansing, Michigan, Wednesday, May 24, 1978: p. A-3.

[2] ...u, Edward. "Oil Estimates Misleading." In *The State Journal*, Lansing, Michigan, Tuesday, July 18, 1978: p. A-4.

[3] De Salyzer, MacNaughton, *20th Century Petroleum Statistics*, and U.S. Bureau of Mines Data.

The problem is serious but not hopeless. It is hopeless only if each of us fails to act now.

What can *you* do to reduce energy use? Perhaps a more important question is, What *will* you do to reduce energy use?

now being explored whereby mountains of trash can be recycled and used as a source of cheap energy.

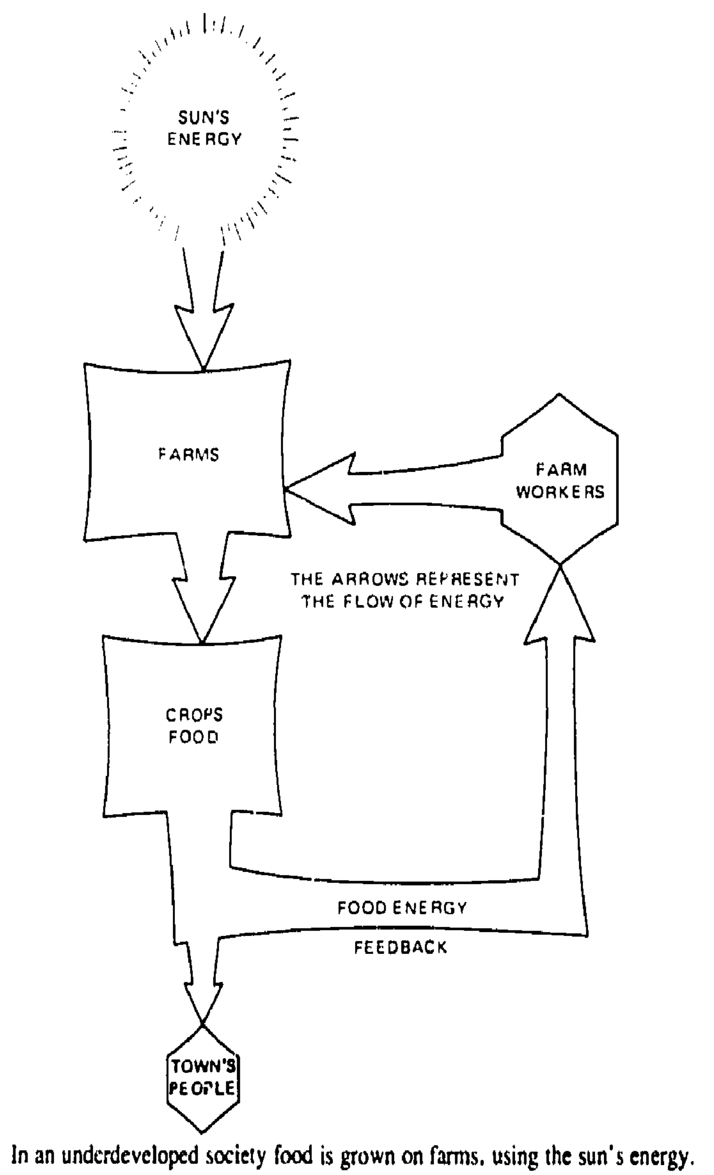
HOW DOES ENERGY CONTRIBUTE TO OUR WAY OF LIFE?

By Milton A. Rothman

Since the production of energy in large quantities results in such undesirable effects—the generation of smoke, radioactivity, and other forms of environmental pollution—we might ask ourselves why we continue to create more and more power plants, to burn more and more fuel, and to give ourselves more and more trouble. The answer is simple: civilization runs on energy.

Look at very primitive societies. The most primitive rely on hunting and fishing for food, and use hardly any energy at all, except perhaps fire for cooking. The societies on the next step up the ladder use agriculture to grow grain and vegetables, and also keep herds of domestic animals for food. This type of society can maintain a larger number of people than the hunting society. A large part of the population, however, must spend most of its time just raising the food that supplies the energy to keep these people alive.

Figure 1 shows how energy flows through a society like this. Most of the energy comes from the sun and is used, by way of photosynthesis, to grow crops, in order to keep alive the farm workers who grow the food. A very small amount of energy comes from the concentrated fuels such as wood, coal, or oil for cooking and light. There is very little energy left over for other purposes like recreation, travel, science, and so on.



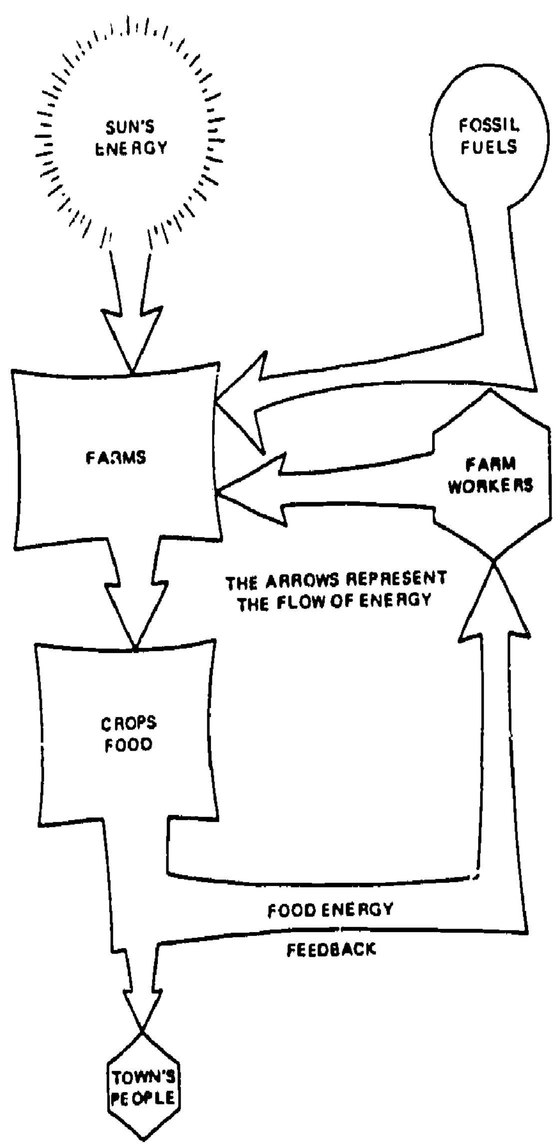
In an underdeveloped society food is grown on farms, using the sun's energy. Energy is also required to till the soil and harvest the crops. This energy is supplied by the food eaten by the farm workers. Thus, most of the food energy produced by the farm goes right back to the farm itself, with little left over for people living in the towns. This is known as a *feedback cycle*, because the energy is "fed back" to the farm from the farm.

