The *Asian Programme of Educational Innovation for Development (APEID)*, initiated on the recommendation of the Third Regional Conference of Ministers of Education and Those Responsible for Economic Planning in Asia (May–June 1971, Singapore) and the authorization of the General Conference of Unesco at its seventeenth session (Paris, 1972), aims at stimulating and encouraging educational innovations linked to the problems of national development in the Asian region.

All projects and activities within the framework of APEID are designed, developed and implemented co-operatively by the participating Member States through their national centres which have been associated by them for this purpose with APEID.

The 20 countries in Asia and Oceania participating in APEID are: Afghanistan, Australia, Bangladesh, India, Indonesia, Iran, Japan, Lao People's Democratic Republic, Malaysia, Nepal, New Zealand, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Republic of Maldives, Singapore, Socialist Republic of Viet Nam, Sri Lanka and Thailand.

The Asian Centre of Educational Innovation for Development (ACEID) has been established at the Unesco Regional Office for Education in Asia and Oceania in Bangkok to co-ordinate the activities under APEID and to assist the associated national institutions in carrying them out.

The aims of APEID are:

- to stimulate efforts of the Member States to impr... e the quality of life of the people through creating and strengthening national capabilities for the development and implementation of innovations in education, both formal and non-formal;
- to encourage the Member States to make all groups (students, teachers, parents, village and community leaders, administrative personnel and policy makers) aware of the need for relevant changes in education (both formal and non-formal) as an essential pre-requisite for the improvement of the quality of life of the people;
- to promote understanding and appreciation of the differences in educational practices and approaches of the Member States, and thereby contribute to international understanding and the creation of a new international economic order.

WHERE DO WE GET ENERGY?

By Boy Scouts of America

Where we turn to get the energy we need is often determined by what we are going to use it for. Food is the obvious source of the energy we need to stay alive, to grow, and to replace worn-out cells and tissues. Coal, oil, or gas provides the energy we need to warm or cool our homes and other buildings. Gasoline or diesel oil provides the energy needed to drive our automobiles, trucks, planes, ships, and trains. Usually electrical energy drives our small motors, operates telephones, radios, TV sets, and other communication systems. Chemical energy in explosives moves things.

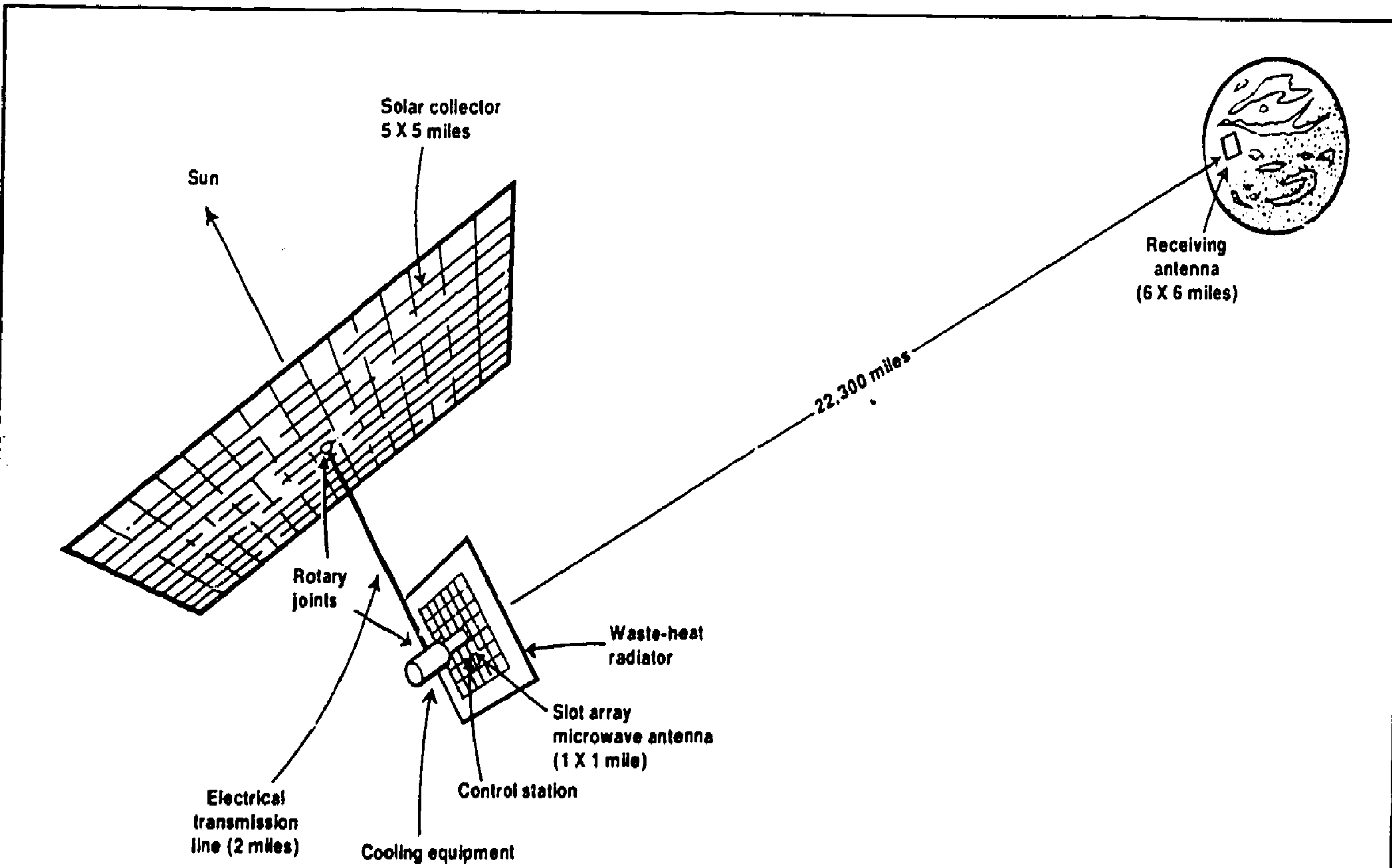


Figure 1. Satellite Power Station

2

able 1 gives examples of the immediate sources f much of the energy we use. We can also ask here the energy comes from that these sources rovide. We now that foods store solar energy. imilarly, the energy in coal, oil, and gas can be raced to solar energy that was stored in plants illions of years ago. Electrical energy is produced by generators. The generators, in turn, are powered by coal, oil, gas, water power, or nuclear reactors, which produce the heat energy needed to make the steam that drives the generators.

TABLE 1

UNITED STATES ANNUAL GROSS ENERGY SUPPLY AS OF MID-1973: PERCENT OF TOTAL DEMAND

(Total rate of energy consumption in 73,836 quadrillion Btu per year)

Source	Net Domestic Production (%)
Petroleum [a]	29.9
Natural Gas (dry)	30.6
Coal	19.6
Hydropower	4.0
Nuclear	1.0
Wood [b]	1.4
Production and Distribution Waste	13.5
TOTAL	100.0

[a] In... atural gas liquids
[b] R... mate

Generators produce electrical energy by taking advantage of a principle that was discovered by Michael Faraday in the early 1800's. Faraday proved that electrical currents are generated when an electrical conductor moves through a magnetic field. Today, large turbines are set spinning by steam or water power. Attached to these turbines are large coils of wire which move through magnetic fields. As a result, electrical energy is generated in these moving coils.

Energy Transformations

Although energy enables us to do all the things we like and need to do, energy isn't always available in the form that best solves our problems. Many people, especially engineers, spend their time and use their minds to figure out how to change energy that is available in one form to another form so that the energy can be used to solve our problems.

For example, electricity provides a way to transport energy. Power companies can send energy in large or small amounts anywhere they can string wires or cables. The electrical outlets in our homes become convenient sources of energy.

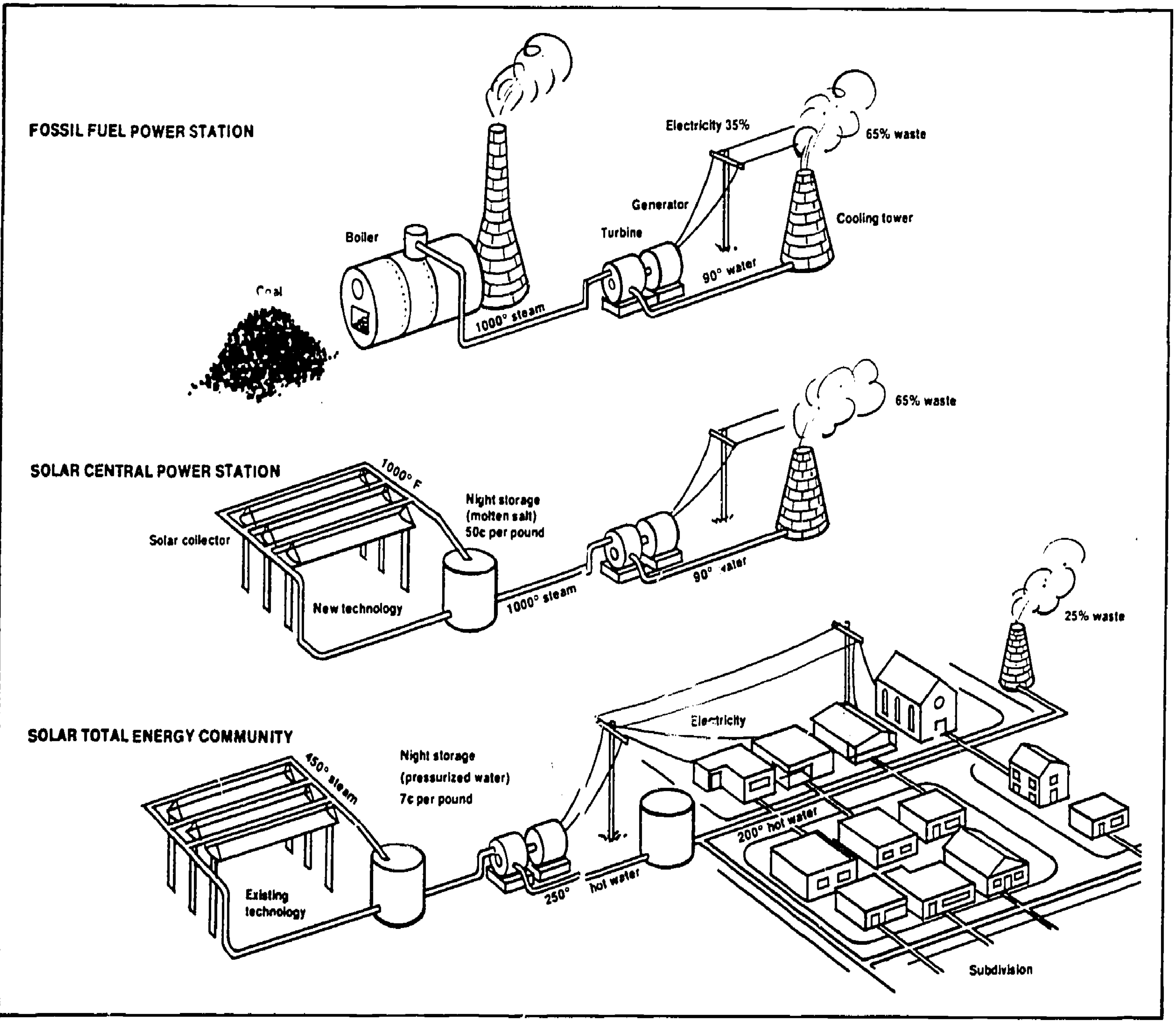


Figure 2. Different Methods of Generating Power

But electricity as such solves very few of our problems. It must be changed to another form of energy. This is shown in Figure 3.

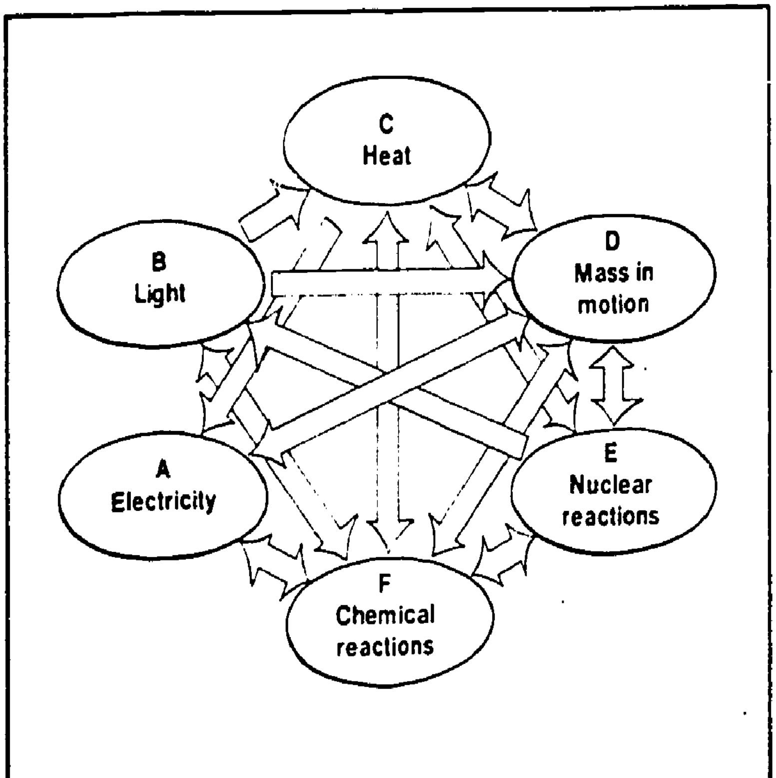


Figure 3. Transforming Energy

Much information is summarized by the diagram. Suppose, for example, you are reading this . . . after the sun has gone down. You need light, so you flip on electrical switch A. Immediately electrical energy is changed to heat C and light energy B. But the electrical energy came from whirling turbines and generators—that is, from mass in motion D. In turn, these turbines and gen-

