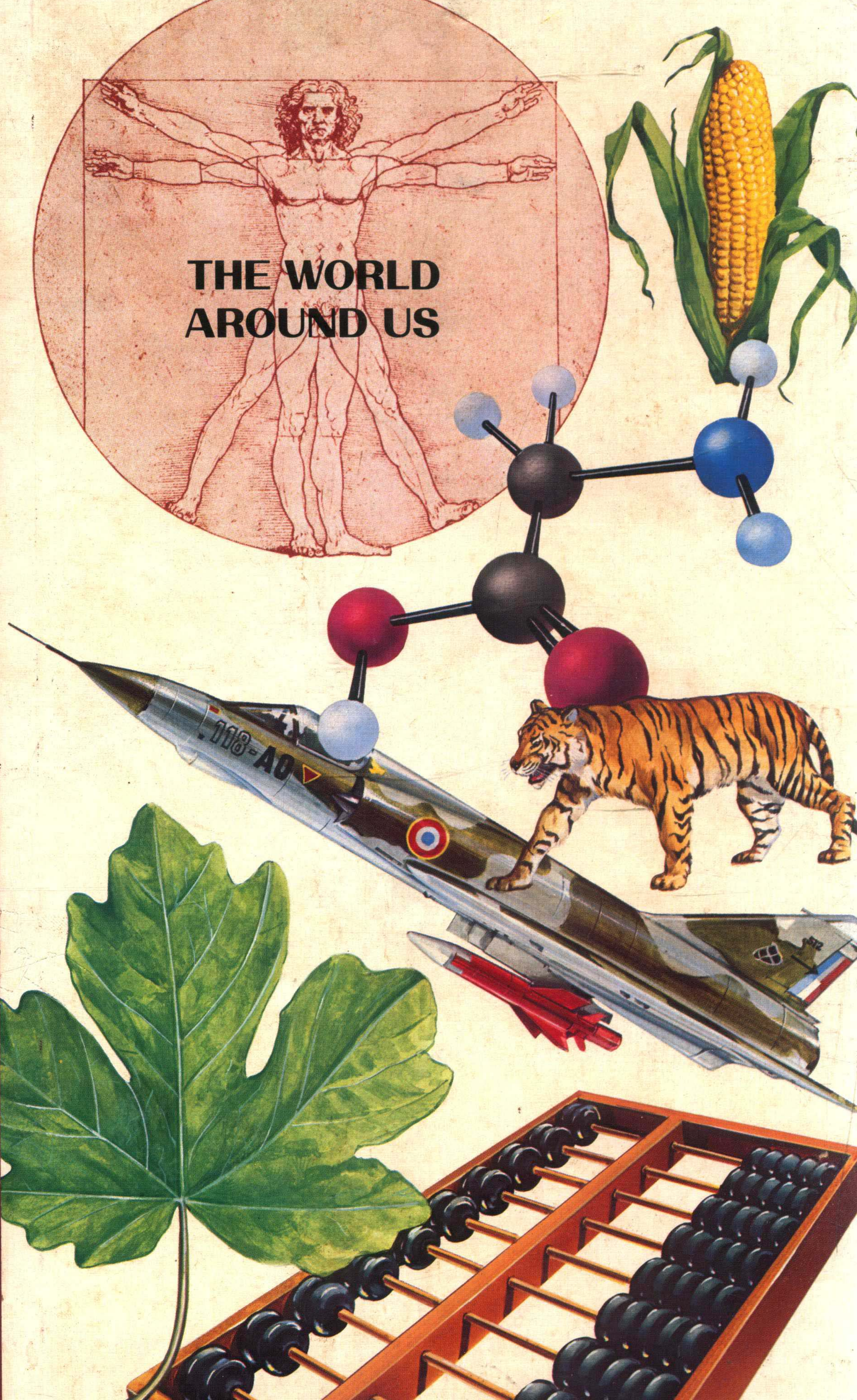
SCIENCE AND TECHNOLOGY ILLUSTRATED

THE WORLD AROUND US



Science Technology

The World Around Us

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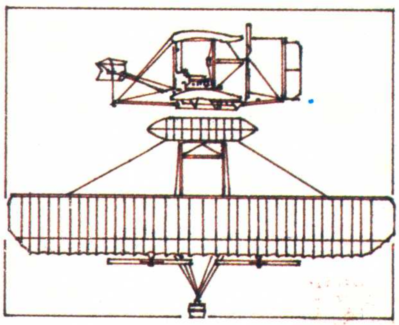

