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ABSTRACT

Pennsylvania's Department of Education provides eight energy education modules that cover different secondary school disciplines. This introductory publication is designed to accompany each of the eight subject-area modules. It contains background information for teachers on topics ranging from energy's definition and past uses to nuclear waste disposal, energy conservation, and principles of energy economics. Also included are a glossary, bibliography, and list of free films and other resource materials. (WB)

ENERGY

PENNSYLVANIA'S ENERGY CURRICULUM FOR THE SECONDARY GRADES

Informational Module

Pennsylvania Department of Education 1980
Funds Provided by Governor's Energy Council

Commonwealth of Pennsylvania
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Department of Education
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PREFACE

Throughout history, the advancement of civilization and the quality of human life have been directly related to the availability of energy resources. From the discovery of fire to the splitting of the atom, there has been a steady increase in the amount of energy used by the world's people.

Our nation and the rest of the world are now faced with a situation where the major energy sources of oil and natural gas will be significantly depleted during our lifetimes. U.S. dependence on imported oil is weakening our economy, and skyrocketing fuel prices are a major cause of inflation.

Although energy problems have been with us now for many years, our nation seems to be foundering without any clear program to deal with them. The President and Congress are at odds over questions like the windfall profits tax and gasoline rationing. The country is divided on the issue of nuclear power. Some people think we should turn our backs on society as we know it, and return to a "simpler" lifstyle. In the face of this confusion, it is important that the public become aware of the energy problems and the various alternatives available to us. The decisions made now will affect our quality of life in the future, including our home life, our job, our health, our leisure time, and many other aspects of our lives.

The purpose of these modules is to help you guide your students to an understanding of energy, particularly as it relates to your specific discipline. There are eight modules, covering the following subject areas:

- English
- Home Economics
- Social Studies
- Industrial Arts
- Biological Science
- Earth Science
- Physical Science
- Environmental Studies

This introductory module is included with each of the subject area modules. Its purpose is to give background information for all teachers. It also includes a bibliography and a list of free films and other resource materials available to teachers.

Also included with each module is a copy of The Pennsylvania Energy Primer, a publication of the Governor's Energy Council. It contains energy information especially pertinent to our state.

It is hoped that through the use of these materials, both teachers and students can come to a better understanding of the energy situation, and can thus be more informed and vocal citizens.

ENERGY: WHAT IS IT?

DEFINITION OF ENERGY

The word "energy" can have a number of meanings. We will define it here as scientists and engineers do: energy is the ability to do work. The word "work" in this definition also has a specific meaning: it refers to the movement of matter from one point to another. For example, we do work when we push or pull an object for some distance, and energy is the ability to do this work.

Energy can appear in many different forms. Some common forms are mechanical energy, radiant energy, chemical energy, and electrical energy. We will talk at greater length about these different forms of energy in a later section. We will also discuss how the various forms of energy can be changed from one form into another.

Throughout history, people have developed sources of energy to work for them. Primitive humans had only the strength of their bodies, and later the use of fire. People tamed animals to work for them. They used the energy of wind to move sailing vessels, and the energy of water to turn mills. With the invention of the steam engine, steam could be used to run machines. The discovery of electricity created another important way of using energy. So did the invention of the gasoline engine. A new era in the use of energy was entered with the application of nuclear energy.

Most of the energy we use comes directly or indirectly from the sun. For example, when the radiant energy of the sun falls on the earth, it is changed to heat energy, warming the earth. When the sunlight falls on the leaves of plants, it is changed into chemical energy, enabling the plants to make food for animal consumption, and wood which we can burn to work for us. Other plants have been stored under the surface of the earth, where they have undergone chemical changes into coal, oil, and gas. These are called the fossil fuels, and they are presently our major source of energy.

KINETIC AND POTENTIAL ENERGY

There are two general categories of energy, encompassing the various forms. These categories are potential energy and kinetic energy.

Energy that is stored is called potential energy. It is energy that an object has because of its position or condition. For example, a tightly stretched spring has potential energy–it has the ability to do work if released. A rock lying at the top of a hill also has potential energy–it can do work if allowed to roll down the hill. A pile of coal has potential energy, since work can be done when the coal is burned.

On the other hand, the energy that an object has because of its motion is called kinetic energy. If a stretched spring is released, it has kinetic energy. A rock rolling downhill also has kinetic energy.

Potential energy represents work that has already been done. For example, suppose someone lifts a weight off the ground. As a result of this work, the weight possesses a certain amount of potential energy. If the weight is allowed to fall, its potential energy is changed into kinetic energy. At the instant it strikes the ground, all its potential energy is gone. When it rests on the ground, the kinetic energy is also gone, having been changed into some other form of energy, usually heat.

FORMS OF ENERGY

Mechanical Energy

Mechanical energy is that form of energy which is acquired or released by moving objects. A rolling wheel, a turning windmill, and a rotating waterwheel are examples of objects with mechanical energy.

Mechanical energy can be easily changed into other useful energy forms. For example, falling water can spin the blades of a turbine. The mechanical energy of the spinning turbine can be converted into electrical energy if the turbine is connected to an electrical generator.

Other forms of energy can also be changed into mechanical energy. For example, gasoline or diesel fuel, which contain relatively large amounts of potential energy, undergo controlled combustion in the engine of a bulldozer and produce motion in the pistons and other parts of the engine. The bulldozer can then do work.

By its very nature, mechanical energy is closely associated with kinetic energy.

Gravitational Energy

One important form of potential energy is gravitational potential energy. This is the energy of a rock poised at the edge of a hill, or of droplets of water at the top of a waterfall. These are examples of gravitational potential energy because it is the earth's gravitational pull which will set them in motion.

One application of gravitational energy is to use falling water to turn turbines and produce electricity in a hydroelectric dam.

Chemical Energy

Chemical energy is that energy which is involved in chemical reactions. In most chemical reactions, energy is released or absorbed in the form of heat.

Photosynthesis and respiration, two biological processes, are basically chemical reactions. The rusting of iron is a chemical reaction which releases heat, but it generally occurs so slowly that the heat released is not detected. In a battery, chemical energy is stored for later release as electricity.

Chemical reactions that release heat are of particular importance as usable energy sources. The burning of fuels such as wood, coal, gas, and oil provides for release of stored chemical energy. Note that some initial energy is necessary to start these chemical reactions. For example, wood begins to burn only after it has been heated to its kindling temperature. The burning of coal, gas, and oil provides heat which can be used to boil water, creating steam which can then turn turbines to generate electricity. We again can see how one form of energy can be changed into many other forms.

Electrical Energy

Have you ever run a comb through your hair and had your hair crackle and stand up? Or have you walked across a carpet, then touched a door handle, and felt a shock? These are examples of the action of electric charges.

There are two kinds of electric charges: positive and negative. We will see how these electric charges can become a usable form of energy. But first we must discuss some basic concepts. All matter is made up of very small particles called atoms. Every atom except the simplest hydrogen atom has a nucleus which consists of neutrons and protons. (The simplest hydrogen atom has no neutrons–it is simply a proton.) Neutrons have no electrical charge; that is, they are electrically neutral. Protons are positively charged, and every proton has the same amount of charge, no matter what kind of atom it is from.

The nucleus of an atom is surrounded by negatively charged electrons. Every electron has the same amount of charge, and the magnitude of the negative charge of the electron is equal to that of the positive charge of the proton. Thus in an atom that is electrically neutral, the number of electrons surrounding the nucleus is equal to the number of protons in the nucleus, so that their charges exactly "neutralize" each other. If an atom has more electrons than protons, it is negatively charged; if it has more protons than electrons, it is positively charged.

In much the same way as magnetic forces operate, objects with opposite electric charges attract each other, while those with the same charge repel each other.

If a glass rod is held in the hand and rubbed by a wool cloth, the friction causes electrons to transfer from the wool to the glass. Thus the glass becomes negatively charged, and the cloth positively charged. When these two oppositely charged objects are brought close enough together, electrons will return to the cloth and each object will again be electrically neutral. This neutralizing action will create a spark in the small gap of air between the two objects.

However, if a metal rod is held in the hand and rubbed with a wool cloth, it will not become electrically charged. The charge which is created simply flows through the metal and through the hand of the person holding it. This is because metals are good electrical conductors. In a conductor, some of the electrons can move about freely, and thus move the electric charge through the conductor. If the metal rod is held by a piece of rubber, however, the rod can be charged. This is because rubber is an insulator or non-conductor. In an insulator, electrons are tightly held, and thus are not free to move through the system. So the electric charge cannot move through the rubber insulator and into the hand.

With this background, we can now think of electricity as the movement of electrons.

The examples of electricity that we have mentioned so far are all examples of static electricity. Static electricity involves electric charges on insulators, such as a glass rod and wool cloth, or a comb in dry hair.

But of much more practical interest from an energy standpoint is an electric current–a continuous flow of electrons through a conductor. There are several ways of producing an electric current. One way is by using the relationship between electricity and magnetism. Electric charges in motion are always accompanied by magnetic effects. For example, a bar of iron placed in a coil through which a current is flowing becomes magnetized. In this way, it is possible to make electromagnets, which are extremely useful in converting electrical energy into mechanical energy, a major component of electric motors.

Conversely, it was discovered that when an electrical conductor is moved through a magnetic field–that is, an area where magnetic forces are present–an electric current is produced in the wire. If a conductor wire is formed into a loop, and the loop is moved through the magnetic field which exists between the north and south poles of a magnet, an electric current will be produced in the loop. Note that the conductor or the magnet must be moving–there must be movement of one in relation to the other–for the current to be produced. The type of motion determines the direction in which the current flows. If, for example, the conductor loop is spun between the poles of the magnet, the electrons in the loop will move back and forth within the loop. Thus the current flows first in one direction and then in the reverse direction. Current produced in this way is called alternating current, and this is the kind of current we use when we plug something into an electrical outlet.