Figure 1. Energy Feedback Cycle in a Rural Environment

On the other hand, in an advanced technological society, such as we have in the United States and other similar countries, a large amount of concentrated energy from fossil fuels is used to power farm machinery, to make fertilizer, and to transport food from the farm to the city (Figure 2). As a result, a relatively small number of people are able to grow enough food to support the rest of the population.

This means that many people are free to do things with their time other than working in the fields: people can be scientists, engineers, doctors, salespersons, machinists, and truck drivers. They can pursue all the occupations that are available as long as there is enough energy. They can also carry on activities that are not absolutely necessary for the maintenance of life, but which add to the pleasures that we have become accustomed to. Entertainers, writers, artists, philosophers, all add their accomplishments to what we like to call civilization. In the past such activities were mainly enjoyed by the very rich; with the growth of middle-class society made possible by the increased use of energy, a larger part of the population can take part in the benefits of technology.

The higher the standard of living in a country, the more energy is used for each person. Every piece of machinery a person uses to make life more c[illegible]ient, more pleasant, or more interesting



In an advanced technological society, concentrated energy is obtained by burning fossil fuels to produce farm machinery and fertilizers, so that a few farm workers can supply food energy for all the people living in the cities. Most of the energy to operate the farms comes from the fossil fuels, so that there is only a small amount of energy in the feedback part of the diagram.

Figure 2. Energy Interdependence Between Farm and City in an Advanced Technological Society

requires energy. Both the manufacture and the operation of the machine use energy.

During the past few hundred years we have seen a steady increase in the use of energy by the people of the world. There are two reasons for this growth in energy. First, the number of people in the world has been increasing; and second, each person has been using more and more energy as he or she buys cars and air conditioners and stereo sets.

In the United States in 1968 about 23% of the total energy used was in the form of electricity (household, commercial, and industrial); 24% was used for transportation (gasoline and oil); and 53% was burned for non-electric purposes such as heating. You can see from these figures that our need to drive around in gasoline-powered cars accounts for a large amount of the increase in energy use.

During the first half of the twentieth century we took it for granted that there was always going to be enough energy for people to do anything they wanted. There seemed to be no reason for anyone to suffer in the summer without air conditioning. There seemed to be no reason for anybody to go without a car, to travel instantly to any destination.

Then, during the 1950's and 60's there came signs that something was going wrong. The air around Los Angeles and other large cities became hazy with smog. In 1965 the breakdown of an electrical relay caused a complete interruption—a *blackout*—of electric power for several hours in the northeastern part of the United States. In the years following that incident the *brownout* became a common event in certain large cities. The brownout was caused by the power companies reducing voltage on the hottest days of the summer, because their generators could not keep up with the fantastic demand placed on the power system by the large number of air conditioners. Then in the winter of 1972 an oil shortage arose, and in the summer of 1973 there was a gasoline shortage that forced many gas stations to close down.

Finally, by winter of 1973 and spring of 1974, there was such a great shortage of gasoline and heating oil that the President had to issue regulations to close gas stations on Sundays, to limit driving speeds to 55 miles per hour, to reduce the temperatures inside buildings 6 degrees below their previous level.

Each of these events was the symptom of a different malady, but all were connected. The smog arose because the atmosphere could not get rid of the impurities injected into it by auto exhausts. The electric blackout came about because the electric distributing system had become so vast and complex that one small trouble was able to trigger a chain of events that threw the whole works out of kilter. The brownouts were the result of unleashed demand colliding head-on with the limits of a fixed energy supply. On one hand, the electric-appliance industry had published advertis' 'g encouraging people to buy new air condition but on the other, new generators were not bei.)uilt fast enough to supply power for the new a. conditioners.

Another factor entered the picture in the late 1960's. A number of people, alarmed at the effects on the environment caused by the rising production of power, joined together in powerful organizations (such as the Sierra Club) for the purpose of slowing down some of the changes taking place. Constant court challenges delayed construction of many nuclear power plants on the grounds that not enough attention had been paid to safety precautions. Construction of an oil pipeline linking a new oil field on the northern coast of Alaska to the south was held up for several years. People were concerned that this pipeline would permanently damage the Alaskan environment by melting through the frosted surface layer of ground. While such conflicts did slow down some energy-producing projects, they were a warning to the public that we could no longer continue in actions that were making the world increasingly uninhabitable for the purpose of obtaining greater amounts of energy.

A number of factors joined together to produce the gasoline shortage of 1973–74. The basic problem was that the demand for gasoline had increased faster than the country's oil producers could deal with it. Operating at top speed, the present oil wells in the United States are draining the known supplies at a rate so great that they will last for only a few more years. Construction of new oil refineries and drilling of new oil wells had slowed down because it was cheaper to import oil from abroad. Then, in the autumn of 1973, immediately following the Israeli-Arab October War, the Arab oil-producing countries stopped the export of oii to a number of countries that supported Israel. Simultaneously the Arab countries raised the price of oil to the rest of the world.

Crude oil is refined into both gasoline and heating oil. In order to have enough home heating oil for the winter, the supply of gasoline was cut down, producing the shortage that caused lines to form at the gasoline stations. When the price of gasoline and heating oil went up sharply, the oil companies maintained that they needed the additional money to drill for new oil wells.

While Arab oil amounts to only a few percent of the total oil used in the United States, the trouble produced by the removal of that amount indicates that we were already approaching the point where demand was greater than supply. The sudden crisis of 1973 brought to the public's attention the hard choice that must be made very soon. Do we want more energy at any cost, or are we going to level off the rise of energy use and pay more attention to our resources and environment?

One thing is absolutely certain. We cannot continue to increase the population of the earth very much longer without running into serious trouble. The more people there are, the more food, energy, and mineral resources are used up. The earth's resources are not endless. There are fixed amounts of coal, oil, uranium ore, iron ore, and atmosphere. We now burn in one year fossil fuels that took the earth one million years to manufacture. Once these fuels are gone they cannot be replaced. The greater the number of people on earth, the faster the materials are used up and the greater the amount of pollution poured out into the environment. Every time energy is used to manufacture some article, a certain amount of waste material must result.

We can describe the situation in the following way: imagine a room that has space for exactly one thousand people. The space in the room and the air for breathing are fixed resources. When they are used up there is no more left. Now suppose that one day a single person goes into the room. The next day another person enters, so that the number of people in the room doubles. The next day two more people enter the room, so that the population doubles once more. Each day that goes by sees a doubling of the room's population. (This is actually the way the population of the earth has been increasing; every thirty years or so the population has doubled.)

To see what happens in the room, we make a table of its population, showing how many people are in it each day:

DAY	POPULATION
1	1
2	2
3	4
4	8
5	16
6	32
7	64
8	128
9	256
10	512
11	1,024

We see that for the first several days the room is rather empty. Even on the tenth day the room is only half filled—that means it is still half empty. But then on the eleventh day suddenly the room is all filled up and there is not any space left. Things suddenly seem to explode at the end.