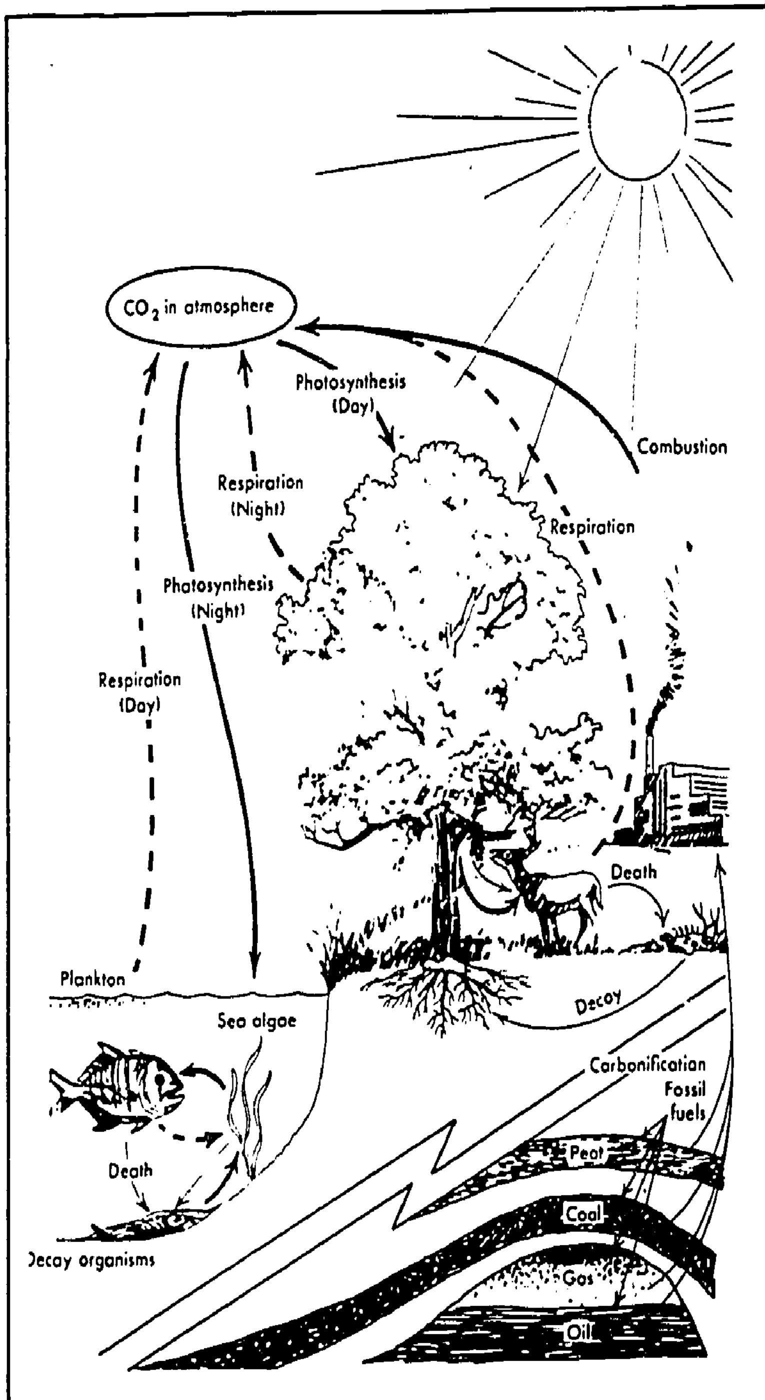
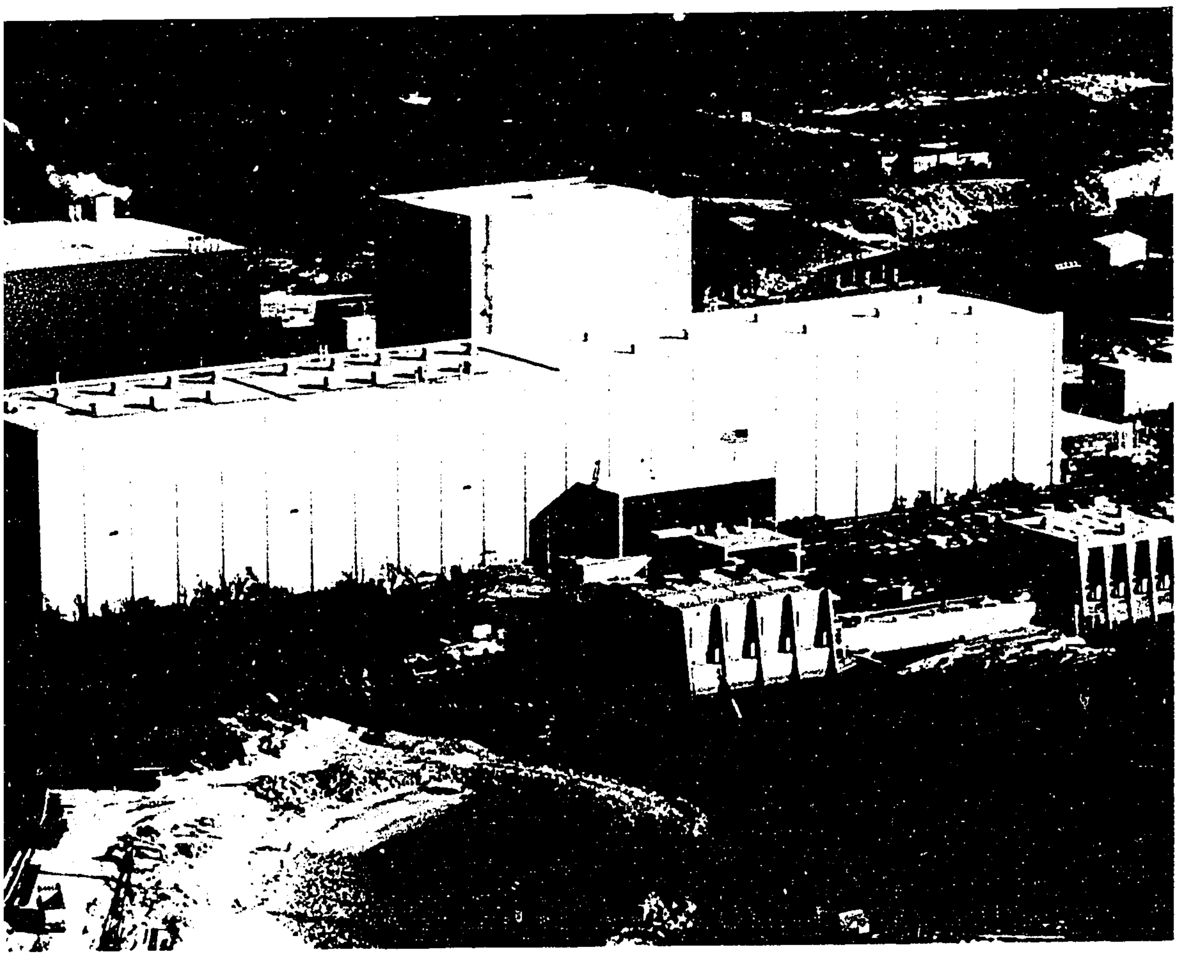


Figure 4. Energy Flows and Material Cycling

Concentrated sunlight striking a steel target on th



is the largest operating nuclear unit in New England. It generates 830 megawatts of electricity.

erators may have been driven by steam. Steam is an effective way to store and move heat energy—heat energy that may have been obtained by burning coal, oil, or gas F. When these fuels burn, chemical energy is released—chemical energy that may have been locked up millions of years ago by green plants putting carbohydrate molecules together in the process known as photosynthesis.

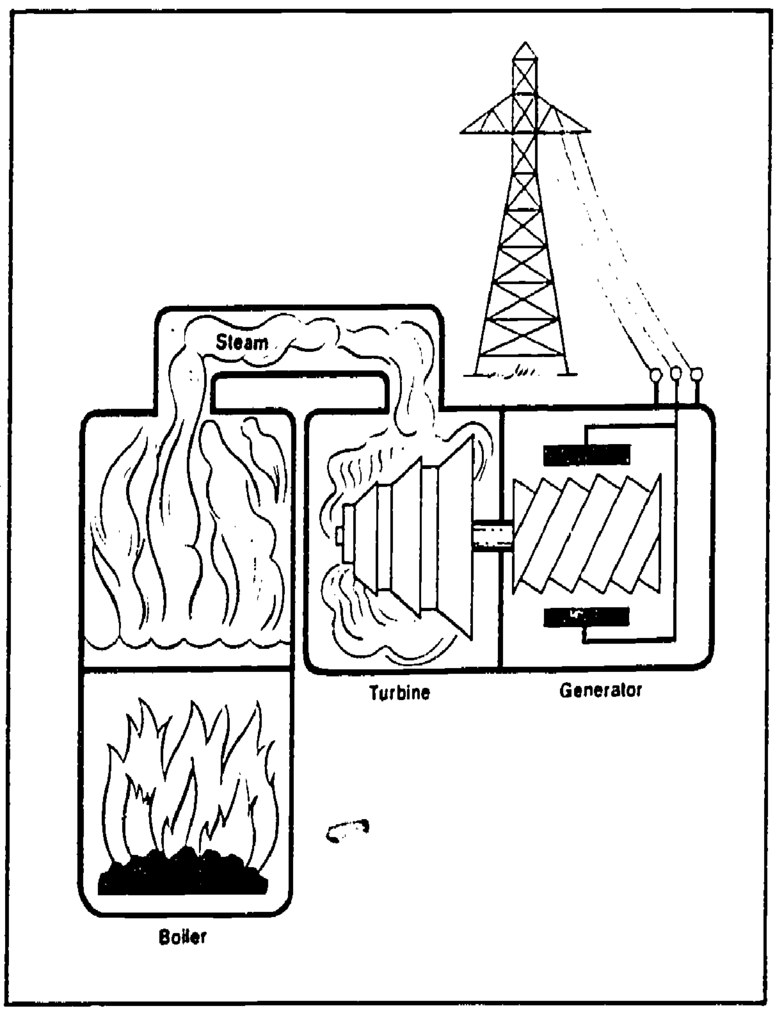


Figure 5. *Fossil Fuel Generating Plant*

A generally accepted theory says that the sun's energy comes from an enormous hydrogen reaction E going on in the sun. On this basis, we can add another link, nuclear energy, to the long chain of events which enable you to obtain light by flipping a switch. You can ask, of course: Where does the energy come from that is released when heavy hydrogen atoms are fused to form helium

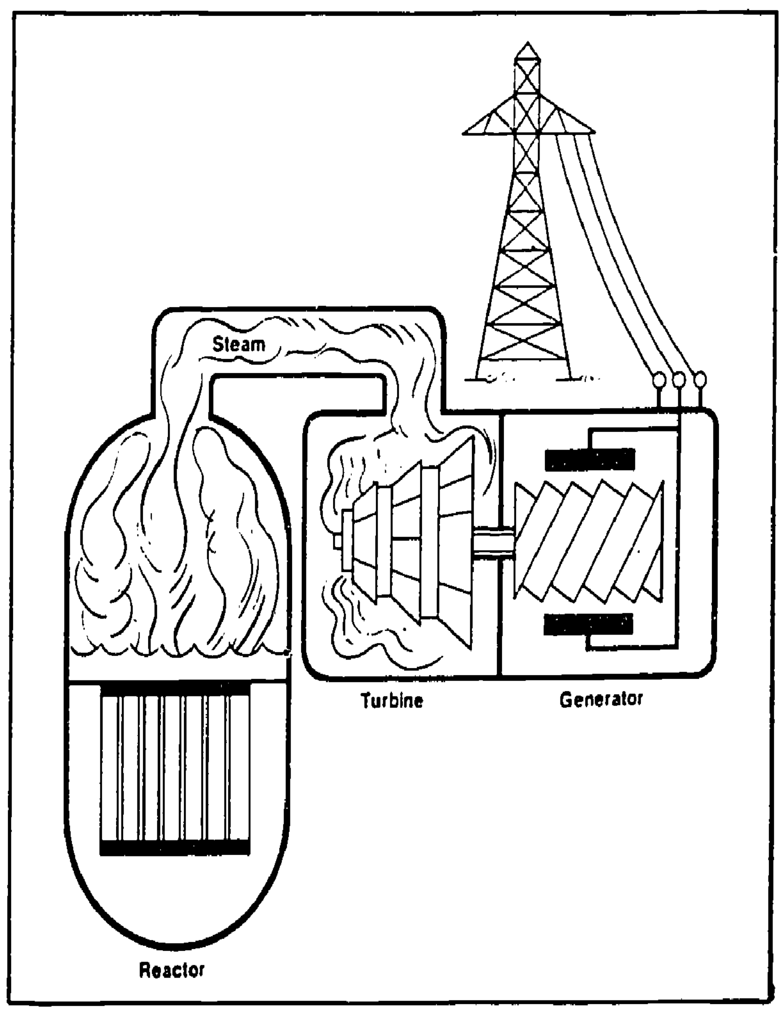


Figure 6. Nuclear Energy Generating Plant

atoms? Or, why is energy created when mass disappears? There are theories that give answers to these questions—theories that take years of study to understand. For many of us, it is enough to appreciate the effectiveness of the sun as a source of energy and turn our curiosity to other things.

Other Transformations

What has been said in these paragraphs can be traced in Figure 3 as: A←B←B←D←C ←F ←B←E. Try to trace other examples of using energy transformations to solve problems.

Suppose, for example, you prefer cooked rather than raw eggs for breakfast. What energy transformations do you take advantage of? Or suppose you want a snapshot for a souvenir of a holiday? Or want to ride the bus rather than walk to school? Practice putting together the "links" in energy transformation "chains" until you feel you can tell the story of how different forms of energy help you solve problems.