Electromagnetic or Radiant Energy

The movement of electrically charged particles of matter in magnetic fields produces energy in the form of electromagnetic waves which radiate from the source at the speed of light. This energy is often called radiant energy. Depending on the conditions uner which they are generated, these electromagnetic waves may have a long wave length, which means they have low frequency and energy. They may be of the particular wave length that can be detected by the human eye, in which case they are visible light waves. Or they may be of shorter wave length and higher energy, such as x-rays. Thus a wide band or spectrum of electromagnetic waves exists.

The sun is the major source of radiant energy for the earth. Sunlight is that portion of the sun's total radiation that is visible to the human eye. Other electromagnetic waves radiated from the sun are infrared and ultraviolet radiation, gamma rays, x-rays, and radio waves.

Nuclear Energy

Nuclear energy is the energy released or absorbed during alterations within the nucleus of an atom. We have already said that the building block for all matter is the atom, and that an atom can be considered to be a dense core of particles called protons and neutrons forming a positively charged nucleus, surrounded by a swarm of negatively charged electrons.

Any one of the more than 1800 species of atoms characterized by the number of neutrons and protons in the nucleus and by energy levels is called a nuclide. For example, an atom of chlorine with 18 neutrons in its nucleus is one nuclide, while an atom of chlorine with 20 neutrons in its nucleus is another nuclide.

All nuclides can be placed into one of two categories: radioactive or stable. Radioactive nuclides (radionuclides) undergo spontaneous nuclear changes which transform them into other nuclides. This transformation is called radioactive decay, and through the decay, the radioactive nuclide is changed eventually into a stable nuclide.

There are some 265 stable nuclides and 66 radionuclides found in nature. All the rest of the nuclides are man-made radionuclides. Thus most known nuclides are radioactive.

In changing to a stable state, the nucleus of a radioactive atom emits radiation. Radiation may be in the form of particles, or in the form of electromagnetic rays called photons. Some radionuclides decay by the emission of alpha particles, which are high energy helium nuclei. Others decay by the emission of beta particles, which can be either negatively charged electrons (negatrons) or positively charged electrons (positrons). Decay by the emission of these particles is usually followed by the emission of photons of two types: gamma rays, which are produced in the nucleus of the decaying atom, and x-rays, which are produced as a result of the rearrangement of orbital electrons. Except for their origin and the fact that x-rays are usually lower in energy and therefore less penetrating, x-rays and gamma rays are the same.

Loss of this radiation changes the atomic structure of the radioactive nuclide, a process which continues until a stable (nonradioactive) nuclide is reached. Uranium, for instance, is radioactive; it decays slowly into elements like radium, radon, and polonium, and finally stops at lead. The time required for one-half of the radioactive atoms of a nuclide to decay to its daughter nuclide is known as the half life of that nuclide. An atom with a short half life quickly decays. Half lives vary from minute fractions of a second to billions of years.

As a source of useful energy at the present time, the most important nuclear reaction is the fission reaction. When atoms of certain heavy nuclides are bombarded by neutrons, the nuclei of some of these atoms will capture a neutron and become unstable so that they fission, or split, into two or more smaller atoms. These smaller atoms are generally radioactive. Together the fission products weight slightly less than the original atom and the bombarding neutron combined; this missing mass is converted into energy, as described by Einstein's formula: energy equals mass times the velocity of light squared ($E = mc^2$). It is this conversion of mass into energy that makes nuclear fission so powerful, and sets it apart from ordinary chemical reactions, where no such conversion occurs. As fission fragments fly apart, most of this energy appears almost instantaneously as heat as the fragments lose their energy of motion to the surrounding material. The heat from this fission reaction can then be used to boil water to make steam, which in turn spins turbines that generate electricity.

When an atom fissions, several free neutrons are released. These are available to strike other atoms, causing them to fission. This is the chain reaction. If a chain reaction is to continue, there must be enough fissionable atoms packed closely enough to insure the capture of enough neutrons to keep the rate of fission constant. The amount of material required for this is called the critical mass.

Uranium is the basic nuclear fuel because it contains uranium-235, the only nuclide found in nature that readily undergoes fission. The natural concentration of uranium-235 in uranium is seven-tenths of one percent; the balance is uranium-238, which does not readily undergo fission.

The process of nuclear fusion also releases a tremendous amount of energy, but we have not yet come to the point where we can make practical use of it. In fusion, two light nuclei are forced together to form a heavier nucleus. The fusion reaction will use forms of hydrogen called deuterium and tritium to make a single helium nucleus and a neutron, releasing a large amount of energy.

Heat Energy

Early experiments showed that heat had to be some form of motion. But obviously an object can be hot without any motion being visible. Thus the motion must be occurring in parts of the object which are too small to be seen. These small parts are called molecules. The speed of a molecule can be quite large, but the molecules of solid objects move through a very short distance. The higher the speed of the molecules in an object, the greater the amount of heat energy it contains.

The combustion of gasoline in an automobile engine produces heat energy, or high speed motion of the molecules in the cylinders. The motion of these molecules against the pistons make the engine run. Thus work is obtained from the heat energy of molecular motion.

Note that heat and temperature are not the same thing. Temperature measures the average kinetic energy of molecules in an object. When an object is heated, this average speed is increased, and the temperature increases. The amount of heat in an object, however, depends on the number of molecules present as well as their kinetic energy. Thus a cup of boiling water has the same temperature as a quart of boiling water, but the quart of boiling water has four times as much heat energy, since it has four times as many molecules.

Heat can be thought of as the simplest form of energy, since it is the form of energy into which all other forms can be most readily converted. It is also the form that is most difficult to convert into any other form.

ENERGY TRANSFORMATIONS

We have already seen that energy can be converted from one form to another. But no one has ever found a way to create energy out of nothing. Furthermore, there is no known way of destroying energy–energy is never lost. Under special circumstances, energy can be converted into matter and matter into energy, but this is still transformation, not creation or destruction of energy.

One of the biggest problems with energy is the fact that when energy is converted from one form to another, some of the energy is wasted. It is not destroyed–it just changes into a form where it is no longer of practical use. This form is usually heat, which escapes and is eventually dispersed into space, never to be seen again.

Of course, heat energy can be converted into other types of energy, but a great deal of effort must go into the transformation. On the other hand, other forms of energy can be converted into heat much more easily. There thus seems to be a definite direction in which energy seeks to flow, and this direction is toward a dilute, scattered form of energy. Scientists call this form "entropy," and its precise definition need not concern us. In practical terms, it means that energy that has become so dilute and scattered cannot be used ever again to do work.

This inherent wasted heat energy represents a permanent challenge to the energy conservationists. It is energy "down the drain" as far as providing useful work to meet energy needs. We must learn to reduce energy waste to acceptable levels, keeping in mind that complete elimination of energy waste is impossible.

MEASUREMENTS OF ENERGY

We need not concern ourselves with many sophisiticated terms in energy measurement, but we do need some basic definitions to serve as tools in talking about energy.

A basic unit of energy measurement is the British Thermal Unit, or BTU. One BTU is the amount of heat energy that must be supplied to one pound of water to raise its temperature one degree Fahrenheit.

Energy from all fuels can be converted to BTU's. Approximate conversion rates are as follows:

One 42 gallon barrel of oil —————— 5.8 million BTU's
One cubic foot of natural gas —————— 1031 BTU's
One kilowatt-hour of electricity —————— 3413 BTU's
One ton of coal —————— 25 million BTU's

The word power refers to the amount of energy used or produced in a given amount of time. One important unit of power is the watt. One watt is equal to .00948 BTU per second. One kilowatt is 1000 watts, while one megawatt is 1,000,000 watts.

The kilowatt-hour is the familiar measurement of electricity. A kilowatt-hour (KWH) is 1000 watts of power used for one hour.

All electric appliances and light bulbs are rated in watts. For example, a 100 watt light bulb will light for 10 hours with one KWH of electricity. An appliance with a rating of 1000 watts will run for one hour on one KWH of electricity.

In biological processes, the unit of energy is the calorie. One calorie is the heat required to raise the temperature of one gram of water one degree Centigrade. The Calorie (note upper case C) is called the kilocalorie, and is equal to 1000 calories. One Calorie is about 4 BTU.

ENERGY AND THE LIVING WORLD

We have discussed various forms of energy, and their transformations. Later sections will deal with how people use these forms of energy to do work for them. But before we leave the general topic of energy, let us examine some aspects of energy as it pertains to the world around us.

As we have said before, the sun provides the energy that sustains life on earth. The sun has probably existed for some five or six billion years. It is really just an average, middle-sized star when compared with the rest of the stars in the universe. What is so special is the earth's location in relation to the sun. The earth is just the right distance from the sun to support life as we know it.

The exact source of the sun's energy is not really known. It has been theorized that the sun is a giant fusion reactor, fusing hydrogen into helium and converting the mass difference into energy. It is believed that the sun produces more energy in one second than has been used by all people throughout human history.

The tremendous energy produced by the sun radiates out in all directions. Only a very small fraction (one two-billionth) ever reaches the earth's atmosphere. Not all of this energy reaches the earth's surface. In fact, 40 percent of the solar radiation is reflected back to space (mainly by clouds); 17 percent is directly absorbed by the atmosphere, including water vapor, clouds, and dust. The remaining 43 percent is absorbed by the earth, and is used to power the winds, water cycle, and ocean currents, and to support life. Actually, only about one percent of the incoming solar radiation is used to support life through photosynthesis.

The earth's atmosphere plays an important part in regulating the temperatures here on the earth. Because of our atmosphere, we do not have the large temperature fluctuations that are found on the moon.

Another benefit provided by the atmosphere is what is called the "greenhouse effect." We have said that 43 percent of the radiation from the sun that reaches the atmosphere, mostly visible light, passes through the atmosphere and is absorbed by the earth. This is transformed into heat (infrared radiation) and is radiated back toward space. The water vapor and carbon dioxide found in the atmosphere are good absorbers of heat. They then trap much of this heat energy and prevent it from immediately escaping back into space. This keeps the average temperature of the earth higher than it would be without the atmosphere.