This is what has been happening in the world. We speak of the "population explosion" as though it is something that suddenly happened. But the population has been increasing at the same rate for the last few hundred years. We just no-

it at the last minute when suddenly every-
ig seems to get very crowded. The problems we encountering concerning energy and resource rtages are a signal that we are just beginning get into the overcrowded state.

There are some who say that we can avoid se problems by going back to a simpler and re natural way of life, to use less energy, to e fewer material posessions. It is true that ig less energy will leave more resources for the of future generations and will be less harmful the environment. But we must ask selves what energy-using things we can really e up now without seriously lowering the quality he life of the average person.

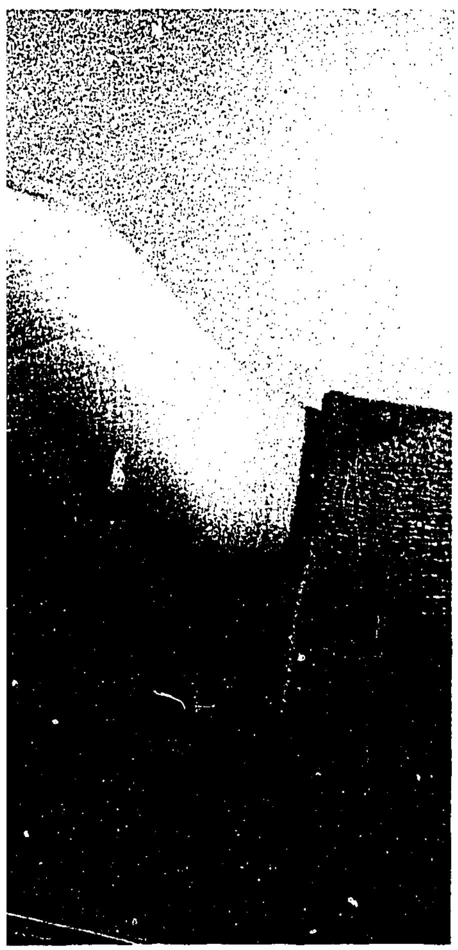
For example, we are accustomed to good lical care. If we have an accident we want a tor on hand with X-ray equipment, oxygen, gs, and the other apparatus of modern medi-. Each one of these items requires a whole anization of people to manufacture and deliver

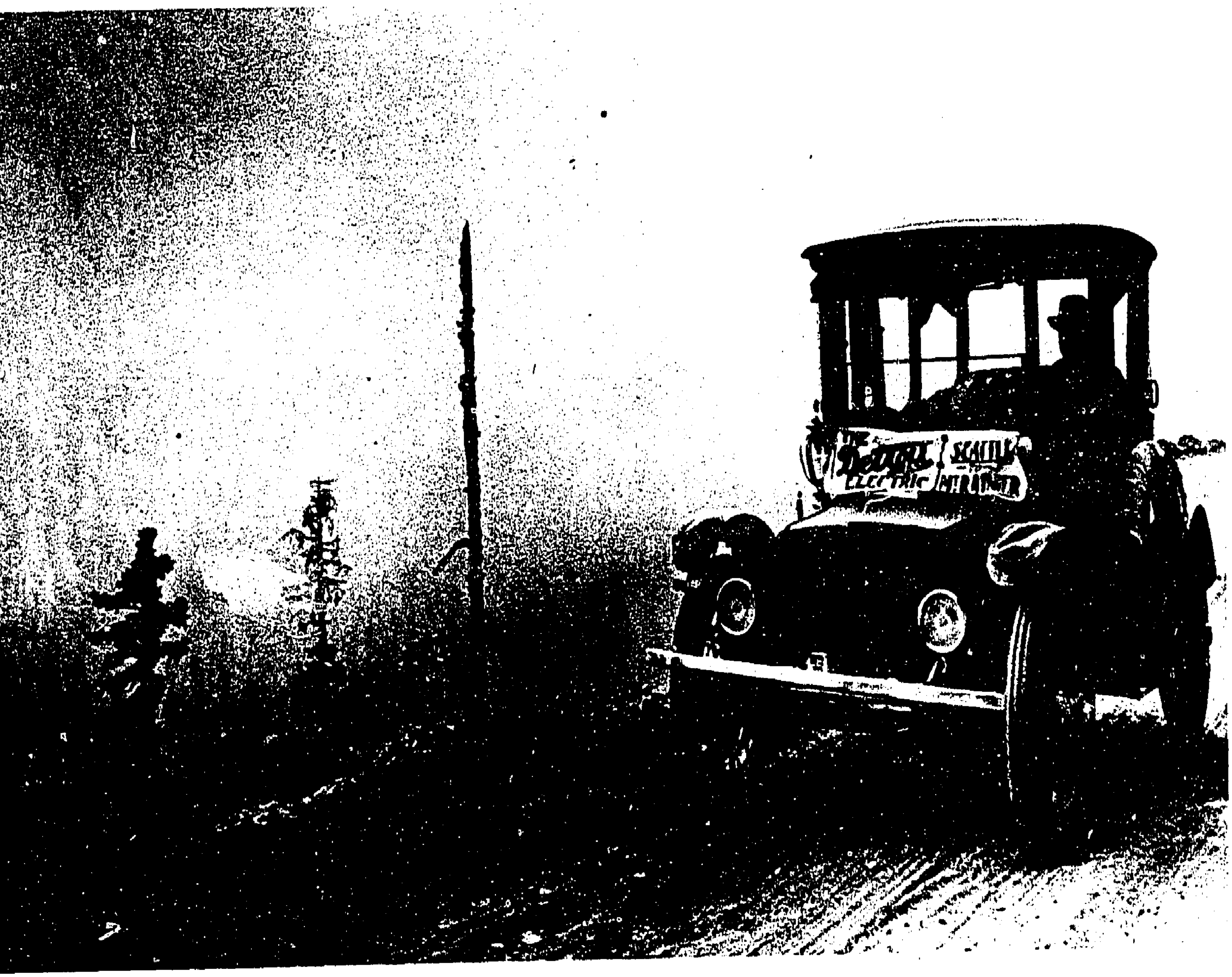
We want comfortable homes, heated in the ter, and perhaps cooled in the summer. This takes a great amount of energy. We know that heating is considered a necessity, while air conditioning is often thought of as a luxury. Yet there is no doubt that it is very difficult to work in excessive heat, so that air conditioning is very useful for raising working efficiency. Furthermore, high temperatures and humidity place a strain on the heart and circulatory system. If air conditioning can save lives, it is not entirely a luxury.

What about music? Would you be willing to do without your stereo, records, or tape recorder? The transistor that is the heart of all electronics requires a fantastically advanced technology to produce it. Records require the miracles of plastic chemistry, and building tape recorders requires the use of the most advanced physics. As basic a matter as feeding the billions of people now living on earth requires that we use our scientific knowledge and resources to the utmost degree. Otherwise millions of people would starve.