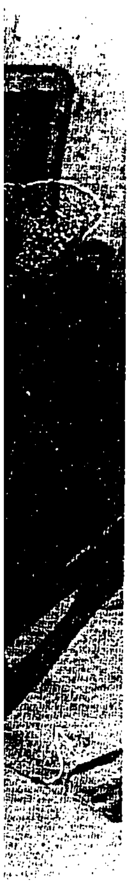
Don't overlook the energy changes that occur in your body. Something happened, for example, before you decided to flip that electrical switch when you needed light. To come to this decision may have called for some kind of energy transformation. You are alive, and life depends on energy transformations. But how energy is involved when our brains do what they do takes us into very, very complex questions.

Less mysterious are the energy changes whereby muscles enable you to reach and flip the electrical switch. We know that nerve impulses involve chemical energy. Chemical energy, in turn, can cause muscles to contract—that is, to set mass in motion—and it is the movement of your arm and fingers that we are trying to explain. Keeping these ideas in mind adds at least two more "links" to our lightswitch energy transformation chain.

SELECTIONS FROM

THE FIRST BOOK OF ENERGY

By George Russell Harrison

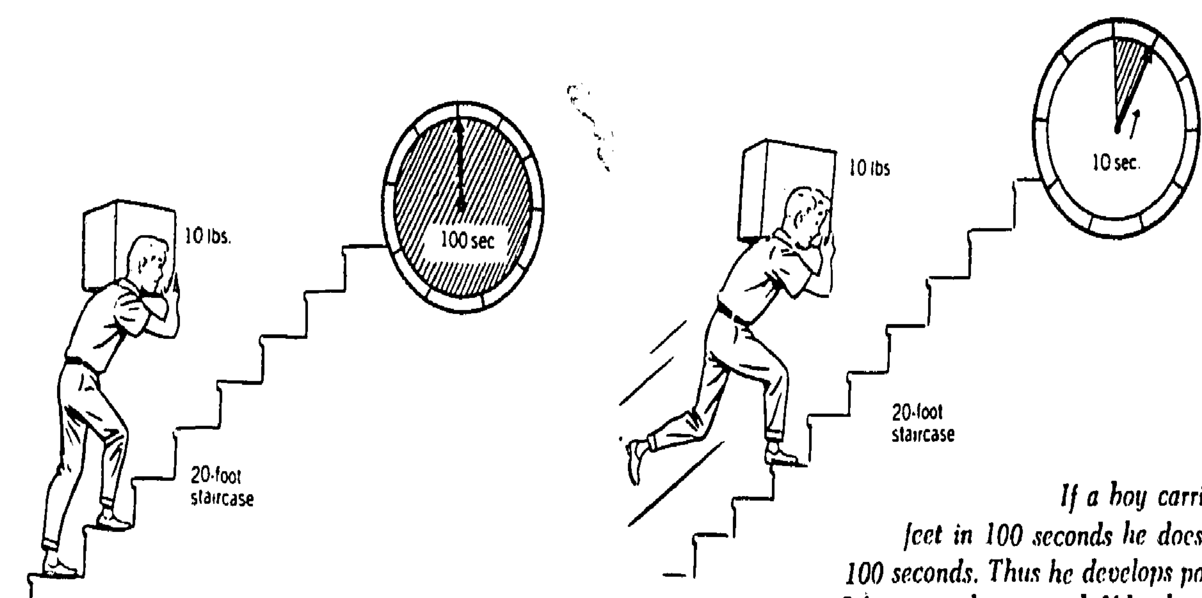


HOW ENERGY IS MEASURED

If we are to learn how to avoid wasting energy, we must first know how to measure it.

The best way to measure energy is to see how much work it can do. Work is easily measured in units called *foot-pounds*, by multiplying the force needed to do the work by the distance this force moves while doing it. If you raise a 10-pound box 20 feet, by carrying it from the basement to the attic, you will do 10 × 20, or 200, foot-pounds of work.

Another good way to measure energy is in terms of *power*. Power measures the rate at which energy flows or is used. If you carry the 10-pound box up 20 feet so slowly that it takes you 100 seconds to do the work, you will be generating power at the rate of 10 × 20 (or 200) divided by 100, or 2 foot-pounds per second. But if you run, so as to get the 200 foot-pounds of work done in 10 seconds, you will use power at the rate of 10 × 20 (or 200) divided by 10, or 20 foot-pounds per second. You have done the same amount of work in both cases, and have used up the same amount of energy. But in the second case you have used power ten times as fast for only one-tenth as long.



If a boy carries a 10-pound weight up 20 feet in 100 seconds he does 200 foot-pounds of work in 100 seconds. Thus he develops power at the rate of 200/100 or 2 foot-pounds a second. If he does the work faster, he generates more power. If he runs up the stairs with the same weight in 10 seconds he generates power at the rate of 20 foot-pounds a second.

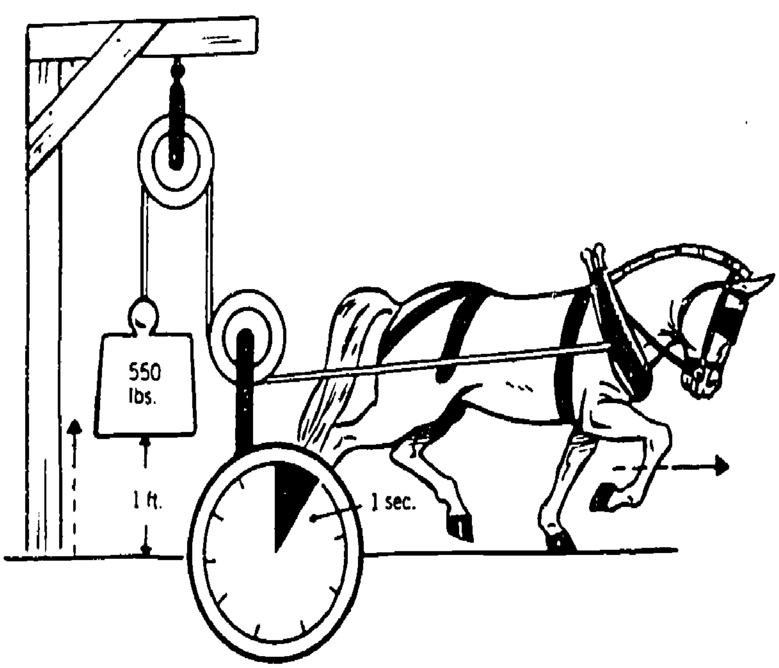
Figure 1. Energy Measured in Foot-Pounds per Second

The idea of power measurement originated nore than a century ago when engineers wanted to neasure the ability of steam engines to pump vater out of coal mines. Because the pumps had previously been turned by horses, new steam engines were rated in terms of how many horses they could replace. If an engine could operate pumps at about the same rate as 10 horses, it was called a 10 horsepower engine (usually written 10 h.p.).

Today one horsepower is defined as 550 foot-pounds of work per second. One horse can develop power at the rate of several horsepower for a few minutes, but it can *average* only about 1/7 h.p. over a long stretch. A horse needs time to eat, rest, and sleep, and in order to give as much power all the time as a 1 h.p. engine, about seven horses would be needed. A man can do steady work at the rate of about 1/20 h.p., or nearly 28 foot-pounds per second, for an eight-hour day. He can develop more than 1 h.p. for a short time.

Some gasoline engines of the kind used in large automobiles can develop 300 h.p. or more when given gasoline as rapidly as they can burn it. A large airplane of the sort that flies across the Atlantic Ocean uses four jet engines which together may develop more than 50,000 h.p.

To find out how much energy a given amount of power brings, we multiply the power by the time



A horse generates one horsepower if it does work at the rate of 550 foot-pounds a second. It could do this by exerting enough force to lift a 550-pound weight one foot in each second, or a one-pound weight 550 feet in each second, or an 1,100- pound weight six inches in each second. A horse can do much more than this for a short time, but soon gets tired.

Figi ... nergy Measured in Horsepower

during which it acts. A 10 h.p. engine working for 2 hours at full power changes 10 × 2, or 20, *horse-power-hours* of chemical energy into mechanical energy, if it doesn't waste any.

Electrical power is usually measured in kilowatts. Since one kilowatt is equal to about 1.3 h.p., 1 kilowatt-hour of energy, usually written 1 kw-h., is equal to about 1.3 horsepower-hours. When the owner of a house pays his electricity bill at the end of the month, he usually pays from three to six cents for each kilowatt-hour that came into his house through the electric power meter. In factories, because a great deal of electrical energy is used, each kilowatt-hour may cost as little as one cent or less.

Heat energy is usually measured by seeing how much the heat can raise the temperature of a certain amount of water. The energy needed to heat a pound of water one degree on the Fahrenheit temperature scale (1°F.) is called a *British thermal unit,* written Btu.

If you should want to know how much heat is needed to warm the water to fill a hot-water bottle, you need only multiply the amount of water (say 2 quarts, which is 4 pounds) by the number of degrees you want to heat the water (say from 60 F., as it comes out of the faucet, to 120°F.). Thus you find that 4 × 60, or 240, Btu are needed. As one pound of coal gives out about 9,000 Btu of heat energy when it is burned, you would need to burn only a teaspoonful or so of coal to heat the water, if you did not waste any heat.

The energy in food is usually measured in *large calories* instead of British thermal units. A *large calorie*, or *kilocalorie*, is the amount of heat needed to raise the temperature of one kilogram of water (about 2.2 pounds) one degree on the Centigrade temperature scale. Kilograms and Centigrade degrees are units of weight and temperature which are used in many European countries, and by scientists all over the world.

A human being needs on the average about 1,500 calories of energy from food each day just to keep him alive, if he rests in bed. If he moves the muscles of his arms and legs he will need more calories. As most people use at least 1,000 extra calories a day in working, they usually take from 2,500 to 3,000 calories of chemical energy in their food each day. A man who does very hard work, such as digging with a pickax and shovel, or cutting down trees with an ax and saw, may need as many as 5,000 calories a day.

If a person eats more than he needs, some of the energy he does not use is stored as chemical energy in his body, in the form of fat, which the body may "burn" later.

Since any kind of energy can be changed into any other kind, each can be measured in any of the energy units.

e small farms still use this vanishing method of tilling the soil.

ENERGY IS NEITHER CREATED NOR DESTROYED

An Indian twirling a firestick with the string of a bow is changing muscular energy from his arm into mechanical energy moving the stick. This is changed into heat energy by friction, and this energy warms up the wood so that it bursts into flame.

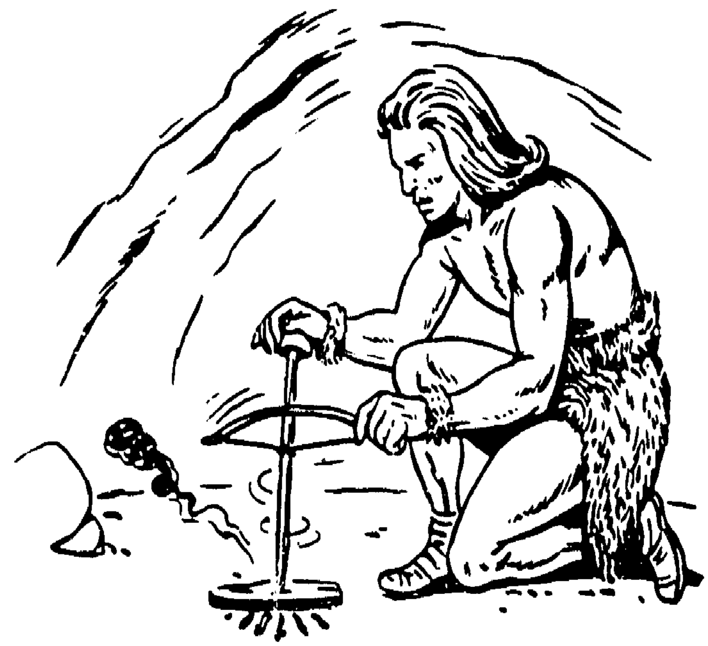


Figure 1. Converting Muscular Energy to Heat

Scientists have made many experiments to measure the amount of energy that comes out of a machine as work when a certain amount of energy is put in. Always it turns out that the amount of energy that appears as work is less than the original amount of energy. If the scientists carefully measure all the energy that is lost as well as that which produces work, however, they find that the total energy that has been used up is exactly *equal* to that which was originally put in. This finding is stated in the *law of conservation of energy.*

This law, based on the way nature has been to act, says that energy is neither created nor destroyed, but merely changed from one form to another.

As long ago as 1798 a physicist named Count Rumford, working in Germany, made many careful measurements of the amount of work that his soldier mechanics did in boring holes in cannon, and the amount of heat energy that appeared in the cannon, which got very hot. Count Rumford found that if a certain amount of work was done in turning the drill in the cannon, a certain amount of heat was produced, and if twice as much work was done, twice as much heat appeared. Primitive peoples use the same principle of converting work into heat when they start a fire with a fire stick twirled by a bowstring.

Since Count Rumford's day other scientists have found, over and over again, that one form of energy is equivalent to another, and that an amount of each which can be converted to a certain amount of the other will always do the same amount of work, if no energy is allowed to escape.

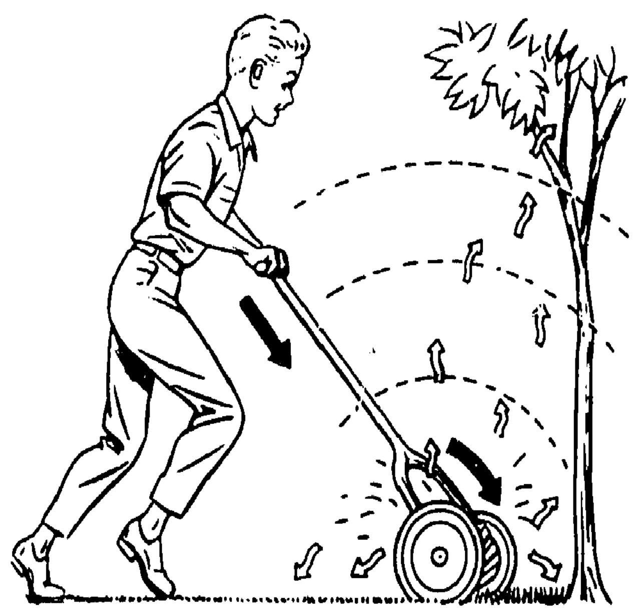
The less energy a device wastes in converting it from one form to another, the higher the efficiency of the device. Since even the most efficient steam engines waste as much as two-thirds of the heat energy put into them, they are only about 33-1/3 percent efficient. A very good electric motor may have an efficiency of 90 percent, wasting only one-tenth of the energy put into it.