The greenhouse effect is also the center of one of our modern-day controversies. One group of scientists is proclaiming that, because of all the smoke we are generating by burning fuels, we are going to block off enough incoming sunlight to lower the earth's temperature several degrees, which would be disastrous. Another group of scientists argue that because of the large amount of carbon dioxide we are generating, also through burning fuels, we will trap more heat in the atmosphere, which would raise the temperature of the earth several degrees and also prove disastrous. Might the production of energy prove in some way to be the downfall of the human race?

Only green plants can directly use the incoming solar radiation. All other organisms must then depend on the green plants for their life support.

Green plants use solar energy in the process of photosynthesis, where the sun's energy is transformed into chemical energy and stored as food. As the sun beams down on a green plant, the plant is taking molecules of water, minerals from the soil, and carbon dioxide from the atmosphere, and is using the sun's energy to combine these molecules into various new arrangements to form sugars, starches, proteins, and vitamins. These new molecules contain the chemical energy that other organisms will then use to sustain their life.

The process whereby animals use the energy stored by plants is called cellular respiration, and is really just the opposite of the process of photosynthesis. In cellular respiration, the food molecules (sugar, starch, and protein) are torn apart and energy is released, while carbon dioxide and water are produced. The energy released is then used by the animal for motion, growth, and other life processes.

Some of the energy from the plants is also stored again in the tissues and fat of the animal. Thus if an animal is eaten by another, the first animal is providing energy for the next animal—energy that actually originated in the sun.

This process of passing on the sun's energy can continue for only a limited time, because as in most energy transformations, energy is being lost at each step of conversion. As the energy is passed from one organism to the next, most of it (80 to 90 percent) is lost through respiration and heat, and only 10 to 20 percent is available to the next organism. Because of this loss, a country that eats large amounts of meat, like the U.S., has to produce many times more plants (grains) to supply everyone with food than a country such as India or China that eats more of the plants directly. In other words, eating meat can be considered a waste of energy because so much of the energy is lost as the corn and wheat are transformed into the meat of the animal.

The sun provides the energy for many other phenomena besides life support. Wind is caused by the uneven heating and cooling of different parts of the earth by the sun. As the temperatures of two different regions of the earth are unequal, the air pressures over these regions are also different, and winds are produced. The energy in these winds may then be used for various purposes, including steering weather systems, driving ocean currents, shifting desert sands, and powering some machines.

The sun's energy also drives what is known as the water cycle. It all begins with the sun causing evaporation of water from the land and oceans. The water vapor later condenses and falls back to the land in the form of rain or snow. Gravity causes the water to run from the land back to the ocean.

ENERGY: ITS PAST

From their earliest orgins, human beings have sought to ease their labor through the use of tools. Early hunters used tools to kill animals, and thus obtained energy from eating the bison and mammoth to supplement the energy they received from eating plants.

The most vital Stone Age discovery was how to make fire.

During the later Neolithic period, humans used stone tools for agriculture, and were able to produce renewable crops. The first stable communities began to develop, and various forms of housing were built. These primitive dwellings were all designed to meet the climatic needs of the area in which they were located. Thus communities could flourish, since the population did not have to migrate with the seasons to escape unfavorable weather conditions.

Further technological progress brought the ability to mine metals and use fire to forge them into tools and weapons. First came the Copper and Bronze Ages, and then the Iron Age, which may have begun in Africa or the Orient some 2400 years ago.

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Before the time of the Greek and Roman civilization the only significant energy sources were natural ones. The power of falling water was used by basic industry, agriculture, and mills. The power of the wind was used for ships, and fire from the burning of wood was another energy source. One major source of energy in both Greece and Rome was the energy of human bodies–particularly slaves. From the Greek and Roman era to the beginning of the Industrial Revolution, sophisticated tools were developed, but they were still powered by humans or animals.

Between the fall of the Roman Empire and the last few years of the 17th century, many important inventions were developed and some of the great laws of nature were conceived. But to bring about the era of modern technology, an engine was necessary that could use an energy source and produce useful work. The water mills and windmills were limited to specific sites, and there was no way known to transport their energy to where it was needed. By the end of the 17th century, this engine appeared. In 1698, Englishman Thomas Savery obtained a patent for a machine which used fire to boil water, generating steam in a boiler for use in draining water from mines. His steam engine pump was soon improved upon, and these engines made possible the deep mining of coal, which had previously been hampered because of the buildup of underground water in the mines.

Englishman James Watt patented a vastly improved engine in 1782 and by this time the steam engine had become the forerunner of mechanized civilization. They were used for pumping water and supplying power to textile mills, rolling mills, and flour mills. A later breakthrough came with the development of engines that could use high pressure steam, making the engines much more efficient. With Robert Fulton's successful operation of the steamboat Clermont on the Hudson River in 1807, and Richard Trevithick's use of a steam locomotive to transport coal in Wales, the modern era of mechanized transportation began

Little was actually understood about the theory of [illegible] engines, until the [illegible] of the science of thermodynamics. When these scientific principles came to be understood, bigger and better engines could be built

Up until the second half of the [illegible] primarily muscle power of humans and animals, along with wind, wood, and falling water. Ninety percent of the fuel burned in 1850 was wood. Coal accounted for only 10 percent despite the presence of plenty of coal and the technology to use it. But then the extensive cutting of forests in the east raised the price of wood and increased the distance that it had to be transported to the growing cities. So the demand for coal skyrocketed until in 1885 coal surpassed wood as the dominant fuel. In 1885, coal was used to fuel the railroads, to make coke for the steel industry, to power miscellaneous industries, and to provide residential fuel. Coal was to remain the dominant fuel until well into the 20th century

During the 1800's [illegible] burned to produce light were expensive [illegible] England had developed a coal gas pipeline network for lighting, but the scattered population and undeveloped coal industry in the United States made such a network generally impractical. Finally, an Englishman devised a method of producing oil from coal which he called coal oil or kerosine. By the late 1850's, there were many kerosine plants in the Eastern U.S. Then some people began to notice a resemblance between the kerosine and the largely useless "rock oil" that came out of springs and wells in western Pennsylvania. In 1857 a Yale chemistry professor, Edwin Drake, hired by a group of Pennsylvania businessmen called the Pennsylvania Rock Oil Company, gave his report on some of this oil. He concluded that some "very valuable products" might be manufactured from it. Drilling, rather than digging, turned out to be the best way of getting to the oil and so in

September 1859, at Titusville, Pennsylvania, oil was struck at a depth of 69 feet. This was not the first oil well in history—the potential value of oil had been recognized centuries before. But it was only in the Western industrial world of that time that science, technology, and society came together at a point necessary for oil to be exploited as the concentrated fuel that would eventually replace coal.

The crude oil was made mostly into kerosine. Some of the other products were lubricants, which solved another major problem of increasing mechanization, and fuel oil, whose use grew as it began to replace coal for firing boilers for steam generation.

The use of steam for railroads and ships was a great step for transportation but coal was too bulky and inefficient for use in any smaller scale vehicles. What was needed was a smaller engine. In 1870, inventors began testing an engine using gasoline in a compressed air-gas mixture. Up until this time, gasoline had been a generally useless by-product of kerosine refining. In 1887, a gasoline-fueled engine was adapted to vehicles and the first Benz automobile was patented. This engine was the forerunner of all internal combustion engines in operation today. By 1900, many automobiles had been built in the United States, most of them steam driven or electrically powered. But the increasing availability of both fuel and lubricants for gasoline powered automobiles speeded their development. They were light, maneuverable, fast, and competitive in cost. In 1900 the Oldsmobile switched from steam to gasoline, and three years later Henry Ford introduced his gasoline-powered automobile. His mass-production techniques revolutionized industry.

A milestone in energy history, [illegible] Edison himself, however, saw his own greatest achievement not as the light itself but as the world's first electrical power generating and distribution system. In 1882 he supervised the building of this system to light 1200 lamps in a one half square mile area in New York City. Edison's generating station consisted of four boilers which produced steam to power six generators.

[illegible] ally put the steam engine at the disposal of every home, business [illegible] and much of the Western world.

Just [illegible] after Edison [illegible] ting the nation's first hydroelectric power [illegible] Wisconsin [illegible]

[illegible] Work that was [illegible] done by [illegible] labor saving devices and mechanization of the home [illegible]

The latter [illegible] century also [illegible] included the [illegible] inventions were necessary to develop the [illegible] was rapidly evolving.

[illegible] number [illegible] than 8 million in 1920. Electrical power generation [illegible] by 19[illegible] electric consumption was more than [illegible] what it had been [illegible] electric power especially suited to the concept of the assembly line and the number of electric motors soared. Electricity thus made practical the mass production of appliances which were themselves electrically powered.