The problem, then, is how to keep the things we consider essential and desirable and, at the same time, stop using up the resources of the earth. These are some of the questions we still have to think about.

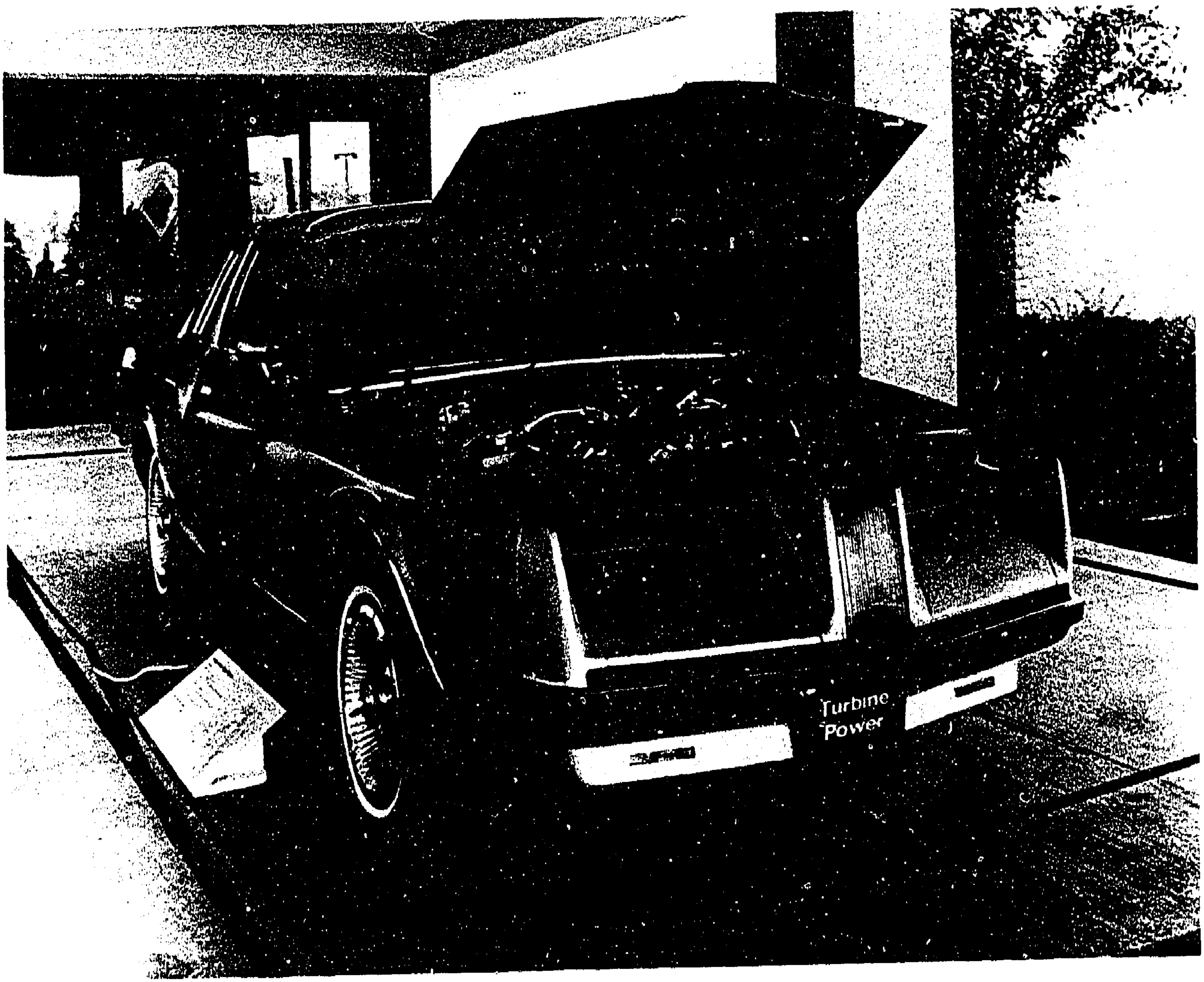
display model of a nuclear-powered heart pacemaker





CHECK YOUR ENERGY VOCABULARY

John M. Fowler and King C. Kryger


Turbine
Power

A GLOSSARY OF TERMS

amperage—A measure of the volume of flow of an electrical current.

anthracite—"Hard coal," low in volatile matter, high in carbon content, with a heat value of 6.40 million Calories/ton.

atom—Consists of a heavy center or nucleus, made up of protons and neutrons, around which revolve blurs of energy called electrons.

atomic number of an atom—The number of protons in the nucleus.

atomic oven—Another name for atomic furnace. Sometimes called a uranium pile or a nuclear reactor.

atomic pile— A nuclear reactor, arranged to get energy out of the nuclei of atoms. The energy appears as heat.

barrel (bbl)—A liquid measure of oil, usually crude oil, equal to 42 gallons or about 306 pounds.

base load— The minimum load of a utility (electric or gas) over a given period of time.

bioconversion—A general term describing the conversion of one form of energy into another by plants or microorganisms. It usually refers to the conversion of solar energy by photosynthesis.

biomass—Plant materials in any form from algae ...ood.

bituminous coal—Soft coal; coal that is high in carbonaceous and volatile matter. It is "younger" and of lower heat value than anthracite or "hard coal." Heat value, 5.92 million Calories/ton.

black lung—A respiratory ailment, similar to emphysema, which is caused by inhalation of coal dust. Identified as a contributing cause in the deaths of many underground coal miners.

bottoming cycle—A means of using the low-temperature heat energy exhausted from a heat engine, a steam turbine, for instance, to increase the overall efficiency. It usually employs a low-boiling point liquid as working fluid.

breeder reactor—A nuclear reactor so designed that it produces more fuel than it uses. Uranium 238 (92 U^{238}) or thorium 232 (90 Th^{238}) can be converted to the fissile fuel, plutonium 239 (94 Pu^{239}) or uranium 233 (92 U^{233}), by the neutrons produced within the breeder reactor core.

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British Thermal Unit (Btu)—A unit of energy commonly used to measure heat energy or chemical energy. The heat required to raise the temperature of one pound of water 1°F, it is usually written Btu, and is equal to 778 foot-pounds of work or energy.