Science and Technology Illustrated

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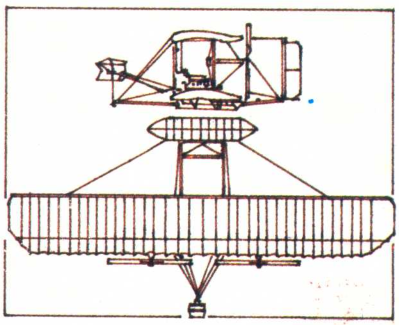
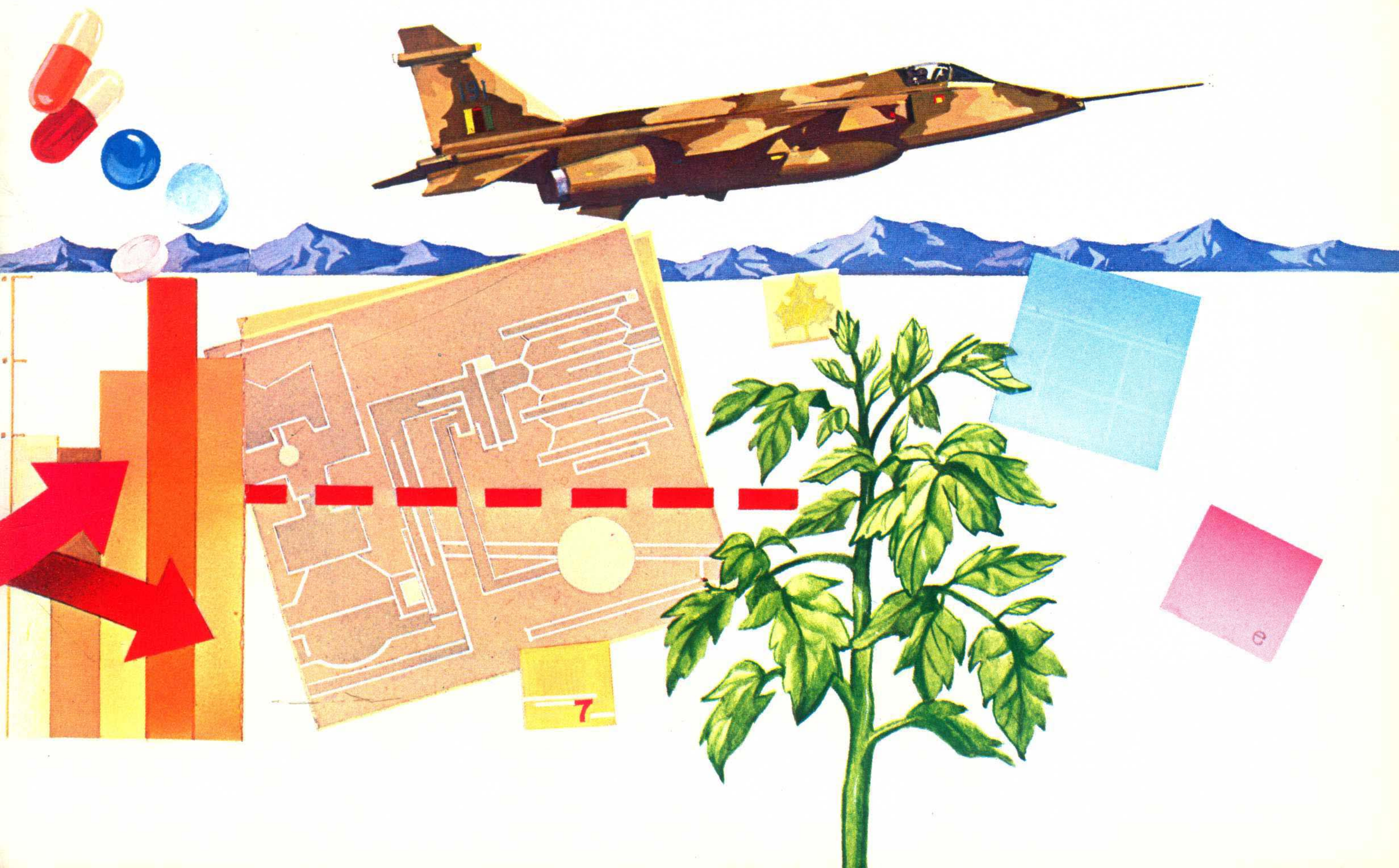




Energy Sources

For centuries, the human body was the chief source of the energy—the capability to do work—used by civilization. Human labor built the Egyptian pyramids and the Roman aqueducts, the Inca temples and the Great Wall of China. Often, the muscle power of domestic animals was used to assist that of human beings. Teams of oxen, mules, or horses have provided the power to grind grain, pump water, and operate other machines down to this century.