Many inventors have tried to build machines that would give out more energy than was put into them. Such a machine would have an efficiency of more than 100 percent and would create energy. Machines of this sort, which are called perpetual motion machines, have never been made to work. This is because, as the law of conservation of energy tells us, nature operates in such a way that energy is neither created nor destroyed—merely changed from one form to another.

HOW ENERGY IS LOST

Although energy cannot be destroyed, it can easily be converted into a form such that we cannot use it anymore. In fact, whenever energy is converted, as when it is made to do work in a machine, some always escapes.

Think about what happens to the energy a boy puts into a lawn mower when he cuts the grass. The force needed to push the mower ahead comes from muscular energy stored in the boy's leg, arm, and shoulder muscles. By pushing the mower he converts this muscular energy into the mechanical energy of rolling wheels and whirring blades. Most of this energy goes into work against the resisting forces of friction, as the cutters snip off dozens of blades of grass at a time. As each grass blade is cut, it is slightly warmed by the energy that overcame this friction. The whole lawn is thus made a bit warmer than it was before it was cut. But soon this heat escapes into the ground and the air, and the energy has all disappeared. As it still exists somewhere, however, it has merely been lost—not destroyed.

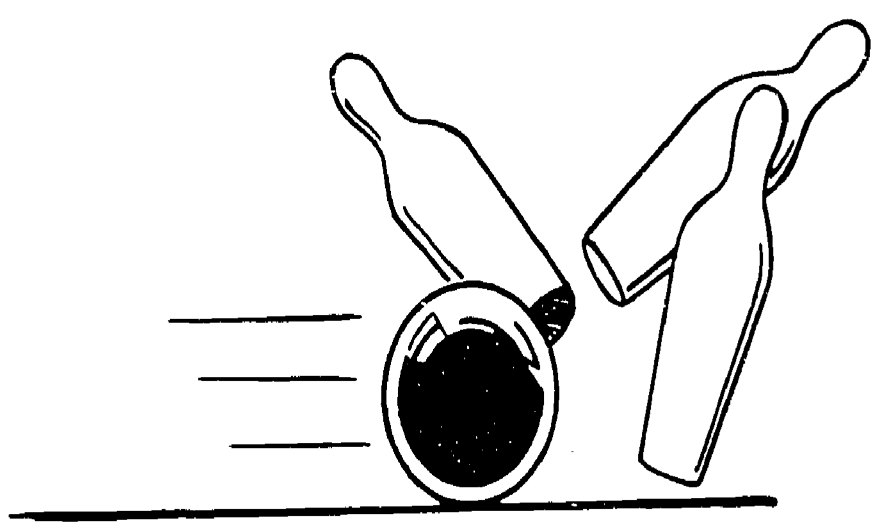


A boy pushing a lawn mower puts into it muscular energy, which does the mechanical work of cutting the grass, and through friction is changed into heat which warms the grass, the mower, and the surroundings.

Figure 1. Mechanical Energy Changes to Heat and Sound

What happens to the energy a man puts into a bowling ball when he knocks over tenpins with it? Muscular energy comes out of his arms and makes the ball roll, storing kinetic energy in itself as it rotates. As it rolls down the bowling lane, it is slowed down a little by friction. This friction changes some of the ball's energy into heat, warming the ball, the wooden floor on which it rolls, and the air. When the ball bangs into the tenpins, it knocks them over, making noise. When both ball and pins finally stop moving and the noise dies down, the energy that was originally in the man's arm and then in the ball has all been changed into heat, which finally is spread far and wide.

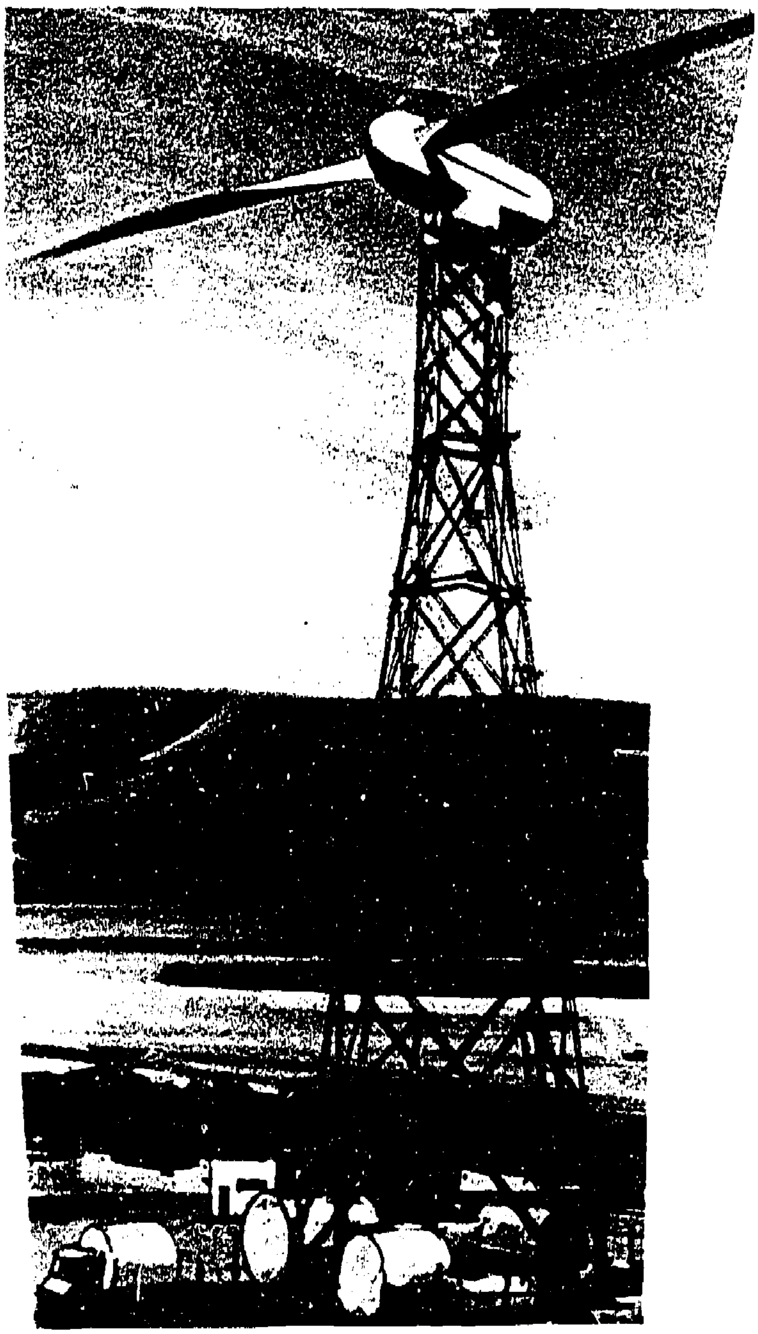
This is what happens to all lost energy. It is changed into heat and warms up the air and earth around it. Gradually all the hotter things in the universe are cooling off, and the cooler things are warming up. Eventually everything will come to the same temperature. Then there will not be any more energy that people can use, because energy can do work only when it flows from a hotter to a cooler place.



The mechanical energy of a rolling bowling ball is changed into heat and sound energy when it strikes the pins.

Figure 2. Relative Amounts of Stored Energy

STORING ENERGY IN MATTER



Artist's rendering of a wind driven turbine.

For several reasons it is important to be able to store energy. One good reason is that it can thus be kept for later use. The energy gathered from the wind by a windmill, for instance, can be used only while the wind is blowing, unless it is stored in some way.

Another reason is that when energy is stored in matter it can be shipped easily from one place to another. Gasoline, butter, coal, and storage batteries are all examples of matter that is valuable mainly because energy is stored in it. So are wound-up clocks, and cylinders full of gas that can be burned. It pays to store as much energy as possible in each pound of matter, in order to avoid carrying too heavy loads of it around.

A third reason for storing energy is that it may thus be carried with us when none is obtainable along the way. An automobile traveling across a desert with no filling stations needs to carry a large amount of gasoline. A jet airplane flying across the Atlantic Ocean must carry in its wings as much kerosene as five large tank trucks could hold.

There are many ways of storing energy. All involve fastening the energy to matter in some way, either to groups of molecules, or inside the molecules, or inside the atoms of which the molecules are made, or even inside the tiniest parts of these atoms.

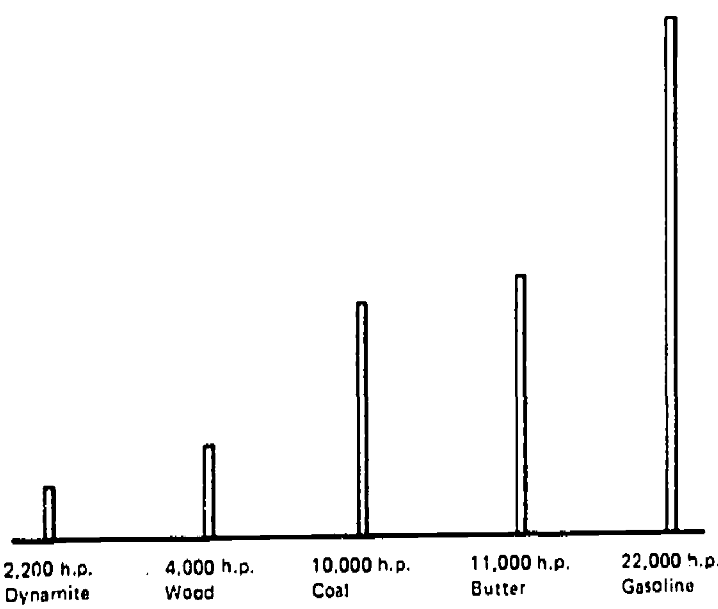
Engineers and scientists frequently ask hemselves the question, How can we store the reatest amount of energy in a small amount of hatter? They have found that the answer is, Store t as deep in the matter as you can. More energy an be tucked into an atom than between the toms of a molecule, and more can be tucked etween the atoms of a molecule than between he molecules themselves.

Although enough energy can be stored in a andful of rubber bands to fly a toy airplane a few undred feet, millions of tons of rubber bands ould be needed to store enough energy to carry a ig airplane across the ocean. This load would be o heavy that the plane could not fly.

Airplanes and automobiles use gasoline and erosene because large amounts of chemical energy an be stored in a given weight of these materials. here is as much chemical energy in a pound of uel oil as there is elastic energy in thousands of arm clock springs fully wound up.

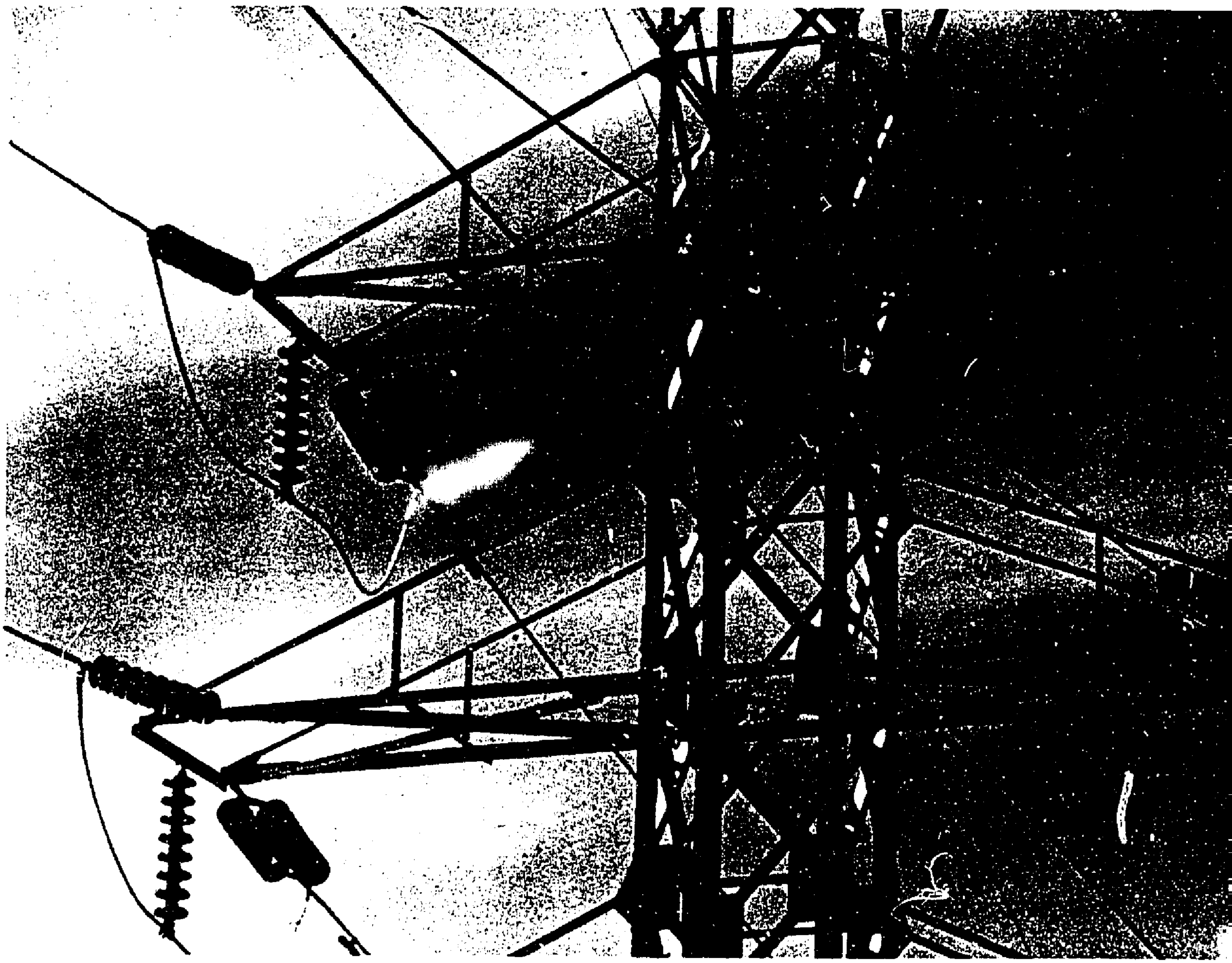
The following diagram shows the relative mounts of energy that can be stored in matter in ifferent ways. It shows that more chemical energy stored in a pound of butter than in a pound of ynamite, and that still more is stored in a pound f gasoline.