Calorie—The amount of heat required to raise the temperature of one gram of water one degree celsius.

capacity factor—A measure of the ratio of the electrical energy actually produced at a generating plant to the maximum design capacity of the plant.

capital intensive—Requiring heavy capital investment. The energy industry, for example, is said to be capital intensive rather than labor intensive because it employs relatively more dollars than people.

carbon dioxide (CO_2)—A compound of carbon and oxygen formed whenever carbon is completely burned (oxidized).

carbon monoxide (CO)—A compound of carbon and oxygen produced by the incomplete combustion of carbon. It is emitted by automobiles and is, as far as total weight is concerned, the major air pollutant.

carcinogen—A substance or agent producing or ...iting cancerous growth.

catalyst—A substance which changes the speed of a chemical reaction without itself being changed.

catalytic converter—A device added to the exhaust system of an automobile that converts the air pollutants carbon monoxide (CO) and hydrocarbons (HC) to carbon dioxide (CO^2) and water. A similar conversion also removes nitrogen oxides (NO_x).

Celsius—The metric temperature scale in which the temperature of melting ice is set at 0°, the temperature of boiling water at 100°. One degree Celsius is 9/5 of a degree Fahrenheit. The Celsius scale is also known as the Centigrade scale.

Centigrade—See Celsius.

chain reaction—A reaction that stimulates its own repetition. In a fission chain reaction a fissionable nucleus absorbs a neutron and splits in two, releasing additional neutrons. These in turn can be absorbed by other fissionable nuclei, releasing still more neutrons and maintaining the reaction.

char—A porous, solid, nearly pure carbon residue resulting from the incomplete combusion of organic material. If produced from coal, it is called coke; if produced from wood or bone, it is called charcoal.

chemical energy—A kind of energy stored inside the molecules of matter, which may be released or absorbed as their atoms are rearranged.

coal gasification—The conversion of coal to a gas suitable for use as a fuel.

coal liquefaction—The conversion of coal into liquid hydrocarbons and related compounds, usually by the addition of hydrogen.

coal tar—A gummy, black substance produced as a by-product when coal is distilled.

coke—Degassed coal (see char).

commutator—A set of electrical contacts that can convey electrical current between stationary and rotating devices.

conduction—(of heat) The transmission of energy directly from molecule to molecule.

confinement time—(in fusion) The time during which the reacting materials (deuterium and tritium, for instance) are physically confined at proper density to react.

convection—(of heat) The transfer of energy by moving masses of matter, such as the circulation of a liquid or gas.

converting energy—Changing energy from one form to another.

cooling towers—Devices for the cooling of water used in power plants. There are two types: wet towers, in which the warm water is allowed to run over a lattice at the base of a tower and is cooled by evaporation; and dry towers, in which the water runs through a system of cooling fans and is not in contact with the air.

critical mass—The smallest mass of fissionable material that will support a self-sustaining chain reaction under stated conditions.

crude oil—A mixture of hydrocarbons in liquid form found in natural underground petroleum reservoirs. It has a heat content of 1.46 million Calories/barrel and is the raw material from which most refined petroleum products are made.

current—The flow of electricity, comparable to the flow of a stream of water.

cyclotron—A machine for splitting atoms on a small scale and under controlled conditions, so that the process can be studied.

declining block rate—A method of charging for electricity wherein a certain number of kilowatt hours (the first block) is sold at a relatively high rate and succeeding blocks are sold at lower and lower rates. Thus the charge for energy decreases as the amount consumed increases. (See "inverted block rate.")

deuterium—A non-radioactive isotope of hydrogen whose nucleus contains one neutron and one proton and is therefore about twice as heavy as the nucleus of normal hydrogen, which consists of a single proton. Deuterium is often referred to as "heavy hydrogen"; it occurs in nature as 1 atom to 6500 atoms of normal hydrogen.

efficiency of conversion—The amount of actual energy derived, by any technique in relation to the total quantity of energy existing in any source being tapped; expressed as a percentage.

elastic energy—The energy involved in the change of a piece of matter from its original shape which tends to restore this shape—as when a spring is stretched or a ball is compressed.

electrical energy—A kind of energy that arises because of electrical forces between particles of matters such as electrons.

electrolysis—The decomposition of a substance by means of an electric current as in the production of hydrogen and oxygen from water.

electron—An elementary particle with a negative charge that orbits the nucleus of an atom. Its mass at rest is approximately 9×10^{-31} kg, and it composes only a tiny fraction of the [illegible]s of an atom. Chemical reactions consist of the transfer and rearrangement of electrons between atoms.

electrostatic precipitator—A device that removes the bulk of particulate matter from the exhaust of power plants. Particles are attracted to electrically charged plates and the accumulation can then be washed away.

energy—A quantity having the dimensions of a force times a distance. It is conserved in all interactions within a closed system. It exists in many forms and can be converted from one form to another. Common units are Calories, joules, BTUs, and kilowatt-hours.

energy intensiveness (EI)—A measure of energy utilization per unit of output. For passenger transport, for example, it is a measure of Calories used per passenger mile.

enrichment—A process whereby the percentage of a given isotope present in a material is artifically increased, so that it is higher than the percentage of that isotope naturally found in the material. Enriched uranium contains more of the fissionable isotope uranium 235 than the naturally occurring percentage (0.7%).

exothermic reaction—A reaction which releases more energy than is required to start it. The combustion reaction (burning) is an example as are fission and fusion reactions.

external combustion engines—An engine in which the fuel is burned outside the cylinders.

Fahrenheit—A temperature scale in which the temperature of melting ice is set at 32° and the temperature of boiling water at 212°. One Fahrenheit degree is equal to five-ninths of a Celsius degree.

fertile nucleus (or "fertile materials")—A material, not itself fissionable by thermal neutrons, which can be converted into a fissile material by irradiation in a reactor. There are two basic fertile materials, uranium 238 and thorium 232. When these fertile materials capture neutrons, they are converted into fissile plutonium 239 and uranium 233 respectively.

First Law of Thermodynamics—Also called the Law of Conservation of Energy. It states: Energy can neither be created nor destroyed.

fission—The splitting of atoms.

fluidized bed—A furnace design in which the fuel is buoyed up by air and some other gas. It offers advantages in the removal of sulfur during combustion.

fossil fuels—Fuels such as coal, crude oil, or natural gas, formed from the fossil remains of organic materials.

fuel cell—A device for combining fuel and oxygen in an electrochemical reaction to generate electricity. Chemical energy is converted directly into electrical energy without combustion.

fuel reprocessing—A recycling operation. Fissionable uranium and plutonium are recovered from uranium fuel rods which have undergone intense neutron bombardment in a nuclear reactor and fission products are removed.

fusion—The formation of a heavier nucleus by combining two lighter ones. In the reaction under study as a source of energy hydrogen (or helium 3) nuclei combine to form helium 4 with a subsequent release of energy.

gasoline—A petroleum product consisting primarily of light hydrocarbons. Some natural gasoline is present in crude oil but most gasoline is formed by "cracking" and refining crude oil. It has a heat value of 1.32 million Calories/barrel.

generating capacity—The capacity of a power plant to generate electricity. Usually measured in megawatts (Mw).

geopressured reservoir—Geothermal reservoir consisting of porous sands containing water or brine at high temperature or pressure.

thermal energy—The heat energy in the Earth's crust whose source is the Earth's molten interior. When this energy occurs as steam, it can be used directly in steam turbines.

enhouse effect—The warming effect of carbon dioxide, CO_2, and water vapor in the atmosphere. These molecules are transparent to incoming sunlight but absorb and reradiate the infrared (heat) radiation from the Earth.

f life—The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

t—A form of kinetic energy that flows from one body to another because of a temperature difference between them. The effects of heat result from the motion of molecules. Heat is usually measured in Calories or British Thermal Units (Btu's).

t engine—Any device that converts thermal heat energy into mechanical energy.

t pump—A device that transfers heat from a cooler region to a warmer one (or vise versa) by the expenditure of mechanical or electric energy. Heat pumps work on the same general principle as refrigerators and air conditioners.

heat value—The energy released by burning a given amount of the substance; also energy equivalent.