But the birth of modern industrial civilization in the 18th century meant that mankind had to turn to other sources of energy. Until that time, wind and water, as well as fuels such as wood, charcoal, and coal, only supplemented muscle power. In the 19th century, coal surpassed the others as an energy source, while in the 20th, petroleum emerged as the primary fuel.

Then mankind learned how to harness the energy inside the atom and began to explore how better to exploit older sources of energy, such as the wind, the tides, and the Sun.

Fossil Fuels

Petroleum, natural gas, and coal are known as fossil fuels. They derive from the remains of plants and animals that lived millions of years ago. These remains were buried by layers of mud and sand and subjected to tremendous pressures and temperatures, which turned the organic material into petroleum, natural gas, or various grades of coal.

Fossil fuels are nearly always found underground, from a few feet (about 1 m) to tens of thousands of feet (5-10 km) below the surface. This often puts restrictions on their accessibility. Expensive equipment must be built to drill for natural gas and petroleum—a single drilling platform in the North Sea can cost over $100 million. Despite extensive geological study, many wells are found to be dry. Coal must be mined, and coal mining is one of the most hazardous of all occupations. Not only is there danger of cave-

							SUN		
AVAILABLE ENERGY	WIND			WAVES	RIVER FLOW		THERMAL GRADIENTS	DIRECT HEAT	PHOTOELECTR EFFECT
	1	2	3	4	5		6	7	8
	Windmills	Eolian generator	Sailboat	Electrical generator float activated by waves	Water mill	Hydroelectric plant	Thermal tide power plant	Solar collectors Solar mirror center	Photoelectric cell center

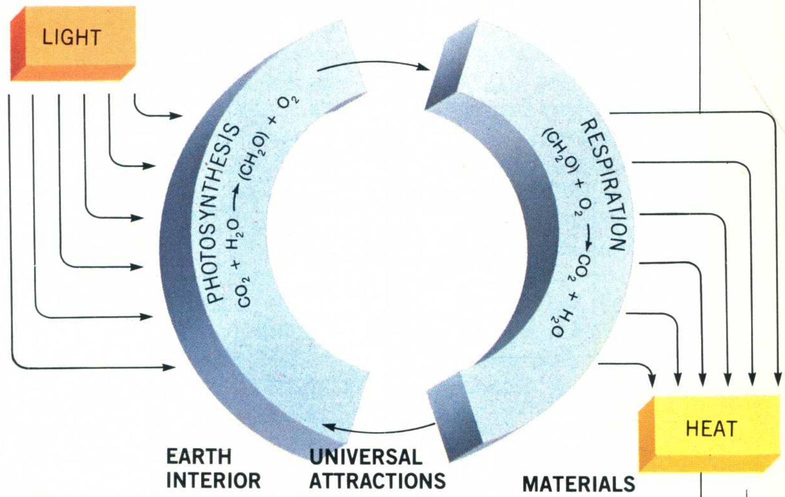
Transformed into energy

Transformed into energy	1	2	3	4	5 (Water mill)	5 (Hydroelectric plant)	6	7	8
Mechanical	●	●	●		●				
Electrical		●		●		●	●	●	●
Thermal								●	