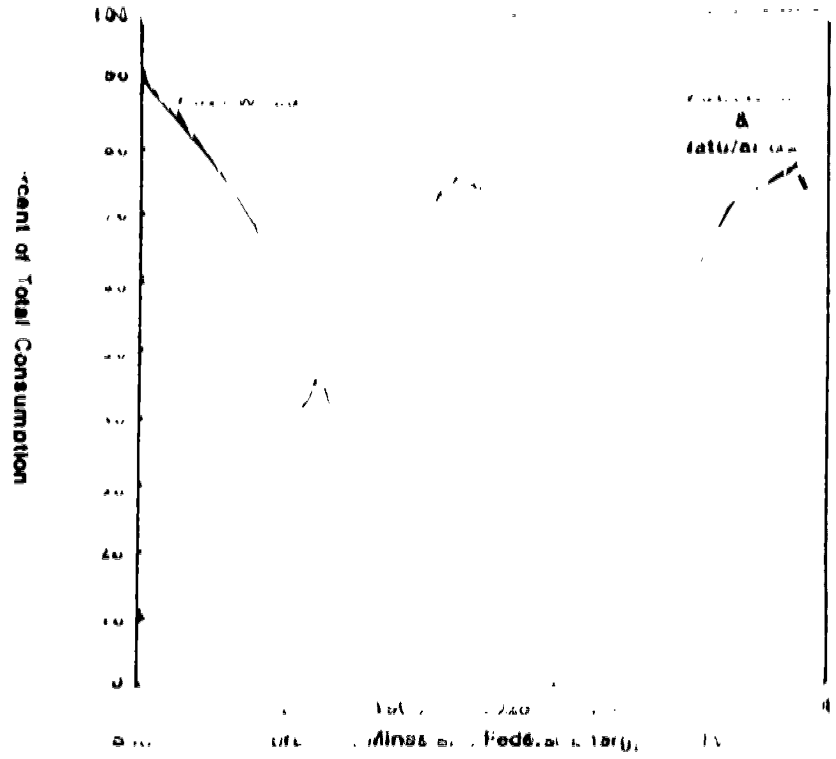
Total energy use in the United States grew much more slowly after World War I, and the shift toward oil continued. Oil overtook coal as the dominant fuel just after World War II, and has continued to claim an increasing share of the market. This shift to oil was brought about by the growing use of the automobile, and the switch from coal to fuel oil for residential heating and powering trains. Gasoline's share of the petroleum market increased very quickly. Two other uses of fuel also increased sharply during the years from the 30's to the 50's: aviation and farm equipment. The major petroleum product being produced was thus changing from kerosine to fuel oil to gasoline to accommodate the changing patterns in consumption. There was also a large increase in the use of asphalt, another petroleum product, to pave roads.

Geographic areas of oil production were also changing from Pennsylvania and neighboring Ohio and West Virginia, to California and Oklahoma, and then to Texas and Louisiana.

Natural gas, which is often found in conjunction with oil, was mostly wasted until the late 1920's, when it became technologically feasible to lay the pipeline to transport it. Natural gas was clean burning, convenient, and cheap, and it thus became the nation's primary household fuel by 1960. Gas also found use in industry, and for electrical power generation.

After World War [illegible] consumption accelerated, although overall energy growth was slower. From the beginning of World War I until 1973 total electric power demand had been doubling every 10 years. In the 1920's and 1930's coal was the fuel for about two-thirds of the electric power generated, with hydroelectric power providing the rest. The shift to oil and natural gas had changed this ratio significantly, until by 1970 coal had dropped to about 45 percent, hydroelectric power provided 17 percent, natural gas accounted for almost 25 percent, oil about 12 percent, and a newcomer to the fuel scene, nuclear power, provided one percent.

[illegible]



[illegible] Mines [illegible] Federal [illegible]

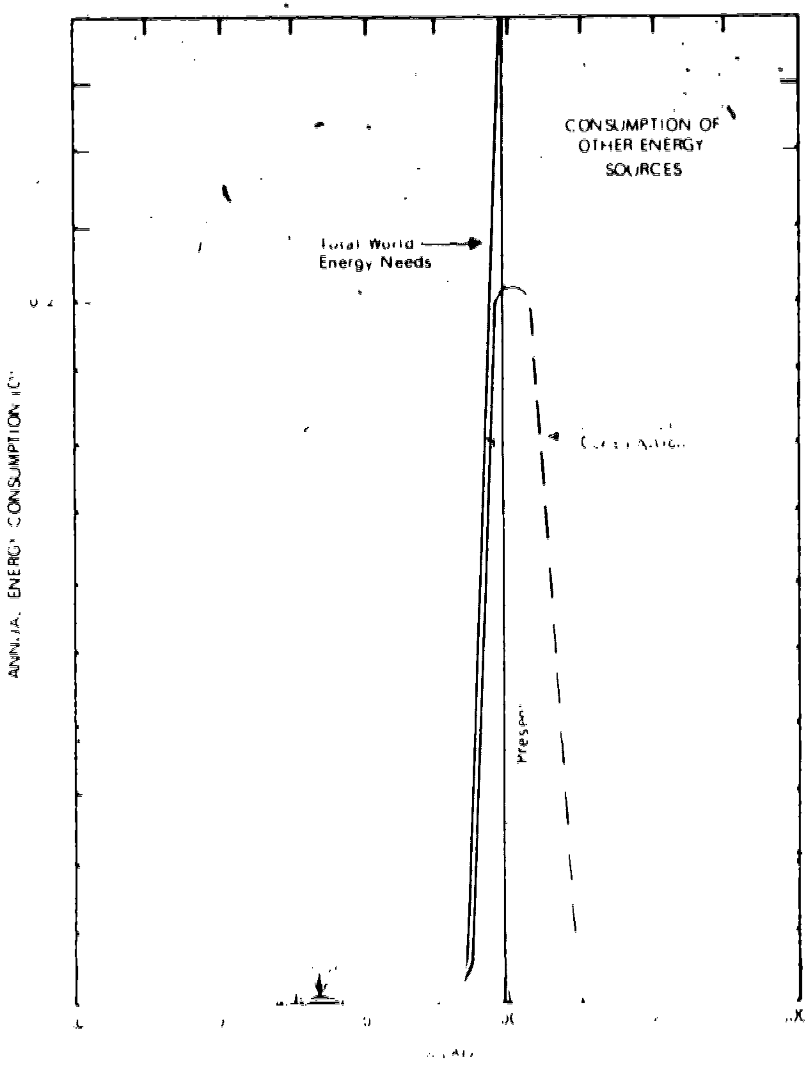
UNITED STATES' CHANGING FUEL BALANCE
FIGURE 1

At the beginning of the 20th century, scientists were investigating the rays given off by radium. In 1905, Albert Einstein demonstrated mathematically the relationship between mass and energy, although it was decades before this theory could be proved. On December 2, 1942, a group of scientists headed by Dr. Enrico Fermi gathered under a squash court at the University of Chicago, where the first controlled nuclear reaction occurred. Scientists have since been working to safely harness that tremendous nuclear energy for the generation of electricity. The nation's first prototype nuclear power plant was built at Shippingport, Pennsylvania, in 1957.

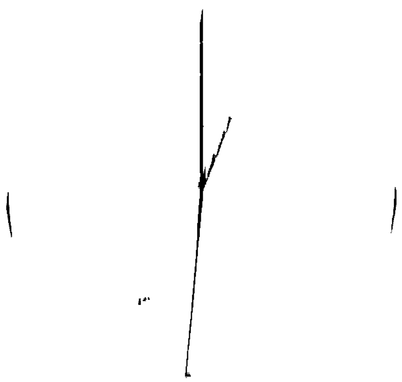
In the years since World War II energy consuming technology has appeared everywhere. During this period, a huge fleet of passenger airplanes has developed, there has been an automobile "population explosion." Air conditioning, central heating, television, clothes washers and dryers are generally thought of as necessities, not luxuries. A mechanized agricultural industry uses tremendous amounts of energy. The various engines that perform America's work produced 7.5 times the number of horsepower in 1971 than they did in 1940 while the number of people in the country increased by only 54 percent. Even with the slowing population growth, more and more energy is being used.

Our country [illegible] also as a basic raw material for plastics, pesticides and synthetic organic chemicals. Everyone alive today was born years after this fossil fuel epoch began, and we have tended to act as if we expect it to go on forever. But Dr. M. K. Hubbert of the U.S. Geological Survey estimates that in a period of only 1300 years from beginning to end humans will have consumed the world's entire available supply of fossil fuels. This is illustrated in Figure 2. Thus the world today is on the brink of transition from the fossil fuel age to some future energy era. As we have seen from this discussion of energy history, humans have moved from one fuel epoch to another not because the old source was depleted but because something better had been found to take its place. Discovery of the new preceded depletion of the old. People did not run out of muscle power, wind or animals; they simply found something better. But this time there must be a change to some other energy form, and in the meantime, until the transition is made, we must conserve the fossil fuel resources we have by cutting down wasteful usage and increasing the efficiency of what we do need to use. This important topic of conservation, what each of us can do personally, is dealt with in a later section.

[illegible] hospitals, theaters [illegible] etc.) [illegible] these sections divide [illegible] energy [illegible] generated by [illegible] five [illegible] sources



[illegible]
Past and Future
FIGURE 2



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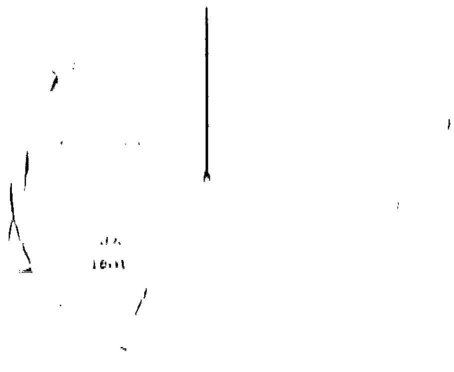

[illegible]

The following sections deal with each of the five primary energy sources of Figure 3, as well as one secondary source, electricity.

COAL

Basic Information

Coal is by far our most abundant domestic fossil fuel resource, with identified reserves sufficient to meet the nation's needs for an estimated 200 years or more.

The basic ingredients of coal are carbon, hydrogen, oxygen, nitrogen, and [illegible]

The starting point for coal is the formation of peat. Peat is essentially an accumulation of dead plants in early stages of decomposition. Peat is usually formed in areas such as swamps and bogs where water covers dead vegetation that has accumulated on the ground. The water blocks the action of bacteria from the air, greatly slowing the rate of decay. This causes most of the carbon in the plant matter to be retained, and it is this carbon that produces heat when burned. After layers of these plants have been buried for periods of about 10,000 years they become peat. Peat is brownish black and looks like decayed wood. When dried, peat can be burned, but it has a relatively low energy content and is very smoky. Peat is used as a fuel in many areas of the world.