Helium 3 ($_2He^3$)—A rare, non-radioactive isotope of helium.

Helium 4 ($_2He^4$)—The common isotope of helium.

horsepower—A unit of power equal to 550 foot-pounds of work per second.

hot rock reservoir—A potential source of geothermal power. The "hot rock" system requires drilling deep enough to reach heated rock then fracturing it to create a reservoir into which water can be pumped.

hydrocarbons—Molecules composed of carbon and hydrogen atoms in various proportions. They are usually derived from living materials.

hydroelectric—Producing electrical power by the extraction of energy from the force of moving (usually falling) water.

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

hydrogenation—The addition of hydrogen to an organic molecule to increase the ratio of hydrogen to carbon, for instance in the production of oil from coal or from organic waste.

hydrothermal reservoir—One of the forms of geothermal reservoir systems. Consists of naturally circulating hot water or steam ("wet steam") or those which contain mostly vapor ("dry steam"). The latter type of hydrothermal reservoir is the most desirable type with present technology.

inertial confinement—One of two major techniques used in nuclear fission experimentation. (See "Magnetic Confinement".) A frozen pellet of deuterium and tritium is bombarded from all sides by an energy source—a laser beam of charged particles. The resulting *implosion* of the pellet results in high temperature and density which allows ignition of the fusion reaction and the pellet *explodes*.

internal combustion engine—An engine in which power is generated within one or more cylinders by the burning of a mixture of air and fuel, and converted into mechanical work by means of a piston. The automobile engine is a common example.

in situ—In the natural or original position or location. In situ conversion of oil shale, for instance, is an experimental technique in which a region of shale is drilled, fractured, and set on fire. The volatile gases burn off, the oil vaporizes, then condenses and collects at the bottom of the region, from which it can be recovered by a well. There also has been some experimentation with in situ conversion of coal.

inverted block rate—A method of selling electricity wherein a first "block" of kilowatt hours is offered at low cost and prices increase with increased consumption.

ionization—Removal of some or all electrons from an atom or molecule, leaving the atom or molecule with a positive charge, or the addition of one or more electrons, resulting in a negative charge.

ions—Atoms or molecules with electric charges caused by the addition or removal of electrons.

isotope—Any of two or more species of atoms having the same number of protons in the nucleus, of the same atomic number, but with differing numbers of neutrons. All isotopes of an element have identical chemical properties, but the different nuclear masses produce different physical properties. Since nuclear stability is governed by nuclear mass, one or more isotopes of the same element may be unstable (radioactive).

joule—A metric unit of work or energy; the energy produced by a force of one newton operating through a distance of one meter. One

Btu = 1055 joules, and one Calorie = 4.185 joules.

erosene—A petroleum distillate with a heat value of 1.43 million Calories/barrel presently used in gas turbines and jet engines.

ilocalorie—See Calorie.

ilowatt (kw)—A unit of power, usually used for electric power, equal to 1,000 watts, or to energy consumption at a rate of 1,000 joules per second.

ilowatt-hour (kw-hr)—A unit of work or energy. Equivalent to the expenditure of one kilowatt in one hour, about 853 Calories.

inetic energy—The energy of motion. The ability of an object to do work because of its motion.

nd subsidence—The sinking of a land surface as the result of the withdrawal of underground material. It results from underground mining and is a hazard of the development of geothermal fields.

ngley—The amount of energy from solar radiation that, falling on an area of one square centimeter facing the sun on a clear day, equals one calorie of heat.

ser—A device for producing an intense beam of ent, sharply focused, light. The name is an acronym for Light Amplification by Stimulated Emission of Radiation.

Law of Conservation of Energy—See First Law of Thermodynamics.

Lawson Criterion—A rough measure of success in fusion. For a self-sustaining fusion reaction to take place, the product of the confinement time (in seconds); and the particle density (in particles per cm^3) must be about 10^{14}.

life cycle costs—The total cost of an item including initial purchase price as well as cost of operation, maintenance, etc. over the life of the item.

lithium—The lightest metal; a silver-white alkali metal. Lithium 6 is of interest as a source of tritium for the generation of energy from a controlled fusion reaction. Molten lithium will also be the heat exchanger.

liquified natural gas (LNG)—Natural gas that has been cooled to approximately −160°C, a temperature at which it is liquid. Since liquefaction greatly reduces the volume of the gas, the costs of storage and shipment are reduced.

load factors—The percentage of capacity actually utilized. For example, the average number of passengers for a certain size car divided by the passenger capacity of that size car.

magnetic confinement—A confinement technique used in nuclear fusion in which electrons are stripped from the reacting nuclei (deuterium and tritium, for example) forming a "plasma" which can be controlled by a magnetic field. There are several different types of magnetic confinement systems under development. (See "Tokamak," "magnetic mirror," and "magnetic pinch device.")

magnetic energy—A kind of energy that arises when electrons or other charged particles move.

magnetic mirror—(See above) Consists of linear tubes in which the magnetic field confining a "plasma" is shaped so as to turn particles around at each end, as a mirror does a light beam. The most successful of these devices is the 2X–IIB at the Lawrence Livermore Laboratory of the University of California.

magnetic pinch device—(See above)—An interior space is filled with plasma which is then "pinched," or compressed bv a magnetic field. This is accomplished by increasing the strength of the field and forcing the plasma toward the center of a tube. The Scyllac at Los Alamos is the major pinch device.

magnetic storage—A futuristic concept in which energy can be stored in a magnetic field around a superconducting material.

magnetohydrodynamic (MHD) generator—An expansion in which electricity is generated from the combustion of fuels without going through an intermediary steam turbine. Hot, partially ionized gases move through a magnetic field, and are separated by charge, generating a current that is then collected by electrodes lining the expansion chambers.

mechanical energy—One form of energy. It is observable as the motion of an object.

megawatt (mw)—A unit of power. A megawatt equals 1,000 kilowatts, or 1 million watts.