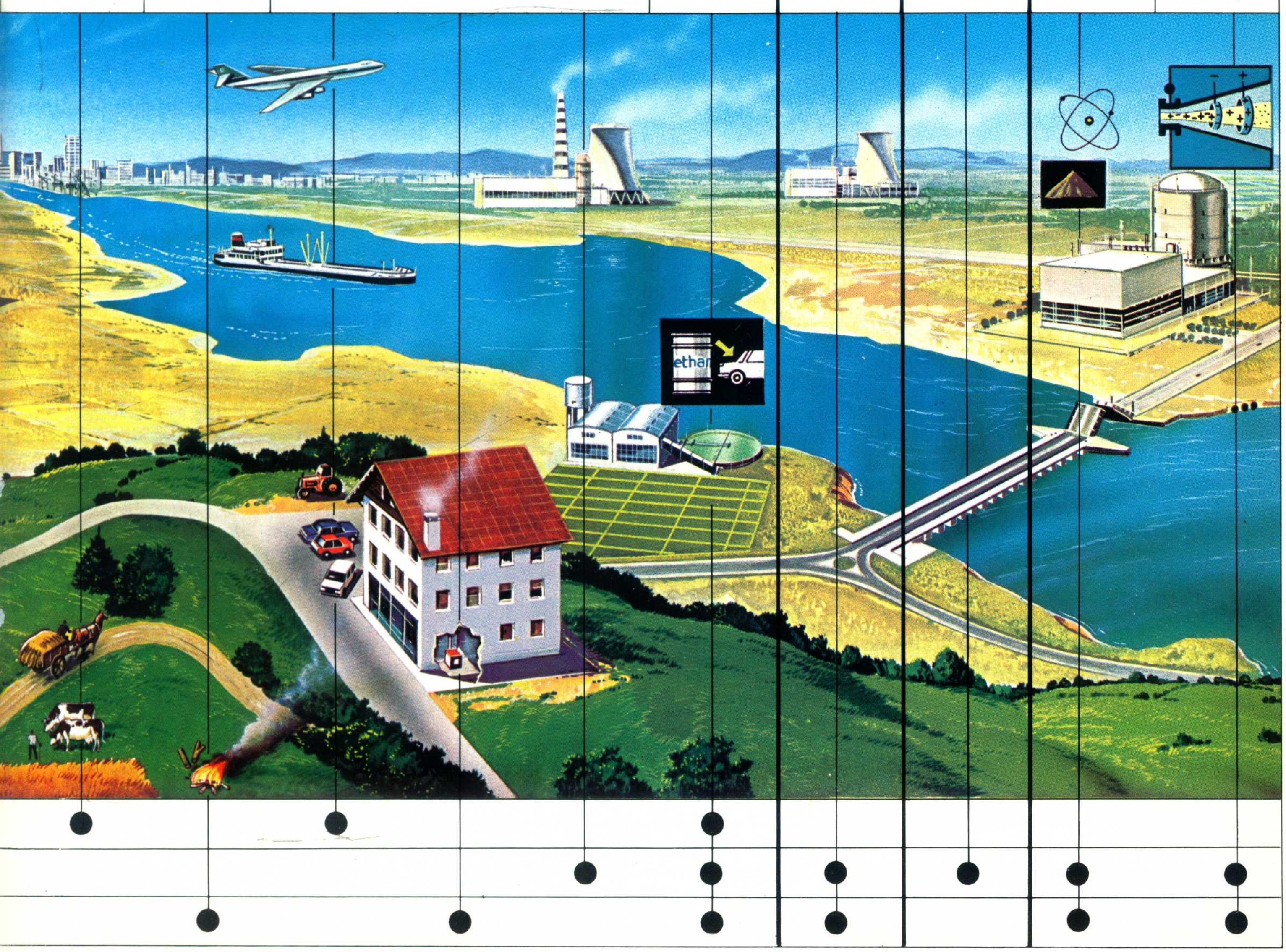
ins, flooding, and explosions from the highly flammable coal dust, but particles of dust collect inside the lungs of miners. "Black lung" is an incurable condition often accompanied by chronic bronchitis, asthma, emphysema, and pneumoconiosis, or a combination of these.