Both kinetic and potential mechanical energy are stored in a piece of matter *as a whole*. Elastic energy is stored *between the molecules* of matter. Because chemical energy is stored *inside* the molecules, *between the atoms*, much more energy of this kind can be stored in a pound of matter.



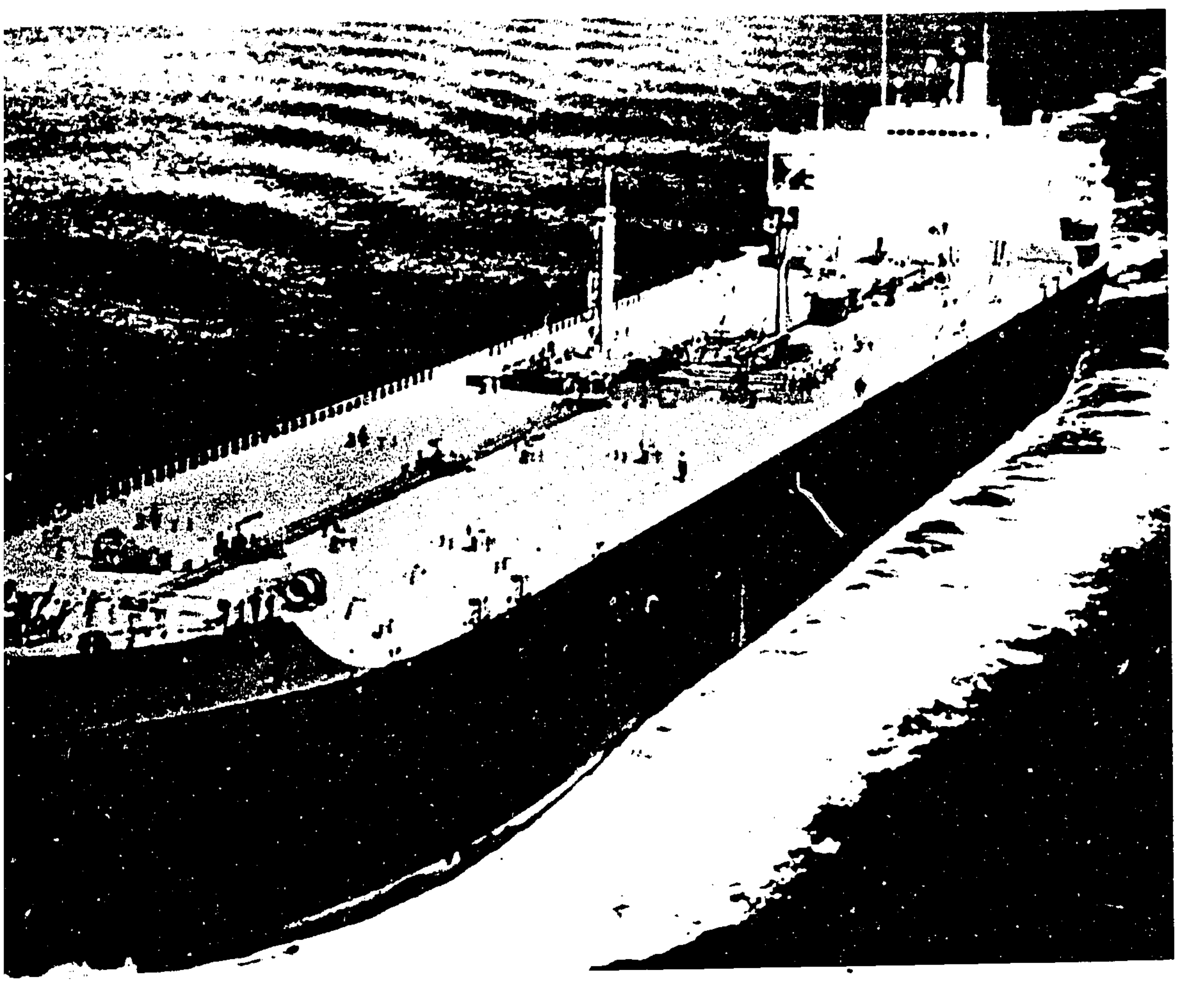
The relative amounts of energy stored in one pound of each of various materials commonly used to provide energy. Note that a pound of gasoline contains ten times as much energy as a pound of dynamite.

Figure 1. Measuring Stored Gas



High-tension wires, each carrying up to 345,000 volts, are the principal means of transporting
tances.

electricity over long dis-



ıpe are used to transport oil to the United States.

CARRYING ENERGY FROM PLACE TO PLACE

The cheapest way to carry energy from one place to another is to carry matter that contains as much energy stored in it as possible. The energy can then be released from the matter at the place where it is to be used.

Today coal can be carried cheaply in ships, if arrangements are made to load and unload them by machine. It can also be sent cheaply overland on a railroad, in coal cars that can be filled from giant hoppers at the coal mine and unloaded through doors at the bottom that let coal tumble down a chute.

Since a ton of oil contains almost twice as much energy as a ton of coal, and since oil can be handled with pumps besides, shipping and using it instead of coal is often worthwhile. Oil is usually sent across the oceans in tankers. A big oil tanker . . . can carry 650,000 barrels of oil at a time. When burned, this amount can provide enough energy to furnish a big city with heat, light, and mechanical energy for many days.

Another good way of carrying oil is to pump it through pipelines. Nowadays large pipes carry oil from the fields where it is pumped out of the ground—in Texas, Oklahoma, California, and other places—to refineries and shipping ports.

Energy stored in matter can also be pumped s gas through pipelines from the oil fields, where t is produced, to cities thousands of miles away, where it can be used. There are about half a million miles of gas lines in the United States today.[1] In recent times, lines having pipes more than thirty inches in diameter and running for thousands of miles have not been unusual.

Gas is harder to store than coal or oil, because it must be kept in a closed tank. Gas-storage tanks of the kind used in most cities are often bigger than a ten-story building. Over each one is a large, upside-down covering tank, which has wheels on vertical tracks so that it can move up and down. The gas is thus kept enclosed under pressure. When more gas is pumped into the tank, the cover rises a bit. As the diagram shows, a column of water between the inner and outer tanks keeps the gas from escaping.

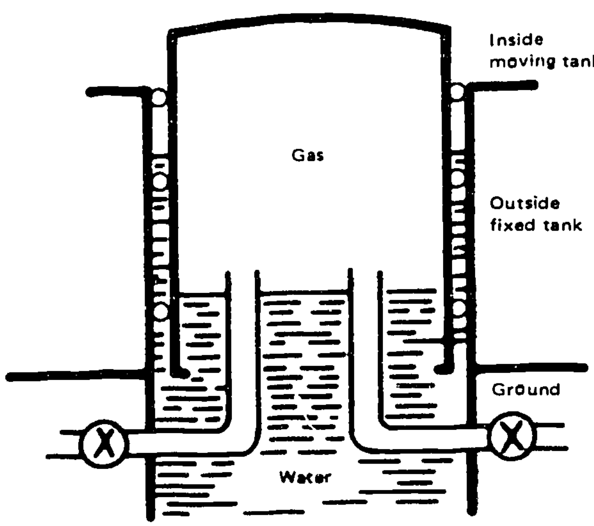
Because coal is so cheap, engineers have long wished that they could send it through pipelines as they do oil and gas. Now they have invented a method of doing this. The coal is ground into a fine powder, and this dust is mixed with liquid to make a soupy substance called a slurry, which can be pumped through pipes. When the coal is to be burned it is allowed to settle out of the slurry, separating from the liquid, which may be either oil or water. Then, without being dried, it is

[1] Editor's Note: As this article was published in 1965, this number may no longer be accurate.

fed to the hot flame of a furnace, where it burns furiously.

A very clean way to carry energy from place to place is not to store it in matter at all, but to convert it into electrical energy and send it through wires. This is not a cheap method, because the wires are expensive and some energy is lost as the electric current warms them. Copper, the metal that carries electrical energy most cheaply, costs so much that wires made of it must be kept thin. The thinner the wires, the more electrical energy is lost as heat when it passes through them, however. Not so much energy will be wasted if less current is sent and the electrical pressure, or voltage, is increased. To send electrical energy for long distances, therefore, the voltage is made as high as possible, and the current is kept low.

The trouble with this solution is that as the voltage is made higher, more electrical energy leaks into the air, and across the insulators that hold the wires. The highest voltage that is ordinarily used nowadays is about 345,000 volts, although lines for using up to 775,000 volts are now being tested.[2] Even then it will pay to use this voltage only in ending electrical energy a few hundred miles.



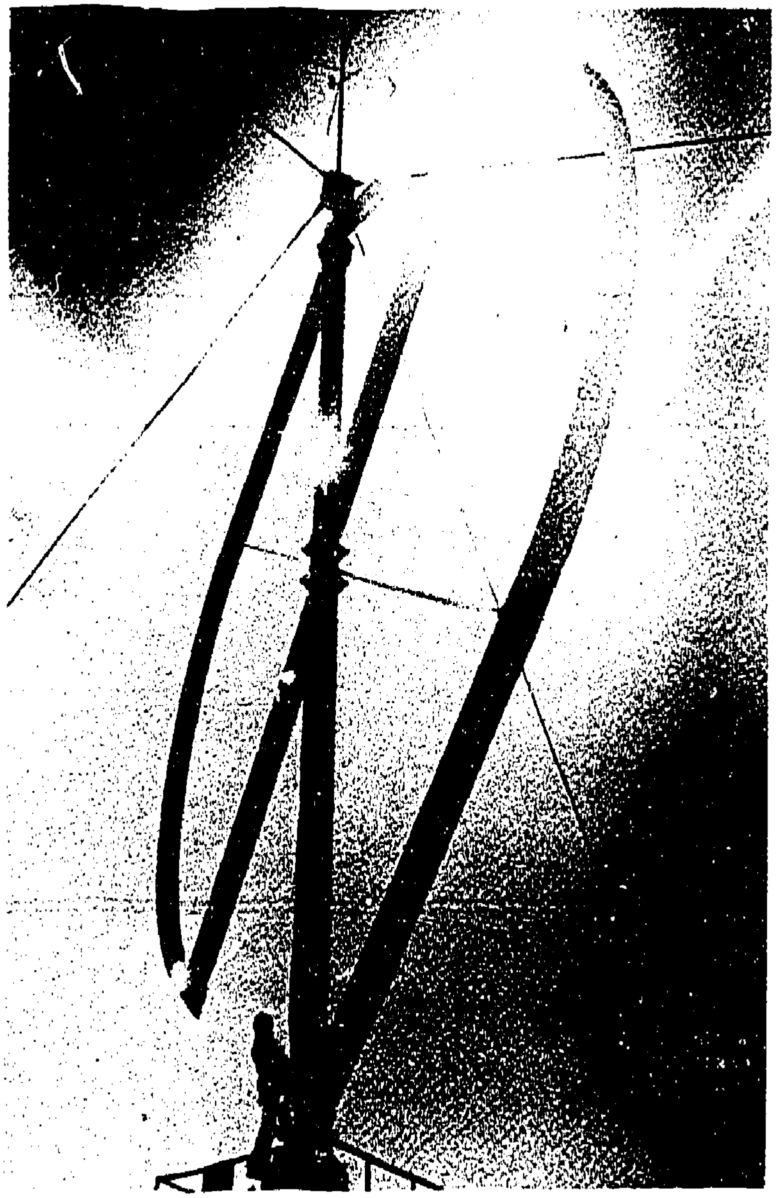
A section of a large tank used to hold gas. As more gas is pumped into the tank from the gas fields, the floating top tank rises, and the water is pushed down inside it and up between the two tanks.

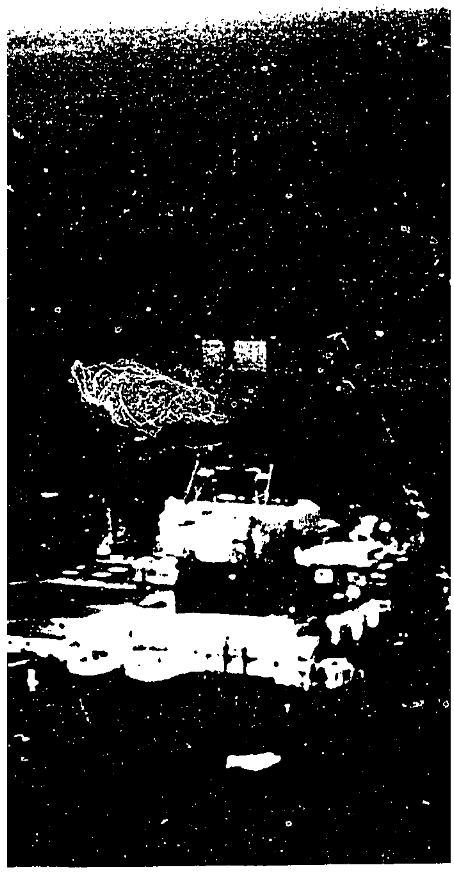
[2] Editor's Note: As this article was published in 1965, this number may no longer be accurate.