The conversion of peat to coal [illegible] As the peat was buried below the surface, increasing temperature and pressure began to convert it to coal.

Coal [illegible] most [illegible] deposits in North America are found in rocks of the [illegible] Pennsylvanian [illegible] to [illegible] million years old.

Coal is classified [illegible] is produced by burning the coal.

[illegible]

easy to handle, burns cleanly [illegible] a major air pollutant resulting from the burning of [illegible] coal is found almost exclusively in Pennsylvania [illegible] the [illegible] difficult and expensive to mine. Anthracite makes up only a small [illegible]

[illegible] easy to handle [illegible] about 25 percent lower than anthracite [illegible] the east and [illegible] central states. Bituminous coal [illegible] which [illegible] mining easier. Unfortunately, it often has a high sulfur content.

Subbituminous coal [illegible] bituminous but also has a lower sulfur content [illegible] usually [illegible]

[illegible] than anthracite. It is relatively [illegible] and crumbles on exposure to air, so it is more difficult to handle than the harder coals.

Slightly more than half of U.S. known coal reserves are west of the Mississippi River. Because of high transportation costs, it is not yet economically feasible to use this western coal in the eastern states, even though its lower sulfur content makes it more environmentally acceptable than eastern coal.

Uses of Coal

In 1976, about 690 million tons of coal were mined in the United States. Table 1 shows how this coal was used by the various sectors.

Table 1
Coal Use in 1976

[illegible]	[illegible]
[illegible] Utilities	[illegible]
Industry (includ[illegible]	150
Residential/Commercial	5
Export	60

As this [illegible] of the coal was used [illegible] industry [illegible] coal [illegible] production.

[illegible] from burning coal [illegible] which drives a generator to produce electrical energy [illegible] the [illegible] steam, turning it back into water.

[illegible] the [illegible] coal [illegible] gas [illegible] [illegible] carbon [illegible]

[illegible]

[illegible] mining [illegible] and [illegible]

[illegible] it to the surface [illegible] 8.6 tons [illegible]

[illegible] the [illegible] coal [illegible] continuous mining [illegible]

Transportation of Coal

Transportation of coal from the mine to the place it is to be used is a major undertaking, since such large quantities are involved. Transportation costs can account for as much as half of the cost of the coal to the user. About 65 percent of the coal is transported by rail, 11 percent by barge, and 12 percent by truck. Another 11 percent is burned in "mine mouth" plants, which are generating plants built right at the coal mine. A small amount of coal is converted to a "slurry," a mixture of coal and water, and transported in a pipeline.

Transportation of coal could be a major problem if coal production increases significantly. The rail system particularly could prove inadequate for the increased load.

Environmental Impacts from Coal

Environmental impacts from the use of coal are evident in the mining process and in its use as a fuel.

Underground mining disturbs [illegible] environmental problems. One such problem is mine drainage which results when surface water seeps into deep mines. This water must be pumped back to the surface to avoid mine flooding. This mine drainage is often acidic and contaminates any body of water it enters. The treatment of mine drainage usually involves using chemicals to neutralize the acid and remove other impurities. The underground mining process produces large amounts of solid waste which must be disposed of properly to prevent acid runoff, erosion and landslides. The solid waste piles are usually covered with earth and a vegetation cover to minimize these problems. Another environmental problem associated with underground mining is subsidence of the land over the mined areas. This subsidence is controlled by leaving sufficient support inside the mine. This means that less coal can be removed.

Surface mining disturbs large land areas [illegible] In 197[illegible] more than [illegible] acres per [illegible] were being surface mined. This land must be restored to keep the environmental impact of surface mining at an acceptable level. The alternative is not only acres of destroyed landscapes but also water pollution as rainwater [illegible] rock and soil containing high levels of dissolved solids and high acidity [illegible] nearby water supplies. A federal act passed in 1977 requires that land must be restored to a condition capable of supporting the uses it was capable of supporting prior to any mining. Reclamation includes restoring the mined land to the desired contour and then planting a vegetation cover. This revegetation is particularly difficult in the dry western regions of the United States. Since surface mining is so much cheaper and safer than underground mining, its use will undoubtedly increase [illegible]

[illegible]

[illegible] antly increased [illegible] the atmosphere [illegible] 200 [illegible] have long term effects on the world's climate. The [illegible] dioxide in the atmosphere [illegible] warm the earth by increasing the "greenhouse effect."

[illegible] growth and [illegible] on fossil fuels within 200 years the earth's average temperature [illegible] degrees Celsius. Some possible consequences of such a rise are warming of the upper layers of the oceans, a rise in sea level, and changes in the polar ice caps. The projections and predictions are very tentative–this situation is so complex and the future trends in energy use are uncertain. The head of the National Research Council study believes that for the next 30 years or so it is safe to use coal, and hopefully well before that time more will be understood about the effects of carbon dioxide on climate.

A major pollutant from the burning of coal is sulfur dioxide which is a colorless gas produced when fuels containing sulfur are burned. Sulfur dioxide affects the respiratory system which includes the lining of the nose, throat, and lungs. Excess amounts of sulfur dioxide in the atmosphere cause damage to plants, trees, and some structures. Low-sulfur coal, primarily from the west, can be used to meet Environmental Protection Agency standards for sulfur emissions. But this often necessitates large costs for transportation. The principal options available now for reducing sulfur emissions from high-sulfur coal are cleaning the coal before it is burned and flue gas scrubbers to control the emissions after the coal is burned.

Coal cleaning is widely practiced primarily [illegible] of the fuel. Such cleaning removes some of the sulfur from the coal but not enough to meet EPA emission standards.

Cleaning the stack [illegible] present time. In a stack gas scrubber a material such as lime or limestone is brought into contact with the flue gas in a cleansing tank. A chemical reaction removes most of the sulfur from the gases going up the stack, leaving a thick sludge in the tank.

In the [illegible] process [illegible] left a sludge must be disposed of. This disposal [illegible] sludge can cause soil and water pollution if not disposed of carefully. The sludge is [illegible] and treated to help it to harden. It is then pumped to a sludge pond. New techniques are being studied to turn the sludge into cement-like compounds which will be acceptable for landfill.

[illegible] be used again and sulfur [illegible] produced. [illegible] help offset the cost of the cleaning. This process is more complex and expensive than the lime or limestone process.

[illegible] plant. There [illegible] would raise a plant [illegible]

[illegible] primarily [illegible] the temperature of the furnace the [illegible]

[illegible] hazard [illegible]

[illegible] but no [illegible]

A growing concern related to sulfur dioxide and oxides of nitrogen is acid precipitation. The acid—mostly sulfuric acid as well as some nitric acid—is washed out of the air in complex chemical processes during the formation of clouds and precipitation. Sulfuric acid, the major offender, is formed in the air by the oxidation of sulfur dioxide. About half of the air's sulfur dioxide comes from natural sources. The other half comes from the burning of fossil fuels, particularly high sulfur coal.

Thus fossil fuel pollutants are significantly increasing the amount of acid in rain and snow particularly in the eastern portions of the United States. Acid precipitation can kill fish and other wildlife, stunt crops and forests and damage metal, wood and stone structures. It has not been shown to be directly harmful to humans.

Formation of the acid precipitation is a very complex process much of which is not yet understood. It is expected that the environmental impact from acid rain ought not to be too severe if all pollution sources are able to comply to the EPA emission standards. [illegible] significant failure to comply with these standards could over a period of time pose severe risks.

Small particles of dust and ash go up the stack with the flue gas. The [illegible] effect on the respiratory system. Particulate emissions are controlled by electrostatic precipitators. Gases from the burning coal are passed through the electrostatic precipitator where an electrical charge is given to the dust and ash particles. This charge allows the particles to be trapped so that they are not discharged into the atmosphere. Electrostatic precipitators are quite effective; they are able to remove about 99 percent of the particles.

[illegible] coal burning plant [illegible] about three quarters [illegible] fly ash [illegible] cinder blocks [illegible] disposed of.

[illegible]

[illegible]

[illegible]

[illegible]

Table 2
Estimates of Annual Health Effects From the Use of Coal in One 1,000 Megawatt Power Plant

Procedure	Occupational Deaths	Occupational Injuries and Disease	Nonoccupational Deaths
Mining			
Accidents	0.45-1.24	22.0-80.0	
Disease	0.00-4.8	0.0-48.0	
Transportation			
Accidents	0.055-1.9	0.33-23.0	[illegible] 1.5
Preparation			
Accidents	0.02-0.05	[illegible] 3.1	1.0-10.0
Power Generation			
Accidents	0.01-0.03	0.7-1.5	
Air Pollution			[illegible]
[illegible]	0.54-8.0	26.0-156	1.62-306.0

[illegible] determining the exact relationship between an occupational [illegible] extremely difficult. [illegible] exposures to routine releases of pollutants often result in the increased frequency of a disease that occurs "naturally" in the exposed population. It is thus hard to isolate the effect of the pollutant. Also, it appears that the interaction of various pollutants can have effects different from those of the individual pollutants themselves.

There can also be considerable individual variation [illegible] groups that appear to be more sensitive to air pollution [illegible] and persons who already have some type of respiratory problem.

[illegible] past have clearly shown that such pollution can cause [illegible] premature death. What is not known with great certainty are the effects of low levels of pollution and the effects of interactions of pollutants. This uncertainty is illustrated by the wide divergence of the estimates for air pollution in Table 2.

[illegible] grounds for [illegible] and some positive [illegible] statistical evidence [illegible] and expected future concentrations of coal-related pollutants may be dangerous to human health. A significant segment of the health community considers that statistical evidence to be meaningless. Several of the objections they raise are valid but do not appear to justify rejection of the evidence." This same study concludes that "Coal's future is a mixture of promise and risk." We desperately need the energy that the coal contains but we also need to be able to tap it without undue risks to our environment and our health.