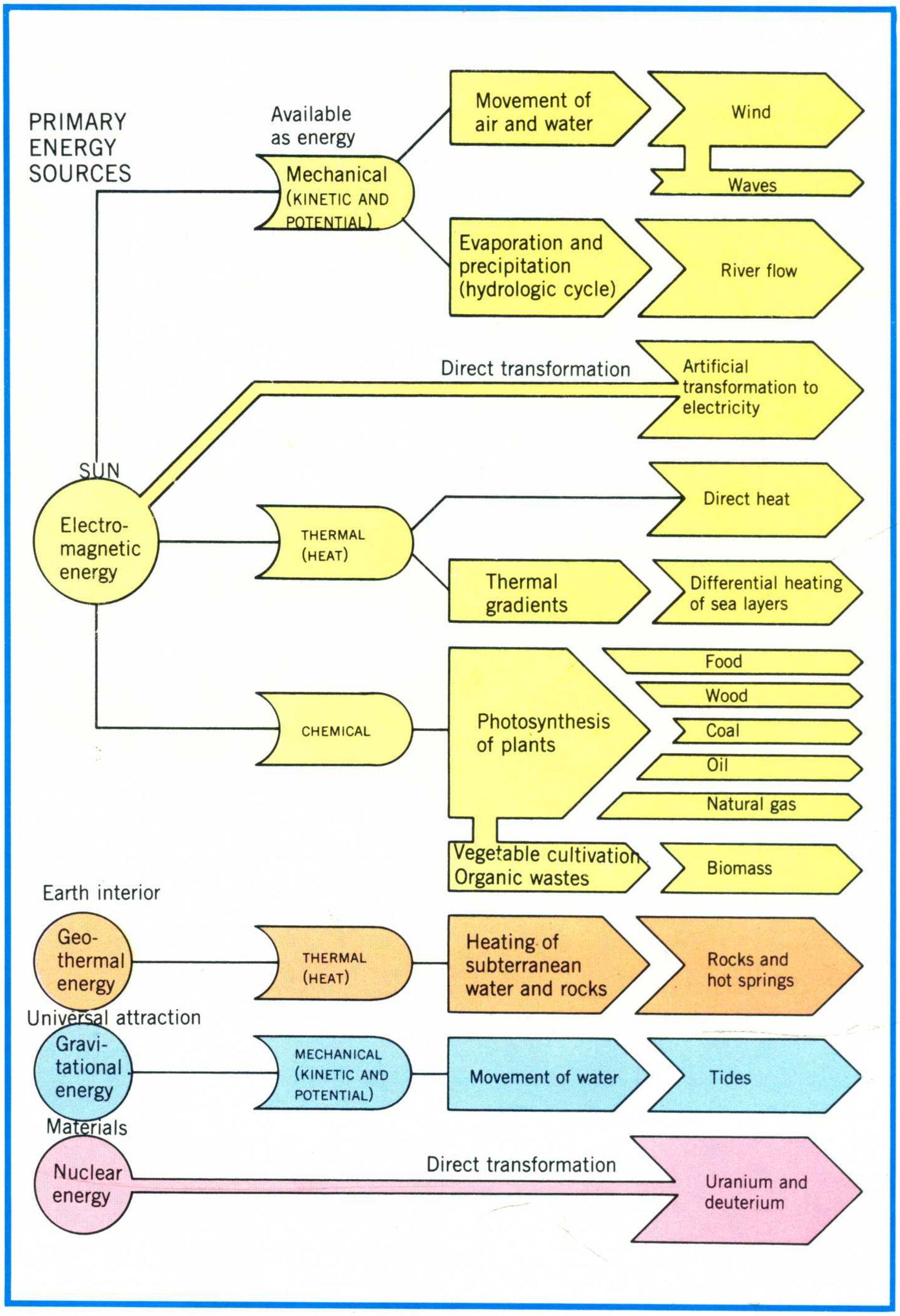
Adverse environmental effects of fossil fuels accompany both their acquisition and their use. Various stages of petroleum production are subject to spills, fires, and leaks, while coal mining scars the land, and mining wastes kill vegetation and clog streams. And when fossil fuels are burned, they release a wide variety of pollutants into the air. Fossil fuels also are unrenewable. While accessible coal deposits will

Light from the Sun makes possible the metabolic processes that form the basis of life—photosynthesis and respiration. Solar radiation is used to remove carbon dioxide and water from the atmosphere and to form a carbohydrate molecule. This process releases a molecule of oxygen. In respiration, the carbohydrate molecule undergoes combustion in the presence of oxygen and produces energy, carbon and its transformations.



FOOD	WOOD	OIL, COAL, NATURAL GAS	BIOMASS	ROCKS AND HOT SPRINGS	TIDES	URANIUM	DEUTERIUM
9	10	11	12	13	14	15	16
Transformation to muscle energy	Wood combustion	Thermic motors Thermoelectric plant Heating of buldings	Chemical transformation organic matter to fuels	Geothermal plant	Tidal power plant	Nuclear fission power plant	Nuclear fusion (future)





last for hundreds of years at the present rate of consumption, petroleum production is expected to drop swiftly within a few decades.