SELECTIONS FROM

ENERGY AND POWER

By Irving Adler





ENERGY CIRCULATES

The Travels of a Dollar

Suppose you buy a book for a dollar. You hand the dollar over to the book-dealer, who puts it into his cash register. But it doesn't stay there forever. Sooner or later the book-dealer spends that dollar. He may, for example, go to a haberdashery store and use the dollar to buy a pair of socks. The dollar then passes into the hands of the haberdasher, and he, in turn, may use it to buy some fruit. Then the fruit dealer may use the dollar to buy some meat. The dollar is transferred from hand to hand as each seller who receives it spends it as a buyer. The dollar is not destroyed when it is spent. It *circulates*, through a series of transfers.

Bat and Ball

The same thing is true of energy when it is spent. It is never destroyed. It merely circulates through a series of transfers. There is a transfer of energy, for example, when you hit a ball with a bat. When you swing the bat, there is kinetic energy in the motion of the bat. When the bat strikes the ball, some of this energy is transferred to the ball. Here it appears again as kinetic energy, in the motion of the ball. In this type of transfer, the energy passes from one body to another. But it is still the same type of energy, energy of motion in both bodies.

Changing the Disguise

Most of the time, when energy is transferred, it doesn't stay in the same form. The different forms of energy are really like disguises that can be put on or taken off and changed. Energy can be converted from one form to another. In fact, we find conversions of energy taking place in everything we do and see in our daily lives, even in a simple thing like rubbing our hands. Rub your hands together, and you will find that as you keep rubbing, your palms begin to get warm. The rubbing converts the energy of motion into heat. We take advantage of this fact when we rub our hands to keep them warm in cold weather.

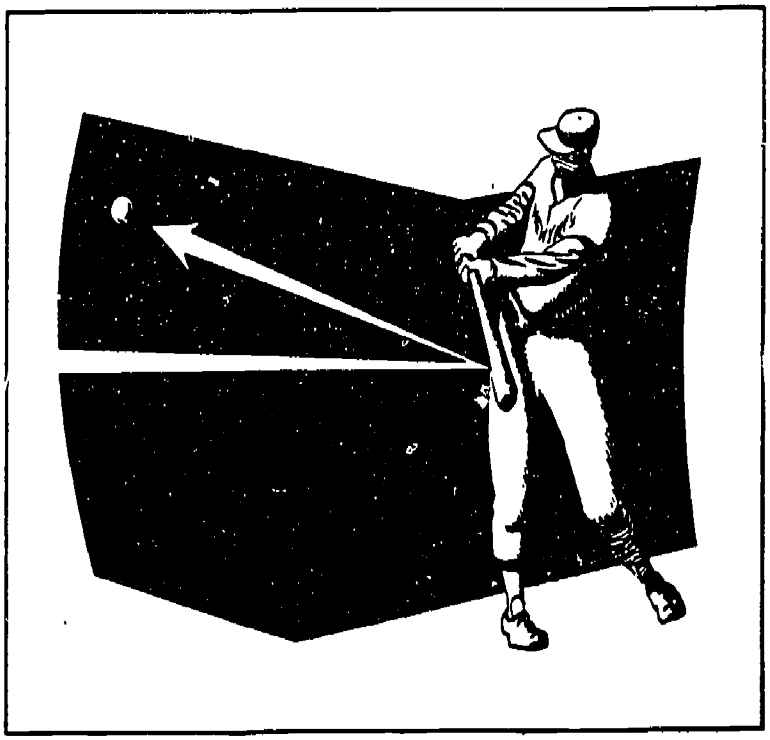


Figure 1. Transfer of Kinetic Energy from Swinging Bat to Ball

The change of energy of motion into heat is a very common occurrence. It happens in your bicycle pump when you pump up your tires. If you feel the pump you will notice that the more air you pump, the warmer the pump becomes. It happens in your woodworking tools. When you drill through a piece of wood, the drill point becomes hot. In fact, you have to interrupt the drilling from time to time, to give the bit a chance to cool off.

Motion can also be changed into electrical energy. Stroke the fur of a cat, and you will hear the crackling of sparks. The stroking builds up electrical charges on your hand and the cat's body, and the sparks are caused when electricity flows from one to the other through the air. If you don't have a cat, you can use a carpet to change motion into electrical energy. When you shuffle across a thick carpet, the rubbing builds up an electrical charge on your body. Then, if you touch your fingertip to a metal object, you can see and hear the spark as the electricity is discharged.

When the spark jumps from your fingertip, the energy changes its disguise again. The fact that you *see* the spark shows that some of the energy has been changed into light. The fact that you *hear* the spark shows that some of the energy has been changed into sound.

Energy on Tap

Electrical energy is a convenient form in w[illegible]o store energy and ship it from place to

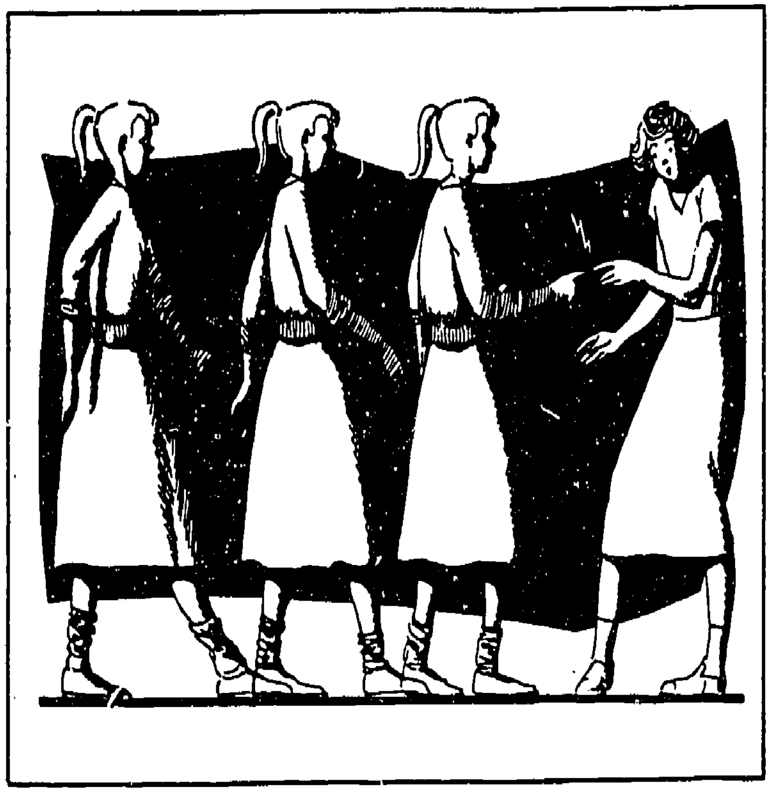


Figure 2. Motion Changing to Electric Energy

place. So the electric company converts motion into electrical energy and then sells it to us. The electric company doesn't rub a cat to convert motion into electrical energy. It uses other more powerful methods. . . . Then it ships the electrical energy through wires. In our homes, offices, and factories we change the electrical energy back again into other forms. In lamps, we change the electrical energy into light. In toasters and broilers, we change the electrical energy into heat. In a radio we change electrical energy into sound. In a sewing machine motor we change electrical energy into motion.

Energy Is Not Made

Energy is never destroyed. It only changes its form. When energy disappears in one form, it pops up at the same time in another form. The opposite is also true. Energy is never made. Whenever we generate heat, for example, we do it only by using up energy in some other form. If we get the heat by burning coal, we are merely changing chemical energy into heat. If we get the heat from an electric broiler, we are changing electrical energy into heat. If we get the heat by rubbing our hands, we are changing motion into heat. The chemical energy, or the electrical energy, or the motion already exist before we change them into heat.

All the energy we use has to be there already in some form, before we change it and use it. So, to get the energy we need, we have to find the places where it is hidden by nature. . . .

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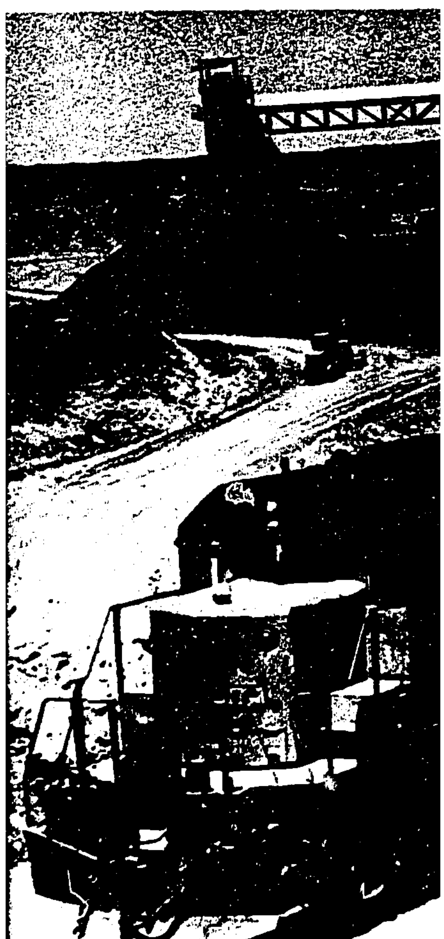


yoming coal is transported to midw

utility companies by train to be used in the production of electricity.

HOW ENERGY TRAVELS

Energy Hitches a Ride

Besides circulating by changing its form, energy can also travel from place to place. One way it can travel is by hitching a ride with something that moves. *A moving body carries its energy with it.* When coal is shipped from the coal mines of Pennsylvania to factories in New York, the chemical energy that is hidden in the coal travels with it. When a hot potato travels from the oven to the dinner plate and then into your mouth, the heat in the potato travels with it. And, of course, as long as a body is moving, it carries its energy of motion with it. But in this case it is hard to say who is the hitch-hiker, the body or the motion. When the body is carrying the motion, if it weren't for the motion the body wouldn't be traveling at all. So it is just as true to say that the motion is giving the body a ride.

Collision

A moving body passes some of its kinetic energy on to another body when it collides with it. A swinging bat that collides with a baseball gives it the energy that carries it into left field. A swinging tennis racquet that collides with a tennis ball gives it the energy that sends it sailing over the net. A billiard ball that collides with another gives it the energy that starts it rolling towards the pocket.

But a collision isn't only a simple transfer of motion from one body to another. Some of the energy transferred can damage or destroy the body that receives it. While a swinging hammer can drive a nail, it can also smash a thumb. An automobile that strikes a man may send him flying through the air, but it can also break his bones. A collision can even damage the moving body itself, because a collision is a two-way affair. When an automobile hits a tree, the tree hits the automobile. So, while the automobile rips the bark off the tree, the tree may even the score by smashing some fenders.

The amount of damage that a moving body can do depends on how much kinetic energy it carries. This, in turn, depends on its weight and its speed. If two bodies of different weights are moving at the same speed, the heavier weight has more kinetic energy than the other. If one is twice as heavy as the other, it carries twice as much energy in its motion. But speed increases the energy of a body faster than weight does. While doubling the weight of a moving body multiplies its kinetic energy by two, doubling its speed multiplies the energy by two times two, or four. Tripling the speed multiplies the energy by three times three, or nine. That is why speeding in an automobile is so dangerous. A car that collides at a speed of 20 miles an hour will do as much damage as a car that falls from a height of 13 feet. A car that collides at a speed of 30 miles an hour will do as much damage as a car that falls from a height of 30 feet. A collision at 40 miles an hour is like a fall from a height of 54 feet, and a collision at 60 miles an hour is like a fall from a height of 121 feet!

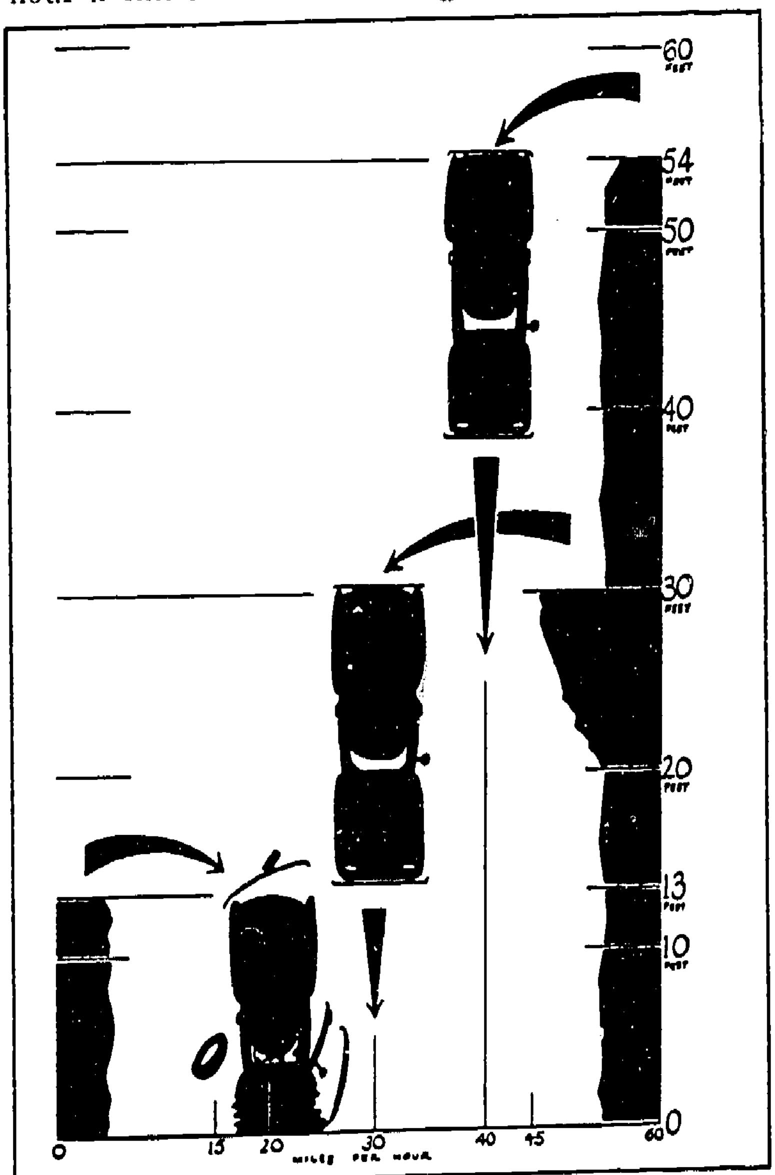


Figure 1. Speed, Weight, and Corresponding Kinetic Energy

Heat Stirs the Air

A moving body carries its heat with it. Sometimes the heat starts the motion itself. Then the heat is responsible for its own ride. This happens all the time over a hot stove. The air directly above the stove is heated by the stove, so that it becomes warmer than the surrounding air. But warm air is lighter than cool air, so it floats upward while the heavier cool air flows in to take its place. The rising warm air carries its heat with it. In this way the heat of the stove is spread to different parts of the room. The flow of air that is started when part of the air is made warmer than the rest is called a *convection current.*

Motion We Cannot See

Heat itself is actually a form of motion, only it is motion we cannot see. The atoms that make up all material objects are joined together in tiny molecules. For example, two hydrogen atoms, joined to one oxygen atom, make up one molecule of water. We cannot see the separate molecules as they move about because most of them are too small to be seen, even with the most powerful microscope. Molecules of ordinary air, for example, are so small that a thimbleful of air contains eighty billion billion of them, and a lot of empty space besides, that separates the molecules from each other. The molecules are always jumping around in a wild dance. The warmer the air is, the faster its molecules jump. The speed with which they move is very high. The average speed of the molecules of air in your room is about 1300 feet per second. This is faster than the speed with which sound travels through the air. The speed of the molecules doesn't carry the air away because they do not all move in the same direction at the same time. While some of the molecules are moving up, others are moving down. While some dash to the left, others dart to the right. The molecules move, and still the mass of air can stay in one place. What happens in the air resembles the scene in a crowded playground. The children run and jump and whirl, moving all the time as they play their games. But while they move, the crowd as a whole remains in the playground. The separate children move, but the crowd seems to stand still.