[illegible] Waste Products

Another [illegible]

generate electricity with steam. We have previously stated that when energy is changed from one form to another, as it is in the generation of electricity, some of the energy is wasted. In fact, nearly 70 percent of the energy produced in an electrical generating plant goes into the environment as waste heat. As the heat energy of the steam in a power plant is converted to mechanical energy, the temperature and pressure of the steam decrease. This steam, called "spent" steam, is converted back into liquid water in a condenser. The heat removed from this spent steam is the waste heat that is released to the environment. Condensation of the spent steam is accomplished by passing large amounts of cooling water through the condenser. This cooling water can sometimes be taken directly from a nearby river, lake or other large body of water, used in the condenser, and then returned to its source. The body of cooling water eventually loses the added heat to the atmosphere. This type of cooling is permitted only if the volume of water is large enough so that only negligible temperature changes occur. If the temperature change in the cooling water were too large, it could upset the ecological balance, perhaps killing some types of aquatic life and favoring the growth of others. In such cases, some other type of cooling system would be required. The use of cooling towers can take the strain off natural waterways. In such a system, water is still drawn from a nearby waterway and used in the condenser. It is then passed through a cooling tower where part of the excess heat is transferred to the air. The cooled water may then be returned to its source or reused in the condenser.

[illegible] cooling [illegible] A 1,000 megawatt plant might require as much as [illegible],000 acres for such a pond.

[illegible] its own [illegible] system for a particular plant must be decided on a case by case basis.

[illegible] heat [illegible] so that [illegible] finding [illegible] waste heat. For example, [illegible] the spent steam from some electrical generating plant is used [illegible] Also, [illegible] heated water has been found to benefit some forms of [illegible] and rejected heat may [illegible] useful in extending the growing season for crops. Thus a "waste product" could become a [illegible]

[illegible]

[illegible]

are suspended in a stream of air directed upward through a very hot bed of ash and limestone. As the coal burns, calcium in the limestone reacts with the sulfur dioxide released from the coal. This produces calcium sulfate, a solid substance which is removed along with the coal ash. Thus the sulfur is eliminated from the flue gas. Fluidized-bed systems are more efficient than conventional boilers. But they are still very expensive, and so are not yet in widespread use.

Coal can be turned into a clean burning gas fuel. Techniques for coal gasification have been known and used for many years but the gas they produce is significantly more expensive than natural gas. In coal gasification, the coal is heated along with water to form a gas which is a mixture of carbon monoxide and hydrogen. This gas can be burned, but it has a low heat value. U.S. industry is currently using such "low BTU" gasification to a limited extent. In a further refining step, the carbon monoxide reacts with steam to produce carbon dioxide, hydrogen, and hydrogen sulfide. Thus the sulfur impurities can be removed from the gas. Further reaction with hydrogen is necessary until methane gas is formed, resulting in a gas that can be used as a substitute for natural gas. One serious problem with coal gasification is the need for large amounts of water. Water is used to provide the hydrogen in the gasification process and is also used for cooling. About two quarts of water will be needed for each pound of coal processed. Unfortunately, much of the coal which would be used for gasification is located in arid regions of the country and would almost surely be surface mined. The water necessary for reclamation in addition to that needed in the gasification process will bring about some difficult decisions between agricultural, industrial, and fuel needs for water in such areas.

[illegible] gasification [illegible] potential for producing [illegible] pollution [illegible] would [illegible] to be disposed of.

[illegible] the [illegible] gas [illegible] prohibitively [illegible] synthetic fuel development program which could support [illegible] deriving other fuels from coal. This [illegible] advantage [illegible] gasification.

[illegible]

[illegible] which [illegible] itself be [illegible] process [illegible] coal is heated with water [illegible] the gasification process. [illegible] liquid fuels. Coal liquefaction requires large amounts of water [illegible] gasification [illegible] liquefaction processes are all potential sources of pollutants. [illegible] full-scale liquefaction plants [illegible] the present time [illegible] too expensive.

OIL

Basic Information

Oil (or petroleum) is our nation's major energy source, providing nearly half of our energy. But the United States is able to produce only about half of its oil needs from domestic resources—the other half must be imported. This has led to serious supply problems and economic difficulties. We will deal here with some aspects of oil use and oil supplies, but the reader must keep in mind that the oil situation is so complex and subject to change that it is nearly impossible to "get a handle on it," especially in a few pages.

Petroleum consists basically of compounds of carbon and hydrogen. It was formed from the remains of minute marine animals and plants that settled at the bottom of ancient seas millions of years ago. This organic material was then buried under layers of silt, sand, and mud, where it was slowly transformed into the hydrogen and carbon compounds that make up oil and natural gas. This transformation was brought about by gradual decay, heat, pressure, and perhaps bacterial and radioactive actions.

The deposits [illegible] the organic matter [illegible] rock layers were too dense to allow penetration by liquids, but others were porous enough to let oil slowly migrate through. Since the oil was lighter than the water that originally filled the porous rocks, it tended to rise until it was stopped by an impermeable rock layer. The oil then collected at this "trap." All accumulations of oil have natural gas associated with them, leading to the assumption that they have the same origin. Many accumulations of gas have no oil associated with them, however, so the origin of some gas may be different from the origin of oil. Methane, the main component of natural gas, is also formed by bacterial decomposition of vegetable matter.

[illegible]

[illegible] Eastern European countries have about [illegible] percent [illegible] Smaller amounts are found in other countries.

[illegible]

[illegible] rate of 3 percent [illegible] would have become [illegible] for petrochemical and other uses [illegible]

[illegible]

[illegible] ground. There are three [illegible]

Occasionally some evidence of oil can be detected at the surface. It sometimes appears as a tarlike deposit in low areas, but more often as a thin film of oil on creeks passing through the area. Seepage of natural gas also occurs, and even small amounts can be detected by instruments. Seawater is sometimes tested for dissolved gas in the hope of detecting underground seepage. The large majority of petroleum deposits do not have any such leakage to the surface, so these methods have limited application. In some areas the visible geologic features give some evidence of possible petroleum traps beneath the surface.

Most oil is found in areas where there is no detectable surface evidence. To find these areas, seismic methods are sometimes used. A small explosion is set off in a shallow hole, and microphones in various locations record the sounds. The sound waves travel at different velocities depending on the types of rock formation, so the records can be used to map underground formation contours, in hopes of finding possible locations for oil accumulations.

The third exploration method is the gravity meter. Changes in the force of gravity at a certain location can indicate geologic features that may contain oil. A gravity meter is often used from an aircraft as a preliminary survey tool to locate areas where seismic methods should be employed.

When a likely area for oil is found, a well must be drilled. In modern drilling operations, the drill bit rotates as it goes downward. A substance called drilling mud is fed into the hole to prevent blowouts (accidental releases of oil or gas during drilling) and to carry crushed rock to the surface as the drill goes down. The drill bit is connected to the surface equipment through a drill pipe, which also carries the drilling mud to and from the surface. Tall derricks contain the equipment needed to raise and lower the drill pipe into the well.

Wells can be drilled in coastal waters and in the open sea. In shallow waters, the wells are drilled from platforms resting on the ocean bottom. In deeper waters, drilling is done from a large floating platform.

After the well has been drilled into the potential oil area, tests are run to see if the well will be commercially productive. If so, it is prepared for production by the installation of various tubings, valves, and pumps. At the surface, any water that comes up through the well is removed and the oil and gas are separated. The oil is usually stored in tanks, and the gas is piped to a processing plant and then to the consumer pipelines. In a productive area, many wells will be drilled.

A large part of the oil cannot be removed by simple pumping. Some method of secondary recovery is generally used to increase oil production. One widely used method is water flooding. Water is injected through some of the wells in a production area, and as it moves through the formation, it pushes oil toward the remaining wells. Water flooding still leaves one-fourth to one-third of the oil behind, and many methods are being developed to try to remove even more of the oil.

Transportation of Oil

The major transportation methods for oil are pipelines for land movement and barge or tanker for water shipment. Pipelines are normally placed underground. One notable example of a pipeline is the trans-Alaska pipeline, which brings oil 800 miles from the Arctic coast of Alaska to the Pacific coast port of Valdez. Pipeline transportation is generally the most economical form for oil wherever pipeline construction is feasible.

Barges are used in inland waters, while overseas shipment is made in huge tankers.

Oil Refining

Oil as it comes from the ground is called crude oil, and it is generally unsuitable for use without some refining. The basic refining process is distillation, which uses heat to separate the various components of the crude oil. As the crude oil is heated, gasoline is removed as a gas which liquifies as it cools. With further heating, kerosene is removed, and then lubricating oil, fuel oil, and asphalt. About 90 percent of crude oil is made into various kinds of fuels: gasoline, jet fuel, heavy duty fuel oil for industries, heating oil, and diesel fuel. The rest goes into lubricants and is a vital raw material in hundreds of manufactured products such as dyes, medicines, detergents, artificial fibers, and plastics.

Oil refineries in the United States are running near their maximum capacity to process the crude oil into the products we need. Unleaded gasoline has sometimes been in short supply because of refinery problems.

Uses of Oil

Table 3 shows petroleum consumption by the various sectors. The numbers are given in millions of barrels per day, where one barrel is 42 gallons.

Table 3
Petroleum Use in 1978

Petroleum User	Millions of Barrels per Day Used
Transportation	9.8
Residential/Commercial	3.5
Industrial	3.4
Electric Utilities	1.7
Total per day	18.4

The transportation sector is obviously the one most dependent on oil. With few exceptions, our entire transportation system of cars, trucks, planes, trains, and ships are fueled by oil products. Other sectors can be more flexible in their choice of fuel—an electric utility can burn coal, for example. But with present technology, the various modes of transportation must depend mainly on oil.

Environmental Impacts from the Use of Oil

On-shore oil production rarely creates any significant environmental problems. Off-shore operations present more problems, with the possibility of oil fouling beaches and affecting animal life in coastal regions. Fires at oil wells could cause significant air pollution.