Yet, fossil fuels are convenient for several reasons. They can be easily stored in small or large quantities and are easily transported. Advanced technology has been developed to make petroleum suitable for powering engines small and light enough to operate transportation vehicles. More than half the petroleum produced worldwide is used for this purpose.

Biomass Fuels

Fossil fuels are produced from the residues of living matter only after the cumulative effect of millions of years of geological and chemical processes. Certain kinds of living matter, however, can be converted into fuel without fossilization. These are called biomass fuels (biomass being a general term for nonfossilized biological material). Wood is the oldest and most familiar biomass fuel. It continues to supply around 10 percent of the world's energy needs.

Wood can be burned directly when being used as a fuel. Other types of biomass material must first be subjected to special processes. The fuel ethanol—ethyl or grain alcohol—is produced by the fermentation of grains such as wheat or corn. The combination of certain organic wastes with hydrogen under high temperatures and pressures converts the wastes into fuel. This process, called hydrogasification, produces methane and ethane.

As with any combustion process, a certain amount of atmospheric pollution accompanies the burning of biomass fuels. They also produce a relatively small amount of fuel for the land used to cultivate them—land that might otherwise have been used to grow food. But biomass fuels are renewable as well as accessible, a cheap and attractive alternative to petroleum for small-scale energy needs.

Geothermal Energy

The Earth has a core and mantle of hot rock many thousands of miles in diameter. At a few places, this hot rock, called magma, melts and pushes close to the surface and manifests itself in the form of geysers or hot springs. These high-temperature regions are sources of energy that may be tapped.

In Iceland's capital, Reykjavik, for instance, nine out of ten homes are heated by water from local hot springs. The Italian town of Larderello uses steam from natural steam wells to spin turbines that produce electricity. Some studies have focused on the possibility of creating artificial steam wells by drilling holes into the crust of recently active volcanoes. Jets of steam produced by pouring water into these holes might be used to drive electric generator turbines of the kind used in conventional power plants.

Water and Wind

Water and wind are both renewable, of course, and, except for the lakes created by dams, their use has little adverse effect on the environment. Hydroelectric dams use the energy of water flowing from a higher to a lower level to operate generators. Attempts have been made to use the rise and fall of the tides for similar purposes, and at least one commercially operating system of this type has been built. Less successful have been plans to tap the motion of the waves.

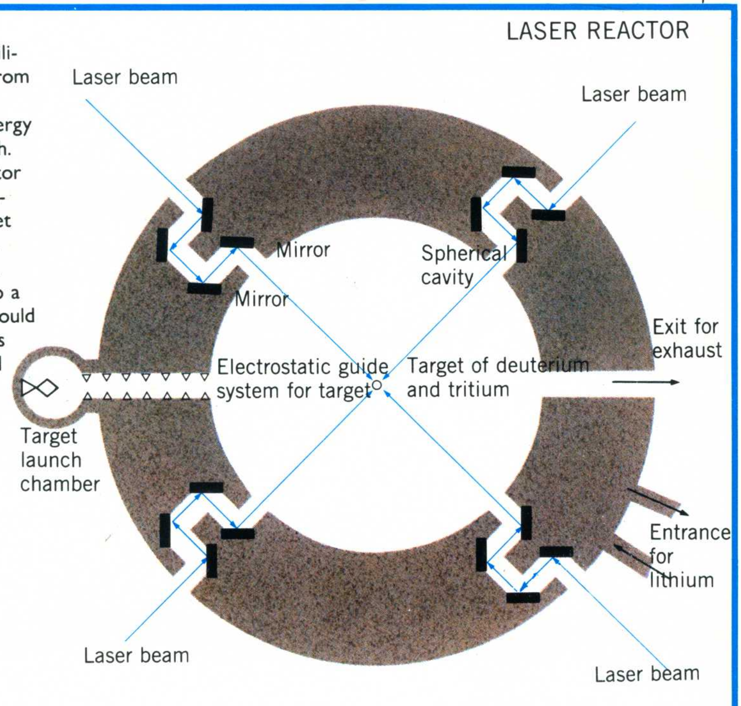
Windmills have long been used to convert the energy of the wind into mechanical energy to grind grain or pump water. Attempts have been made to develop wind generators capable of producing much larger amounts of energy. One approach is to increase the height of the tower and the size of the blades pushed by the wind. Another is to increase the speed of the wind striking the blades by a specially designed set of curved surfaces.