Methane Gas (CH_4)—A light hydrocarbon; an inflammable natural gas with a heat value of 257 Calories/cubic feet. Forms explosive mixtures with air. It is the major part of marsh gas and natural gas but can be manufactured from crude petroleum or other organic materials. (See coal gasification.)

Mev—One million (or 10^6) electron volts—a unit of energy. It is equivalent to 1.6×10^{-13} joules.

MHD generator—See magnetohydrodynamic generator.

mill—A tenth of a cent. The cost of electricity is often given in mills per kilowatt hour.

moderator—A material used in a nuclear reactor to slow the speed of neutrons and thus control the rate of fission. Common moderators are graphite, water, deuterium, and beryllium.

molecule—Atoms combined to form the smallest natural unit of a substance. For example, the water molecule is composed of two atoms of hydrogen and one atom of oxygen.

neutron—An elementary particle which is present in all atomic nuclei except for the most common isotope of hydrogen. Its mass is approximately that of a proton, but it has no electric charge. Neutrons are released in fission and fusion reactions.

Nitrous Oxides (NOx)—Compounds formed whenever combustion occurs in air (in the presence of nitrogen). An air pollutant and component of "photochemical smog."

nuclear converter reactor—A reactor in which the major process is the conversion of fissionable fuel into energy as distinguished from a "breeder reactor" which produces more fuel than it uses. A converter reactor also "converts" some fertile material into fissionable fuel but produces less fissionable fuel than it consumes.

nuclear energy—The energy released during reactions of atomic nuclei.

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

nucleus—The extremely dense, positively charged core of an atom. It contains almost the entire mass of an atom, but fills only a tiny fraction of the atomic volume.

ocean thermal energy conversion (OTEC)—A process of generating electrical energy by harnessing the temperature differences between surface waters and ocean depths.

"off-peak" power—Power generated during a period of low demand.

oil shale—A sedimentary rock containing a solid organic material called kerogen. When oil shale is heated at high temperatures, the oil is driven out and can be recovered.

OPEC—The Organization of Petroleum Exporting Countries. An organization of countries in the Middle East, North Africa, and South America which aims at developing common oil-marketing policies.

particulates—The small soot and ash particles produced by combustion.

peak demand period—That time of day when the demand for electricity from a powerplant is at its greatest.

peak load—The maximum amount of power delivered during a stated period of time.

peak load pricing—Charging more for the delivery of power during the daily period in which demand is the greatest. (See "peak demand period".)

petroleum—(or oil) an oily, flammable liquid that may vary from almost colorless to black and occurs in many places in the upper strata of the Earth. It is a complex mixture of hydrocarbons and is the raw material for many products.

photoelectric—Pertaining to electric effects produced by light.

photon—A quantum (the smallest unit) of electromagnetic radiation. It has no rest mass or electric charge, but behaves like both a particle and a wave in its interactions with other particles.

photosynthesis—The process by which green plants convert radiant energy (sunlight) into chemical potential energy.

Photovoltaic—Providing a source of electric current under the influence of light.

Photovoltaic generation—Direct and continuous generation of electrical energy by a material whenever it is illuminated by light; this is accomplished without breakdown of the material.

plasma—An electrically neutral, gaseous mixture of positive and negative ions. Sometimes called the "fourth state of matter," since it behaves differently from solids, liquids and gases. High temperature plasmas are used in controlled fusion experiments.

Plutonium (Pu)—A heavy, radioactive, man-made, metallic element with atomic number 94. Its most important isotope is fissionable plutonium 239 ($94Pu^{239}$), produced by neutron irradiation of uranium 238. It is used for reactor fuel and in weapons.

potential energy—"Stored" energy. Energy in any form not associated with motion such as that stored in chemical or nuclear bonds, or energy associated with the relative position of one body to another.

power—The rate at which work is done or energy expended. It is measured in units of energy per unit of time such as Calories per second, and in units such as watts and horsepower.

power gas—A mixture of carbon monoxide and hydrogen which has a low heat value (25–75 Calories/cubic feet) and is of most use as power plant fuel.

primary energy—Energy in its naturally-occurring form—coal, oil, uranium, etc.—before conversion to end-use forms.

proton—An elementary particle present in all atomic nuclei. It has a positive electric charge.

Its mass is approximately 1,840 times that of an electron. The nucleus of a hydrogen atom.

SI—Abbreviation for "pounds per square inch." A measure of pressure.

umped storage—An energy storage system in which reversible pump turbines are used to pump water uphill into a storage reservoir. The water can then be used to turn the turbines when it runs downhill.

yrolysis—Heating in the absence of oxygen. Also called "destructive distillation"; pyrolysis of coal produces three fuels: high BTU or pipeline gas, a synthetic crude oil (syncrude), and char, a carbon residue. Also used in the conversion of organic wastes to fuel.

adioactive decay—The spontaneous transformation of an atomic nucleus during which it changes from one nuclear species to another with the emission of particles and energy. Also called "radioactive disintegration."

actor years—One year's operation of a nuclear reactor.

coverable resource—That portion of a resource expected to be recovered by present-day techniques and under present economic conditions. Includes geologically expected but unconed resources as well as identified reserves.

regenerative braking—Braking in which the energy is recovered either mechanically, in a flywheel for instance, or electrically. This energy can then be used in subsequent acceleration.

reserve—That portion of a resource that has been actually discovered but not yet exploited which is presently technically and economically extractable.

secondary recovery—Recovery techniques used after some of the oil and gas has been removed and the natural pressure within the reservoir has decreased.

Second Law of Thermodynamics—One of the two "limit laws" which govern the conversion of energy. Referred to sometimes as the "heat tax," it can be stated in several equivalent forms, all of which describe the inevitable passage of some energy from a useful to a less useful form in any cyclic energy conversion.

Second Law of Efficiency—The ratio of the minimum amount of work or energy necessary to accomplish a task to the actual amount used.

solar cells—Photovoltaic generators that yield electrical current when exposed to certain wavelengths of light.

olar energy—The electromagnetic radiation emitted by the sun. The Earth receives about 4,200 trillion kilowatt-hours per day.

olvent refined coal (**SRC**)—A tar-like fuel produced from coal when it is crushed and mixed with a hydrocarbon solvent at high temperature and pressure. It is higher in energy value and contains less sulfur or ash than coal.

tirling engine—An external combustion engine in which air (or hydrogen in the newer versions) is alternately heated and cooled to drive the piston up and down. It is claimed to be non-polluting and more efficient than the internal combustion engine.

ratified charge engine—An engine in which the amount of charge, fuel plus air, is adjusted to engine conditions, directed to the area where it will burn best and fired at just the precise instant.

rontium 90 (38Sr^{90})—A hazardous isotope produced in the process of nuclear fission. Strontium 90 has a "halflife" of 28 years. Thus it takes 28 years to reduce this material to half its original amount, 56 years to one quarter, 84 years to one eighth, and so on. Strontium 90 typifies problems of radioactive waste storage which are faced in producing power b...ns of nuclear fission.