In the area of transportation, one of the largest problems is that of oil spills and discharges from tankers. Millions of gallons of oil have been released when these tankers have run aground or broken up, and this oil is washed up on shore or sinks to the bottom, ruining beaches and destroying fishing grounds and killing birds. Research is being done on satisfactory ways of cleaning up oil spills, but it remains a serious problem. Pipelines generally produce few environmental problems, although considerable controversy exists over the effects of the trans-Alaska pipeline. During its construction, such diverse considerations as these had to be made: keeping the warm oil from melting the permafrost, not interfering with the ancient migratory patterns of the caribou herds, not disturbing salmon spawning grounds, and allowing for earthquakes and thermal expansion and contraction of the pipe.

Oil refinieries can cause local pollution problems, especially air and water pollution.

The automobile is the source of significant pollution. Exhaust fumes from the engines of automobiles contain a number of pollutants, including carbon monoxide, hydrocarbons (unburned fuel compounds), and nitrogen oxides. When these pollutants are acted upon by sunlight, they produce smog. It was estimated in 1970 that automotive emissions produced 39 percent of the air pollution in the United States. This proportion is being steadily reduced as older cars are replaced by new ones with better emission control systems mandated by federal regulations.

When used as a fuel for industrial processes and for electrical generating stations, oil produces some air pollution, mainly from the oxides of sulfur and nitrogen. But the pollution problems associated with burning oil are not as serious as with coal. This is a major reason why some utilities turned to the burning of oil instead of coal to meet air quality standards. Government policies are now mandating a return to coal, however, in the face of our increasing dependence on imported oil.

Use of Imported Oil

It is this dependence on foreign oil that lies at the heart of many of our energy problems today. In January and February of 1977, the U.S. imported about 9 million barrels of oil per day, half the of total domestic oil consumption. U.S. domestic oil production has generally declined since 1970. New production from Alaska and the Outer Continental Shelf and new recovery methods could reverse this decline, but will still not be able to satisfy the U.S. thirst for oil. Most of our oil is imported from the 13 countries which make up the Organization of Petroleum Exporting Countries (OPEC). The 1973-74 oil embargo by this organization, along with their four-fold increase in prices within the space of a year, demonstrated our dependence on energy sources over which we have little control. In 1973, a barrel of OPEC oil cost $2.80. In 1979, it cost $23.40. The U.S. is expected to pay over 50 billion dollars for imported oil in 1979. Such a tremendous drain of dollars can have grave consequences for the nation's economy. The cut-off of oil from Iran in 1979 due to political turmoil there demonstrated again our vulnerability to supply interruptions.

In 1976, the Strategic Petroleum Reserve was initiated. A stock of oil is to be built up to cushion the damage from supply interruptions and to discourage their use as political tools. A long OPEC supply interruption would ultimately be very damaging.

Federal policies to lessen our dependence on imported oil are discussed in a later section.

NATURAL GAS

Natural gas is very nearly an ideal fuel product. It is clean-burning and convenient to use and transport. It is also an important raw material in many chemical processes. Unfortunately, natural gas production has been decreasing in the United States since 1973.

The major component of natural gas is methane, a compound of carbon and hydrogen. Natural gas can sometimes be used directly from the well, but some gas must be treated to remove impurities such as sulfur.

Natural gas usually occurs in association with petroleum because geological conditions favorable for the presence of oil generally are favorable for natural gas as well. Some natural gas does occur by itself. Natural gas is extracted from the same wells as oil, or in a similar manner if the gas occurs by itself.

Areas with significant reserves of natural gas are the Soviet Union, the United States, Algeria, and the Middle Eastern oil producing countries. Opportunities for the United States to supplement domestic supplies with imports are limited, since the gas must be liquified in order to be shipped, and the liquified natural gas (LNG) is quite expensive. Normal transportation of natural gas within the U.S. is by pipeline, although some gas is liquified and sold as "bottled gas."

Table 4 gives the estimated consumption of natural gas by sectors in 1977. Note that natural gas measurements are given in terms of the volume of the gas.

Table 4
Natural Gas Use in 1977

Natural Gas User	Trillions of Cubic Feet Used
Residential/Commercial	7.5
Industrial	8.5
Transportation	0.6
Electric Utilities	2.8

Environmental impacts of the extraction and use of natural gas are relatively small. The gas is explosive, so some accidents do occur.

HYDROELECTRICITY

A hydroelectric power plant uses falling water to spin turbines for generating electricity. Water may be collected and stored at a high elevation and led through tunnels and pipelines to a turbine at a lower elevation, or dams may be erected across a river to raise the water level. A "high-head" installation (the head is the height of the water above the turbine) requires a smaller volume of water than a low-head installation to produce an equal amount of electricity.

Several projects are underway to improve some of the small, low-head hydroelectric plants in the U.S. These include projects sponsored by the Department of Energy to demonstrate that hydrogen can be produced economically at small dam sites. Electricity generated at the dams would be used to break water down into its components of hydrogen and oxygen. The hydrogen and oxygen could be sold on the commercial market.

Falling or flowing water provided the earliest natural means of generating electricity. Eventually, however, most of the favorable sites for large-scale hydroelectric plants were exhausted, and power production from fossil fuels began to take over.

The remaining potential large-scale hydroelectric sites in the U.S. are in remote areas, far from the electrical demand. Developing such sites could have potentially adverse effects on increasingly scarce wilderness areas and on fishery resources.

Since no fuel is burned at hydroelectric plants, there is no pollution produced. Environmental concerns center on the safety of the dams and their effects on nearby land and water resources.

NUCLEAR POWER

In 1942, a group of scientists, led by Enrico Fermi, first initiated and controlled a self-sustaining nuclear chain reaction. This was the beginning of an energy source that in 1978 supplied over 4 percent of the United States' total energy demand and about 12 percent of our electricity. It has become an energy source surrounded with controversy. Because of this controversy, this section deals with neuclear energy in some detail in the hope that the reader will be better informed on this important issue.

As previously mentioned, it is the fissioning or splitting of atoms that provides the energy in a nuclear power plant. The fissioning uranium produces heat energy which is used to make steam to generate electricity. This harnessing of nuclear energy takes place in a nuclear reactor, which is the heart of a nuclear power plant.

Nuclear Reactors

There are certain components that are common to all nuclear reactors regardless of their specific design. These are the fuel, coolant, control rods, moderator, and shielding.

The uranium fuel, usually in the form of ceramic pellets of uranium dioxide, is contained within fuel rods in the reactor core, which is the heart of the reactor. A typical reactor core contains thousands of fuel rods which in turn contain several million uranium pellets.

The uranium fuel must undergo several preliminary processes before it is used in a reactor. After uranium is mined, it must first be processed to produce uranium oxide, known as "yellowcake." Then it is converted to uranium hexafluoride, a gaseous form essential in the next step, the enrichment process. The natural concentration of uranium-235 in uranium is only seven-tenths of one percent. The rest of the uranium is non-fissionable uranium-238. In order for uranium to be used as a fuel for power plants, the concentration of uranium-235 must be raised to about 3 percent. This fuel is then said to be enriched in uranium-235. The federal government is currently the only provider of enrichment services in the United States. Its three gaseous diffusion enrichment plants provide the enriched uranium for all reactors in the United States as well as for many foreign reactors. After enrichment, the uranium hexafluoride is converted to uranium dioxide, which is then fabricated into fuel rods.

The coolant, either a fluid or gas, flows over the fuel rods and removes heat from the fuel. Since the fuel is contained within the fuel rods, the coolant does not come in direct contact with the fuel. The coolant then is either converted directly to steam or goes through a heat exchanger to convert water into steam. This steam drives a turbine which turns a generator to produce electricity.

Water is the coolant in all except one reactor in the United States (a gas cooled reactor). Thousands of tons of water circulate around the core to carry away the heat. The core and cooling water are both contained in a heavy steel pressure vessel which is in turn shielded by a steel-lined concrete containment structure.

For safety and reliability, there must be some way to control the nuclear reaction–to speed it up, slow it down, or stop it entirely. One way would be to move fuel out of the core until not enough remained to sustain a chain reaction. But this would be a rather cumbersome, unsafe, and time-consuming process. Another way of controlling the reaction would be to somehow stop some or all of the neutrons that are produced in the fission process from interacting with the uranium-235. This can be achieved by the use of control rods, which act as neutron sponges. The control rods, made of materials such as boron that readily absorb neutrons, are positioned inside the fuel assembly. If the rods are pulled out of the assembly, more neutrons are available to cause fissioning of the fuel, so the rate of reaction increases. If the rods are inserted into the fuel assembly, they abosorb neutrons, so that there are fewer neutrons available to the fuel. Thus, the chain reaction slows or even stops completely. This makes it possible to produce heat at a desired rate, or to shut down the reactor.

The moderator, a material within the reactor core, is used to slow down neutrons as they emerge from the fissioning atoms. Slowing is necessary because neutrons traveling too fast are less readily captured by the uranium-235, and they must be captured in order to cause fission. A moderator may cause a decrease in speed of nearly ten thousand times, but even a slow neutron travels at a rate of appreciably more than a mile per second. Graphite, water, or heavy water can be used as moderators. Except for the one gas cooled reactor, which uses graphite, U.S. power reactors use the cooling water as the moderator.

As a by-product of the fission process, several different kinds of radiation are produced. Shielding, consisting of various materials surrounding different portions of the reactor systems, prevents this radiation from escaping into the environment.

Types of Reactors

At the end of December 1978, 72 nuclear power reactors were authorized to operate, producing 52,396 megawatts of electricity. Construction permits have been issued for 92 additional reactors at 51 sites, and meaningful construction has begun for all but 4 units. Thirty additional reactors are in some phase of planning prior to construction.