Chemical Energy

Chemical reactions can also be made to produce electricity; and one device that does this is called a battery.

Inside a battery, the reaction of certain chemicals deposits a surplus of electrons at one point on the battery cell, called the anode terminal, and takes them away from another point, called the cathode terminal. The ordinary flashlight battery, for instance, works through a reaction between the element zinc and the compound ammonium chloride. When the battery is in operation, the zinc combines with the ammonium chloride. As the zinc is slowly eaten away, the voltage—the force pushing the electrons from one terminal to the other—gradually drops. The cell must be discarded when the zinc is eaten away, for the reaction cannot be reversed.

A wide variety of batteries have been designed for different energy needs. Chemical reactions involving mercury, silver, nickel, and cadmium are among those used. Whatever the reaction, the nonrenewable chemicals essentially burn themselves out to create electric current.



There are as many possibilities of obtaining energy from distant stars as there are possibilities of nuclear energy from sources on the Earth. A hypothetical laser reactor consists of laser beams focused on a spherical target of deuterium and tritium. The heat would trigger a microexplosion leading to a fusion reaction; helium would be formed, and enormous amounts of energy would be released.

Nuclear Energy

Chemical energy comes from energy contained in the bonds between atoms. Nuclear energy comes from energy contained within the atom itself. Most people are familiar with the picture of the atom as a miniature solar system, with electrons whirling about a nucleus composed of protons and neutrons. When these protons and neutrons are brought together into a nucleus, a tiny fraction of their mass—a few *octillionths* of a gram—is converted into energy. This energy is equal to the amount needed to hold these particles together in the nucleus so that it does not fly apart. This so-called binding energy is very small for light nuclei, increasing with the size of the nucleus. Around iron, with 56 particles in the nucleus, the binding energy reaches a peak and begins to slowly decrease. The binding energy of uranium atoms with 235 particles in the nucleus, for instance, is less than that of the lighter elements iron and tin.

These differences in binding energy can be used to create energy. When a heavy nucleus such as uranium 235 is split, for instance, the product is two nuclei with higher binding energies than the original uranium atom, and energy is released. This process is known as fission. The reverse process, pushing together two nuclei, can also produce energy. Under certain conditions, two hydrogen nuclei may be squeezed together to form a helium nucleus. The process, known as fusion, also releases energy, since the binding energy of helium is greater than that of hydrogen.

No satisfactory way has yet been found, however, to dispose of the thousands of tons of radioactive wastes created each year by nuclear power plants. Some of these materials will be dangerous for centuries. In at least one place in the United States, for instance, wastes that will be radioactive for thousands of years have been buried in tanks built to last for only 40 years. Either cleaner ways to obtain nuclear power or waste-disposal methods will have to be developed.

Solar Energy

The Sun is a much more powerful energy source than any discussed so far. It drives most of the energy processes on Earth. Its light has warmed the Earth for thousands of millions of years and nurtured the plants and animals from which we derive fossil fuels. As it warms the Earth, it produces wind and rain to feed rivers. Solar energy is accessible and renewable. It is also clean, since the powerful nuclear reactions that create it are 93 million miles (150 million km) away.

But sunlight is diffuse and must be gathered and concentrated by devices called collectors. The collected energy may then be transformed into heat, chemical energy, or electricity.

Less than 0.0000001 of the energy emitted by the Sun reaches the Earth. Farther out in space, there are much more powerful sources of energy, though much less of their energy reaches us. The most powerful energy sources in the Universe, quasi-stellar radio sources (quasars), are also among the most distant objects. They may each be as luminous as 100 galaxies combined, but their light is so faint that it is visible on Earth only through the strongest telescopes.

See also BATTERY.

The enormous energy potential of the seas' perpetual motion has inspired inventors for centuries, but most of their schemes went unrealized because of difficulties such as extreme weather conditions, the corroding effect of saltwater on metal parts, and the high costs and energy losses involved in transmitting electric power from offshore generating facilities to land-based consumers. However, recent technological advances and the search for renewable resources have led to more serious experimentation in the field.