sulfur smog (classical smog)—This smog is composed of smoke particles, sulfur oxides (SO_x), and high humidity (fog). The sulfur oxide (SO_3) reacts with water to form sulfuric acid (h_2SO_4) droplets, the major cause of damage.

superconductor—A material which at very low temperatures, near absolute zero, has no electrical resistance and thus can carry large electrical currents without resistance losses.

synthetic natural gas (**SNG**)—A gaseous fuel manufactured from coal. It contains almost pure methane, CH_4, and can be produced by a number of coal gasification schemes. The basic chemical reactions are $C + H_2O + \text{heat} \longrightarrow CO + H_2$; $3CH_2 + CO \longrightarrow CH_4 + H_2O$.

tar sand—A sandy geologic deposit in which low grade, heavy oil is found. The oil binds the sand together.

tertiary recovery techniques—Use of heat and other methods to augment oil recovery (presumably occuring after secondary recovery).

thermal storage—A system which utilizes ceramic brick or other materials to store heat energy.

thermodynamics—The science and study of the relationship between heat and other forms of energy.

rmostat—A temperature-sensitive device which turns heating and cooling equipment on and off at set temperatures.

orium (Th)—A naturally radioactive element with atomic number 90, and as found in nature, an atomic weight of approximately 232. The fertile thorium 232 ($90Th^{232}$) isotope can be transmuted to fissionable uranium 233 ($_{92}U^{233}$) by neutron irradiation.

kamak—(toroidal magnetic chamber) The Russian adaptation of the toroidal or "doughnut" geometry. The plasma is confined in the central region of an evacuated doughnut-shaped vessel by a magnetic field provided by current-carrying windings around the outside. A separate set of windings produce a heating current in the plasma. American examples are the PLT (Princeton Large Torus) and the ORMAC (Oak Ridge Tokamak).

ping cycle—A means to use high-temperature heat energy that cannot be used in a conventional steam turbine. A gas turbine, for instance, might operate as a topping cycle on furnace gases of 2000°F and its exhaust could then heat steam for a turbine operating at 1000°F.

al energy system—A packaged energy system of high efficiency, utilizing gas fired turbines c... ines which produce electrical energy and utilize exhaust heat in applications such as heating and cooling.

Tritium—A radioactive isotope of hydrogen with a half life of 12.5 years. The nucleus contains one proton and two neutrons. It may be used as a fuel in the early fusion reactors.

voltage—A measure of the force of an electric current.

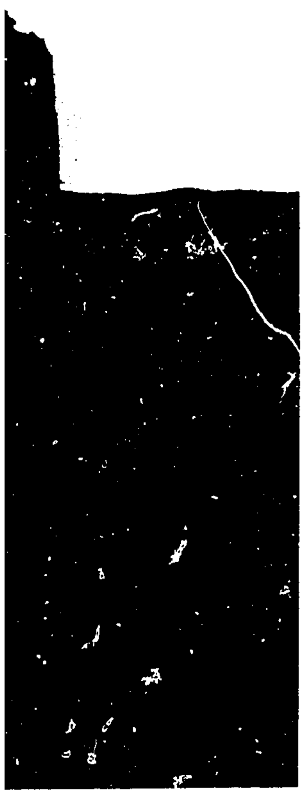
watt (w)—A metric unit of power usually used in electric measurements which gives the rate at which work is done or energy expended. One watt equals one joule of work per second.

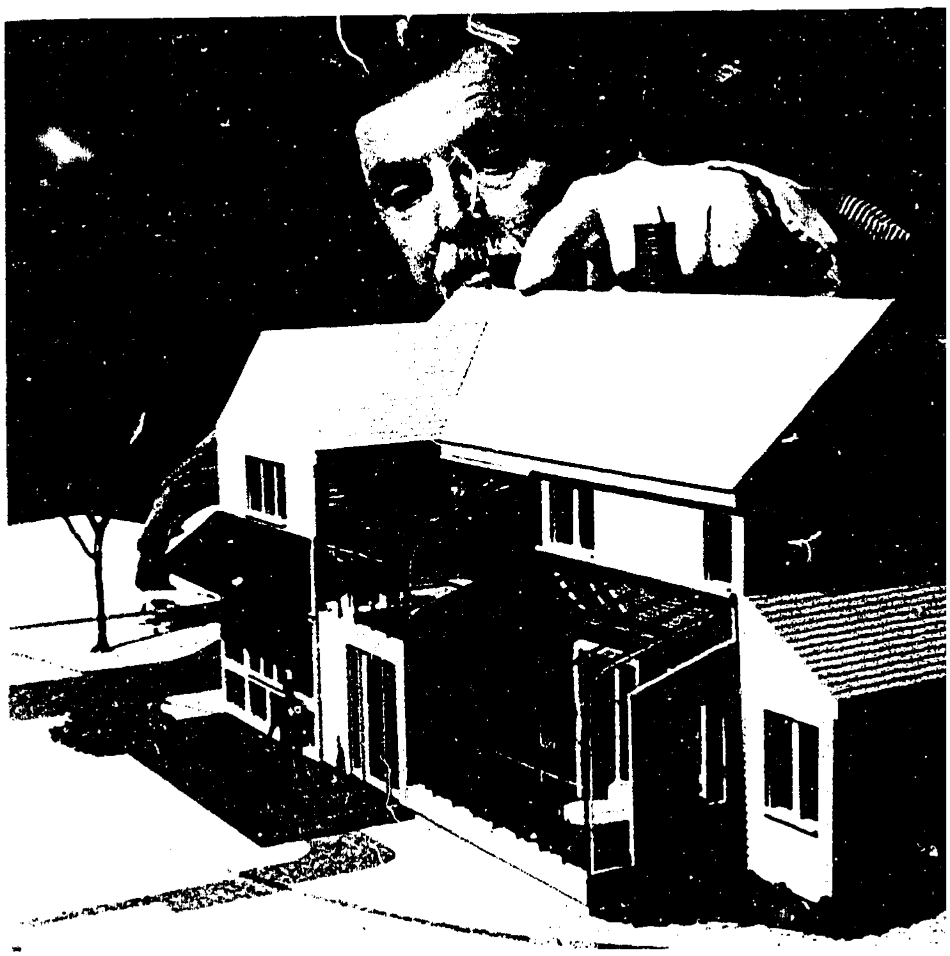
work—Energy that is transferred from one body to another in such a way that a difference in temperature is not directly involved. The product of an external force times the distance an object moves in the direction of the force.

working fluid—The material, usually a gas or a liquid, whose absorption of heat and subsequent expansion drives a heat engine. Steam is the "working fluid" of a steam engine.

yellowcake—The material which results from the first processing (milling) of uranium ore. It is sometimes called "artificial carnotite" and is about 53% uranium, a mixture of UO_2 and UO_3.

SUGGESTED READING





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