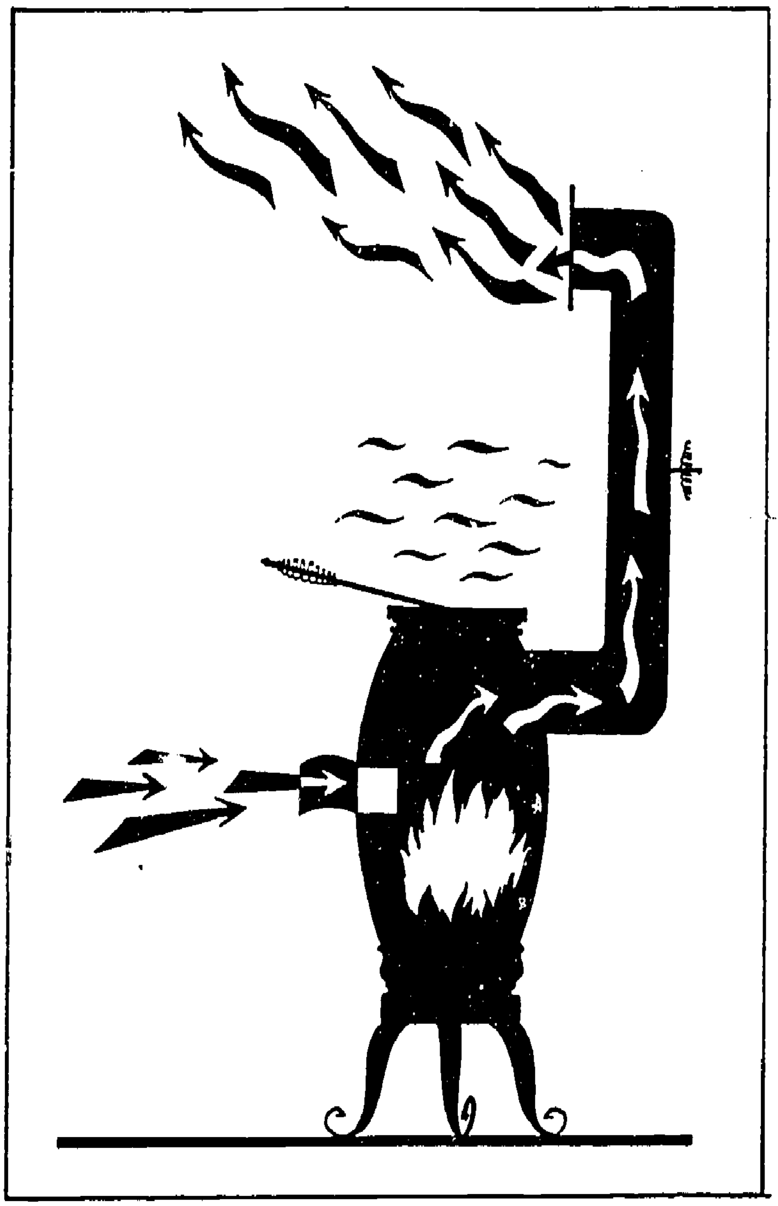


Figure 2. Convection Current Caused by Rising Warm Air

Spreading the Commotion

With so many molecules moving about in a small space, they are bound to have many collisions. Through these collisions, the molecules exchange energy with each other. The fast ones speed up the slow ones. The slow ones make the faster ones slow down. Chains of collisions can serve to carry energy from one end of the room to another. Let's trace such a chain that has its beginning near a hot stove. The stove lid is a solid in which the molecules are packed closely together. Because they are so crowded, the molecules hook onto each other, and cannot wander freely the way molecules do in the air. But while they cannot wander they do *vibrate*, even while they keep their places. Because the stove is hot, its molecules vibrate very quickly. Those that are in contact with ne air, collide with molecules of air and stir up a t of commotion. The air molecules that are struck egin to move more quickly, and collide with their eighbors further away from the stove, and stir nem up. These, in turn, stir up their neighbors, nd gradually the commotion spreads across the oom. The chains of collisions help to spread the eat of the stove throughout the room. When heat transferred in this way by the collisions of mole-ules, we say that the heat travels by *conduction*.

Bucket Brigade

In the days before we had fire engines with owerful pumps, if water was needed to put out a re, it had to be carried in buckets from a near-by ell. Fire-fighters found that they could carry the ater faster if they did not walk back and forth etween the fire and the well. Instead they formed line from the well to the fire, and passed the uckets of water down the line. Then, although the eople stayed in one place, the water moved along a steady stream. The bucket brigade resembles nother way in which energy often travels. While articles can move and carry their energy with hem, there are times when they may stay in one lace, and merely pass the energy along from one the other, as if they were volunteer firemen assing buckets of water.

To see a simple example of energy being as ng by objects that stay in one place, set up a line of dominoes, standing on end, one behind the other. Then push the first domino. As it falls, it knocks down the second domino, the second knocks down the third, and so on down the line. No one of the dominoes moves down the line, but the falling motion does. The motion of the dominoes is energy that they have passed from one to the other. If the dominoes were connected to springs that pick them up again after they fall, we could knock them down over and over again in rapid succession. Then each domino would keep moving up and down, and the movement would travel along the line in a series of waves.

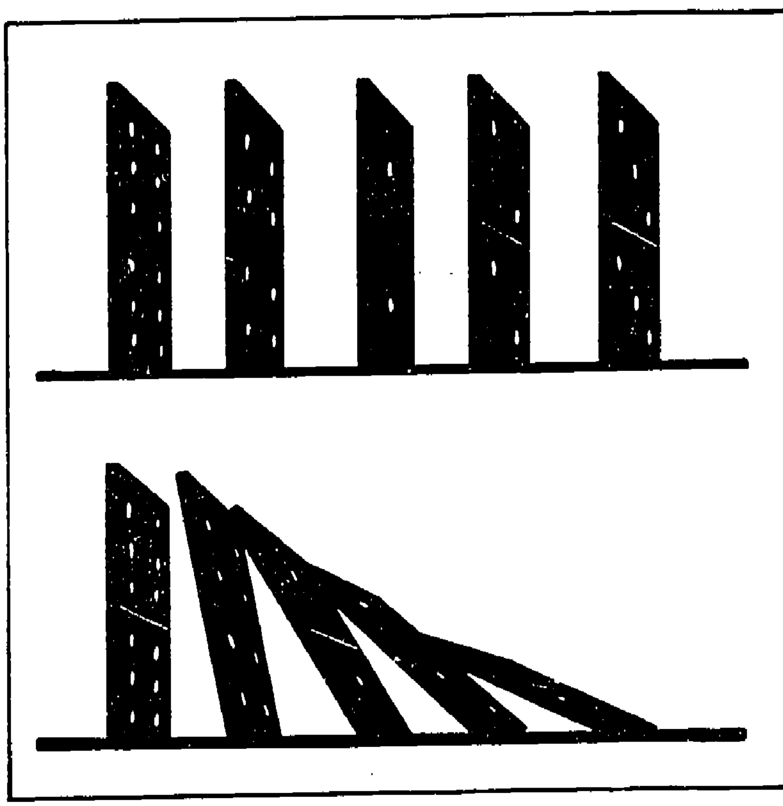


Figure 3. Energy Passing from One Object to Another

Water Waves

A water wave is another example of energy being passed along by particles that stay where they are. If you drop a stone into water, circular waves begin traveling across the surface of the water, moving away from the spot where the stone splashed in. Each wave looks like a mass of water rolling across the surface the way a log might roll across the ground. Actually, the water does *not* move across the surface. The particles of water merely bob up and down like children on a seesaw. Imagine a series of tiny seesaws arranged so that their ends overlap, and stretching across the surface of the water from the place where the stone falls in. Picture each particle of water as being seated on one end of a seesaw. Where the stone enters the water it pushes a particle of water down. But as this particle moves down, it presses its end of the seesaw down, and the other end of the seesaw goes up, carrying up the particle of water that is sitting there. When the second particle goes down again, it pushes down an end of the second seesaw, and another particle, sitting further away from the spot where the stone struck the water, is raised into the air. In this way, the particles on the seesaws pass their up and down motion from one to the other. The particles stay where they are, bobbing up and down, and only the motion travels across the surface of the water. You can prove that this by floating a cork in the water. When a wave reaches the cork it doesn't push the cork along across the surface of the water. The cork merely bobs up and down as the wave rolls under it.

Sound and Light

The energy of sound also travels in waves. When you strike a bell, the bell begins to vibrate. The vibrating bell pushes the air next to it, and makes the air vibrate. The vibrating air near the bell makes air further out away from the bell vibrate, too. The vibrations travel away from the bell while each little vibrating pocket of air stays where it is. When you speak, the sounds you make are vibrations of the air that are started by vibrations of the vocal chords in your larynx. When you hear a sound, it means that vibrations that traveled through the air have reached your ears and made your eardrums vibrate.

Light, too, travels in waves that are caused by vibrations that are passed along. But the vibrations in light are very different from the vibrations in sound waves or water waves. In sound waves and water waves, there are vibrating *particles* that pass their motion from one to the other. In light waves there are no vibrating particles. In fact, light can travel through empty space where there are no particles at all. The vibrations that light waves pass along through space are vibrations of electrical and magnetic forces. The light that comes to us from the sun travels 93 million miles through empty space before it reaches us.

Invisible Light

There are waves that are closely related to light but which we cannot see. Like light they are vibrations of electrical and magnetic forces in space, so they are called *electromagnetic radiation*. They differ from light in the length of their waves. X-rays (which can pass through solid objects that stop light), ultraviolet rays (which cause sunburn), and radio waves are all forms of invisible light. Although we cannot see them with our eyes, we can detect them by other means. We can detect X-rays and ultraviolet rays with the film in a camera. We can feel the heat of infrared rays on our skins. We can pick up radio waves with a radio receiver. The waves of X-rays and ultraviolet rays are shorter than the waves of light. The waves of infrared rays and radio waves are longer than the waves of light. They all travel through space at the speed of light, 186,000 miles per second.

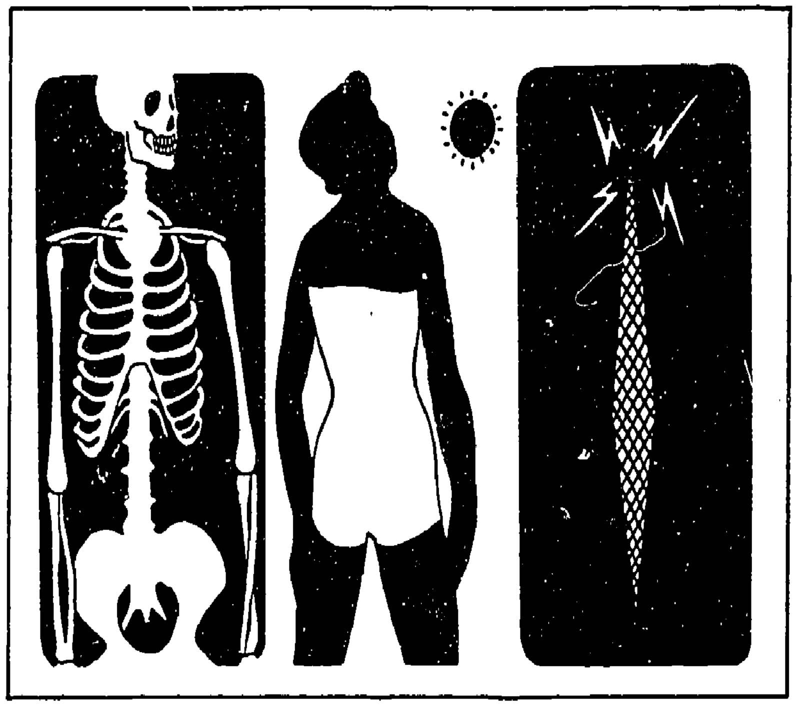


Figure 4. Forms of Invisible Light

WE USE ENERGY: THE "HIDDEN HALF"

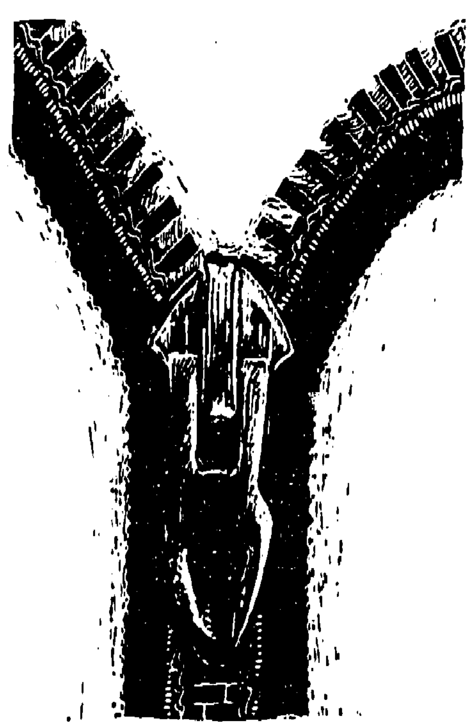
By Peter Jones

Artwork By Cheryl Baer

Question: What's the least known truth about energy?