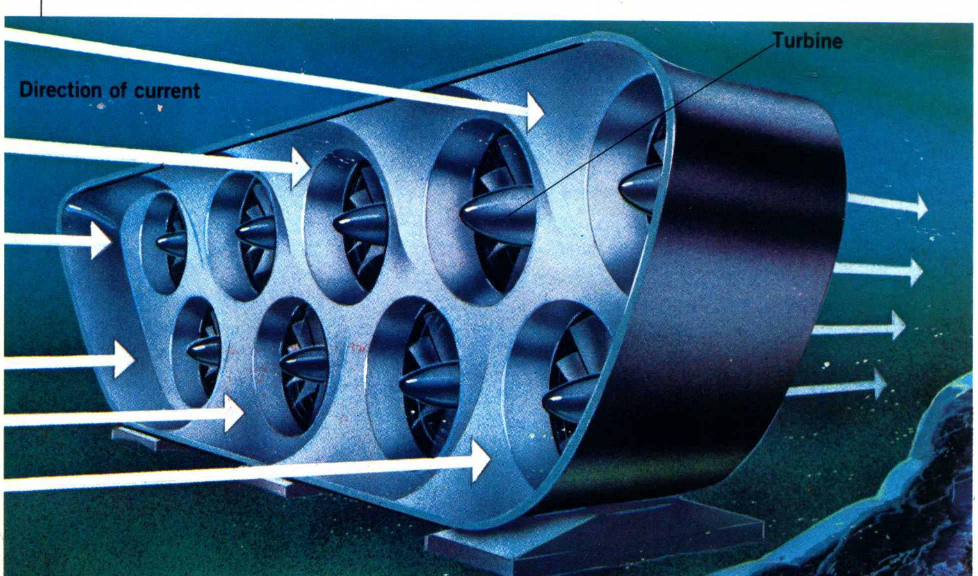
Tide Power

The first important commercially operating system to harness the power of tides was built in the early 1960s on the Rance River estuary near St. Malo, France. It is based on a concept similar to small tidal mills used for at least 1,000 years: the tide flow moves a turbine. A 20th-century improvement is that the turbine operates in either direction, utilizing tide flow both in and out. An inconvenience of tidal power is that one peak generating period may come in the middle of the night, when demand for electricity is lowest. Also, at low tide, there is no potential. A dam helps reduce this problem by prolonging the flow of water in and out of the tidal basin.

The St. Malo plant produces 500 megawatts (1MW = 1 million watts) of electricity per year, enough for a town of 40,000, and is cheaper than any coal, oil, or nuclear plant in France. Critics maintain, however, that the saving is not worth the disruption of an estuary ecosystem, where 60 percent of sea creatures are born.

Only a dozen other places in the world meet the physical requirements for such plants, such as a narrow entrance to the tidal basin for the dam and an average range of at least 14 feet (4.5 m) between high and low tides.

Above: Tidal power plant on the Rance River in France, the first major system to obtain energy from the sea effectively. (A) During high tide, the difference between water levels in the sea and in the reservoir basin forces water through the turbines. (B) To increase the difference in water levels, water is pumped into the basin. (C) As the tide goes out, water flows out, and electricity is generated again. At low tide, the level of water in the basin is lowered to increase the water level difference, and the cycle begins again as the tide returns. Pumping utilizes only 5 percent of the energy generated. *Below:* Proposed turbine for the generation of power from ocean currents.



The Wave of the Future?

A monumental land-based sea-power scheme under consideration in Egypt would utilize the Qattara Depression, a huge area below sea level in the northern Sahara. Nuclear blasting would open a channel to the Mediterranean, and the inrushing water would supposedly generate around 2,400 MW, twice as much as the Aswan Dam. The depression is so large that theoretically it would take 10 years to approach sea level, but the Qattara Depression would never fill up because evaporation would balance inflow.

Most wave-power devices have the advantage of being adaptable to small- or large-scale usage, but waves are as variable as wind, so they have to be supplemented by other sources for a steady flow of electricity. This factor has discouraged significant investment in wave technologies, but some work continues.

One device consists of a floating two-level tank. Waves splashing into a pipe with a one-way intake valve force water into the upper compartment, which then drains into the lower level, turning the turbine and generating electricity.

The British and Japanese are experimenting with hollow buoys shaped in a large ring. Upward motion of the wave pushes water into the buoy through slots in the bottom, forcing air up through the turbines and out through vents in the top of the buoy. Downward motion of the wave sucks the air back in past the tur-