Answer: There is energy in EVERYTHING we buy or use.

It's no secret that the nation's 110 million cars swallow a lot of gasoline. And almost everybody knows that our homes and office buildings burn a staggering amount of natural gas and heating oil. But suppose you added up the energy used for personal transportation, plus the energy needed to heat and cool *all* homes and offices? You'd discover something very interesting. You'd find that all that energy accounts for *less than half* of the energy consumed in the U.S. each year!

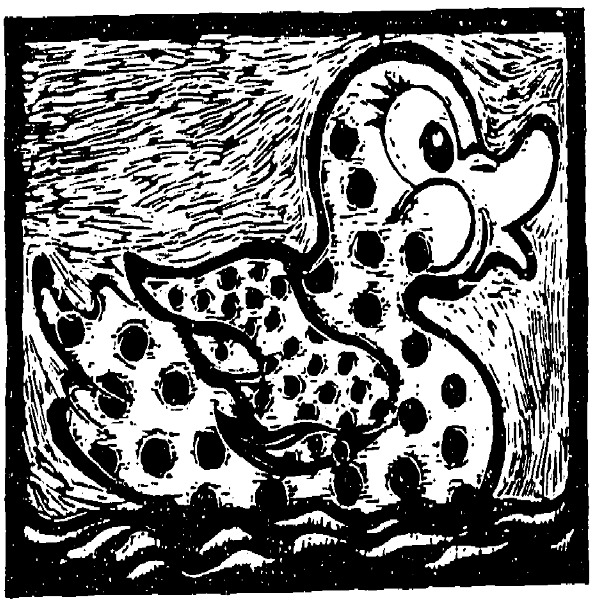


So, where does the rest of that energy go? The great bulk of it—about 40 percent of total U.S. energy consumption—is used by industry. That includes manufacturing, packaging, and shipping of thousands of products. Everything from automobiles to zippers "cost" energy to make and to deliver to the consumer. Under the label "industry" are millions of workers performing millions of jobs. Those workers produce the clothes we wear, the food we eat, our cars and medicines, and a million other things.

Look at the auto industry. It's easy to understand how the steel, paint, and tires of a car cost energy to make. But it also takes about 100,000 gallons of water to build one car. That's water that must be stored, pumped, piped, purified, and either disposed of or re-used. And all of this takes energy and dollars.

Here's something else. Not all the oil the U.S. consumes goes into gasoline, heating oil, and other fuels. About six percent of it is turned into *petrochemicals.* And those petrochemicals actually become part of products we use every day. They are the basis of an industry that employs millions of people and makes products valued at about $40 billion.

What products? About 80 percent of the rubber produced in the U.S. each year is made from petrochemicals. That rubber goes into everything from radial tires to squishy toys.



Nearly 50 percent of all the fabric fibers produced in the U.S. today are synthetic—made from petrochemicals. From them come about 70 percent of all women's and girls' clothing; 40 percent of all men's and boys' clothing; 93 percent of all our carpets, and 81 percent of our blankets. Everything from doll dresses to Green Bay l uniforms uses petrochemicals.

Petrochemicals also play a big part in medicine and health care. From them come antiseptics, anesthetics, and antihistamines—not to mention laxations, vitamin capsules, sedatives, tranquilizers, and cortisone. Even common aspirin is a petrochemical.

Then there's the food connection. Before the first tiny shoots poke through the soil next spring,

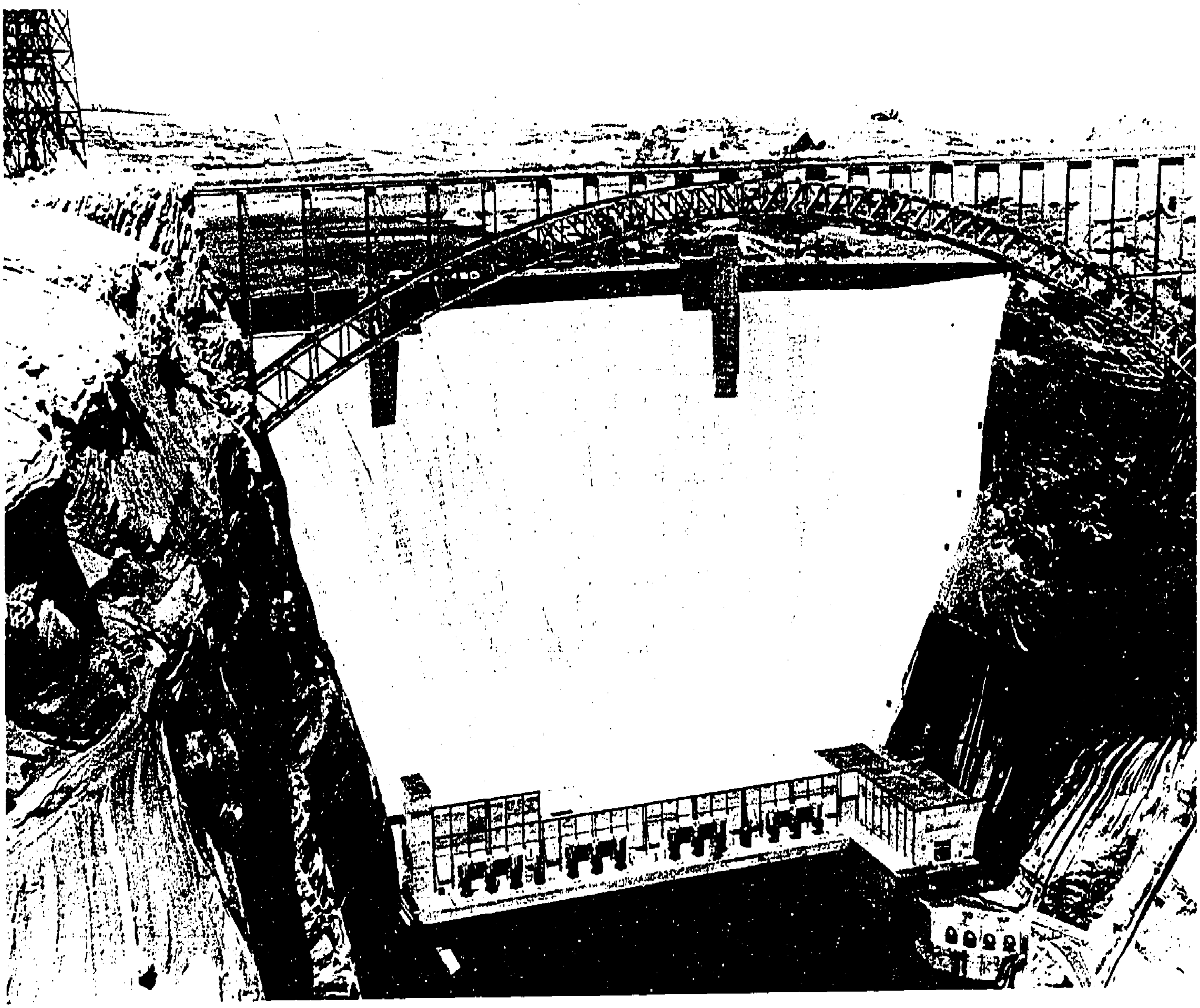
a lot of energy will have been poured into the average American farm. A major part of that energy comes in the form of fertilizers and pesticides. Most of these are manufactured from petrochemicals, too.

A huge amount of energy is needed to turn petrochemicals into fertilizers. For example, in the year from July 1975 to July 1976, U.S. farmers spread almost 10.5 million tons of ammonia-based fertilizers on their fields. Each ton of that fertilizer required the burning of 30,000 to 40,000 cubic feet of natural gas. That's enough to heat the average American home in winter for two and a half months.

After crops are harvested, the energy drain continues. Between 7 and 12 percent of all energy used in the U.S. goes to process, store, and ship food, both vegetable and animal. These add up to the total "energy price tags" for food.

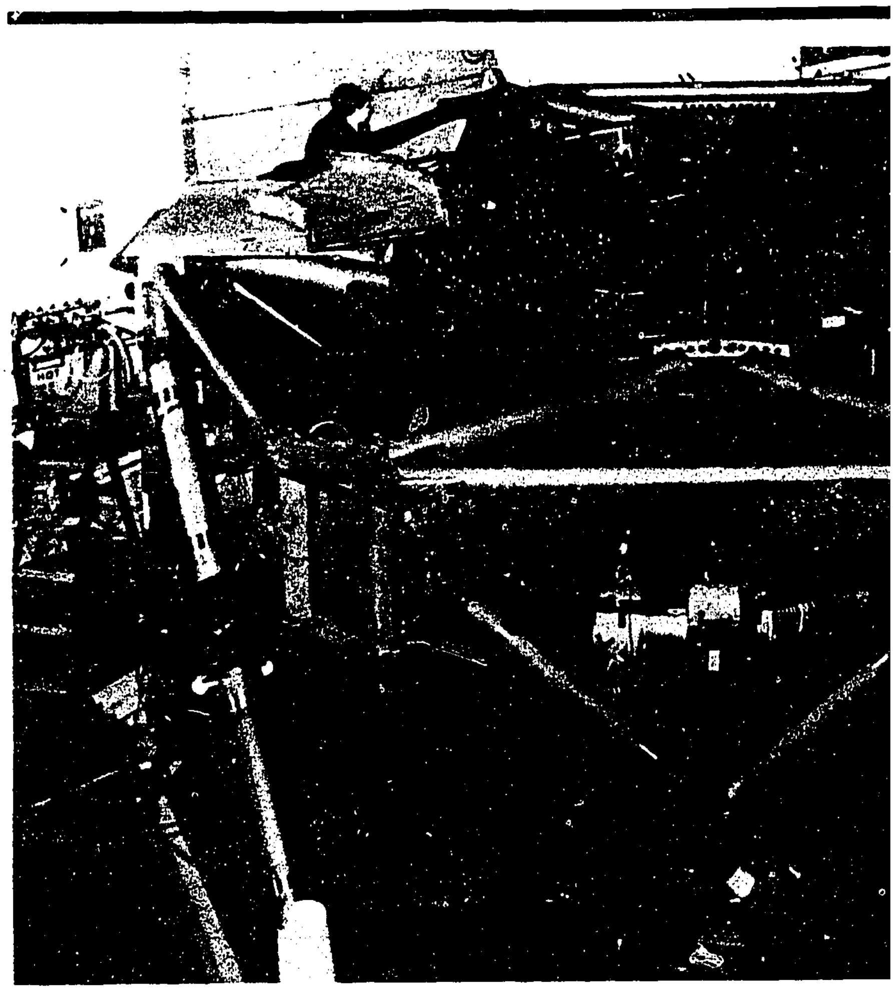
What are some of the specific energy price tags? Well, to put one pound of hamburger on your table requires the same amount of energy you'd get from burning three pounds of high-grade coal. A one-pound loaf of bread requires the energy equivalent of two pounds of high-grade coal.

And if you want to wash it all down with a glass of milk? Well, putting that glass of milk on your table requires the amount of energy in a half-glass of diesel fuel. Everything is energy.



CHECK YOUR ENERGY VOCABULARY

John M. Fowler and King C. Kryger



The Princeton Large Torus (PLT), a tokamak, plays a vital role in contr(

research.

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 to wood.

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^{232}) 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.

[1] Editor's Note: This material was produced in part by the National Science Teachers Association under contract with the U.S. Energy Research and Development Administration, now a component of the Department of Energy. The facts, statistics, projections, and conclusions are those of the authors.

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 inciting 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 combustion 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 ...n 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 mass 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 artificially 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.

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

'ahrenheit—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.

ertile 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.

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

ssion—The splitting of atoms.

uidized 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.

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

geothermal 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.

greenhouse 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.

half 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.

heat—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 (B'u's).

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

heat 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 [illegible]litioners.

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

Helium 3 ($_2He^3$)—A rare, non-radioactive istope 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 (radio-active).

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.

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

kilocalorie—See Calorie.

kilowatt (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.

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

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

land 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.

langley—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.

laser—A device for producing an intense beam of coherent, 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.")

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

agnetic 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.

agnetic pinch device—(See above)—An interior space is filled with plasma which is then "pinched," or compressed by 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.

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

agnetohydrodynamic (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.

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

troleum—(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.

otoelectric—Pertaining to electric effects produced by light.

oton—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.

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

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

otovoltaic 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 horse-power.

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.

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

pumped 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.

Pyrolysis—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.

radioactive 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."

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

recoverable resource—That portion of a resource expected to be recovered by present-day techniques and under present economic conditions. Includes geologically expected but unconfirmed 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.

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

solvent 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.

Stirling 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.

stratified 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.

Strontium 90 ($38Sr^{90}$)—A hazardous isotope produced in the process of nuclear fission. Strontium 90 has a "half-life" 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 by means 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.

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

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

Tokamak—(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).

topping 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.

total energy system—A packaged energy system of high efficiency, utilizing gas fired turbines or engines 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.

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