The most common type of reactor in the U.S. is the light water reactor, including the boiling water reactor and the pressurized water reactor. (Light water is ordinary water, H_2O, as distinguished from heavy water containing the hydrogen isotope deuterium.) There is one high temperature gas cooled reactor in operation in Colorado. About two-thirds of the operating and planned reactors are pressurized water reactors. Most of the rest are boiling water reactors.

In the boiling water reactor, water is brought into the reactor and allowed to boil. It is then expelled from the reactor vessel as saturated steam, which drives a turbine to produce electrical power.

In a pressurized water reactor, pressure keeps the water from boiling. Instead, water is pumped through the core and removed at the top as a heated liquid. The water is then circulated through a heat exchanger, where steam is produced from water in a secondary loop. The steam drives the turbine. The cooled water in the primary loop is returned to the reactor to again cool the core.

In the high temperature gas cooled reactor, the core is cooled by certain gases passing over it, usually purified carbon dioxide or helium. The gas gives up its heat to water circulating through a steam generator. The moderator system usually consists of graphite blocks pierced to contain the fuel.

Uranium Supplies

With today's light water reactor technology, the potential of nuclear power as a long-term energy resource depends upon the supply of uranium-235. Thus, it is necessary to have a good estimate of the uranium resources of the United States.

Uranium is a moderately abundant element in the earth's crust, and it appears in a wide variety of geological situations. Practically no geologic environment is totally free of uranium; however, the concentration of uranium deposits varies considerably. High grade uranium deposits in stream-laid sandstone in Colorado, Utah, New Mexico, Wyoming, and South Dakota have yielded most of the uranium produced in the United States.

The latest available Department of Energy figures estimate that the U.S. has 690,000 tons of known reserves and 1.07 million tons of probable resources of uranium oxide which can be recovered at prices low enough to be economically feasible. Adding uranium oxide which could be provided as a by-product of phosphate and copper production, the U.S. appears to have a reasonably assured supply of at least 1.8 million tons. Typically, a 1,000 megawatt power reactor requires 5900 tons of uranium oxide over its 40 year operating lifetime, under present conditions which prohibit recycling of fuel. This means that the United States can depend upon its known and probable reserves to supply projected reactor needs to at least the year 2020. Another 1.5 million tons of uranium oxide are listed by DOE as possible and speculative resources. How much of this will actually prove to be economically available is not known.

Typically, about a third of the fuel rods in a reactor must be replaced each year. These rods that are removed, called spent fuel, contain fuel that could be salvaged for further use. Some of the original uranium-235 remains and could be used for fuel. The spent fuel also contains plutonium which was formed by neutron bombardment of the uranium-238. The plutonium is fissionable and could also be used for fuel. This uranium and plutonium could be recovered in special reprocessing plants. Unfortunately, plutonium can also be used in nuclear weapons. Many people are worried that this plutonium might be obtained by terrorists or other groups and could then add to the proliferation of nuclear weapons. For this reason, commercial reprocessing in the U.S. was stopped indefinitely as of April 7, 1977. Fuel rods removed from power reactors are now stored in pools of water at the reactor site.

Breeder Reactors

A nuclear reactor that produces new fuel faster than it uses it up and produces electricity at the same time may sound like something out of a science fiction novel. But there is a reactor technology in the pre-commercial stage that does just that–produces new fuel as it produces electricity. This reactor is the breeder reactor.

The idea of the breeder reactor is not new. In fact, the first nuclear reactor to produce electricity was the Experimental Breeder Reactor (EBR-1) in Idaho. It was designed by Argonne National Laboratory and produced about 100 watts of electricity on December 20, 1951. ERB-II is now being operated in Idaho for the Department of Energy by the Argonne National Laboratory and is the only operating fast reactor in the United States. (A fast reactor is one without a moderator, so that the neutrons are not slowed down.) It is providing information on fast breeder reactor fuels, materials, and components under conditions approaching those expected for large commercial plants.

Several breeder reactor strategies have been explored. Presently, the Liquid Metal Fast Breeder Reactor (LMFBR) and the Light Water Breeder Reactor (LWBR) concepts are receiving the most attention, and these will be discussed further here.

It was previously mentioned that uranium-235, the fissionable fuel used in today's conventional reactors, makes up only a tiny fraction of naturally-occurring uranium, with the rest being uranium-238. Uranium-238 does not fission when it is bombarded by slow neutrons. However, it can capture a neutron to form uranium-239, which decays to neptunium-239 and then to plutonium-239. Plutonium-239 is a fissionable fuel. Because uranium-238 can be converted in this way into a fissionable fuel, it is said to be a fertile material.

This conversion from fertile to fissionable material also takes place in current power reactors, but not at such a high rate as in breeders. In the LMFBR, for each atom of fuel consumed, more than one atom of plutonium-239 would be formed from uranium-238. This is achieved by increasing the number of free neutrons released in fission and by decreasing the number of neutrons wasted, thereby making a larger number available for absorption in fertile material.

Fuel produced in such reactors could dramatically extend our energy resources, since breeder reactors could utilize more than 50 percent of the available energy in the world's fissionable and fertile fuel reserves as compared to only one or two percent for light water reactors. One other favorable aspect of breeder reactors is that their fuel can be produced economically from lower-grade uranium ores.

Since the LMFBR is a fast reactor, it contains no moderator material to cause a rapid slowdown of the fission neutrons. Thus the average neutron velocity in the core will be considerably greater than in conventional reactor cores. At these higher energies, there is a much greater probability that the neutrons not needed to maintain the chain reaction will be captured by the fertile uranium-238.

The term liquid metal is used because liquid sodium is the reactor coolant. The fuel in such a system would probably be a mixture of oxides of uranium and plutonium.

Liquid metal fast breeder reactors have the potential of being more efficient than light water reactors, since sodium is considerably more efficient than water in transferring heat from the core. Also, the reactor core can be operated at a higher temperature without pressurization, since sodium has a much higher boiling point than water.

The LMFBR has some disadvantages when it is compared to light water reactors. These disadvantages are due mainly to the sodium coolant. Sodium is a highly reactive metal that will burn if it is exposed to either water or air. Further, it is a solid at room temperature and requires an elaborate heating system to assure that it will remain liquid throughout the coolant system. Sodium is not transparent, which complicates refueling and maintenance.

The sodium coolant captures some of the reactor neutrons and becomes intensely radioactive. Since the main radionuclide produced (sodium-24) has a 15 hour half life and emits extremely penetrating gamma rays, refueling of the reactor and maintenance of the primary coolant system would require remote control equipment.

The LMFBR is more difficult to control than a light water reactor, because an accidental loss of sodium coolant from the core increases reactor power. The opposite occurs in light water reactors.

The cost of building a LMFBR is considerably greater than that of light-water reactors because of the special problems involved.

These problems are now being dealt with in small prototype systems such as the EBR-II in Idaho and the Fast Flux Test Facility in Washington, which are the forerunners of the Clinch River Breeder Reactor demonstration plant that was planned to produce about 350 megawatts of electricity in the late 1980's. Recently, however, the Clinch River project has become a controversial and highly debated power issue in the United States, and the project is faced with significant delays in completion, or indefinite postponement.

The main issue of the controversy centers around nuclear weapons proliferation: the concern that the nuclear fuel produced by the LMFBR, plutonium-239, can be used not only to produce electricity, but also to produce nuclear weapons. There is fear that a terrorist or a hostile nation may either steal or otherwise acquire the plutonium and manufacture a nuclear weapon. This scenario is possible, despite the large risks associated with stealing or diverting plutonium, the difficulty of manufacturing a weapon without a large investment in facilities and personnel, and the low probability of success because of the unrealiability of commercial reactor plutonium for weapons production. In any event, to minimize the chance of theft of nuclear materials at facilities where plutonium is located, accountability of materials and security measures would have to be very strict.

In order to further abate concerns over the weapons proliferation issus, proliferation-resistant fuel cycles are being investigated, such as the Civex process where a small portion of contaminants is added to effectively "denature" the fuel, making it unsuitable for weapons.

As the breeder is being debated, the U.S., once the leader in fast breeder reactor development, finds itself being surpassed by countries such as Great Britain, France, and the Soviet Union, who have committed themselves to acceleration of their fast breeder reactor programs. Many countries, particularly those in Western Europe, feel that they simply cannot afford to give up the breeder because of their lack of other energy resources.

Another breeder reactor concept is the light water breeder reactor. The LWBR differs from the LMFBR in several respects. The LWBR uses ordinary water as a coolant rather than liquid sodium, so that it breeds much more slowly than an LMFBR. Fissions in an LWBR are caused maily by low-energy neutrons rather than fast neutrons. The LWBR is based on an entirely different fuel system, thorium-232/uranium-233 rather than uranium-238/plutonium-239. An experimental LWBR is currently operating at the Shippingport Atomic Power Station in Shippingport, Pennsylvania, where test data is being collected to determine the feasibility of this particular breeder technology for commercial application.

Safety Systems in Nuclear Reactors

Stringent safety precautions must always be taken by the builders of nuclear plants, which cannot be built or operated without a license from the Nuclear Regulatory Commission, charged by law with the responsibility of satisfying itself that the plant will not endanger public health and safety. Licensing was previously done by the Atomic Energy Commission (AEC), which was abolished in 1974. The AEC's research and development activities were taken over by the Energy Research and Development Administration (ERDA), now part of the Department of Energy. The regulatory and licensing activities are the function of the Nuclear Regulatory Commisson (NRC).

Nuclear power plants form small quantities (several pounds per day) of radioactive substances. In normal operation, more than 99.99 percent of these substances stay within the fuel assemblies. The small amount that escapes from the fuel enters the reactor coolant system, where almost all of it is removed by purification equipment. An extremely small amount of radioactivity is released to the environment under strict control, subject to conservative and rigidly enforced health and safety regulations.

There are several natural safeguards that operate in nuclear power plants. In today's water-moderated power reactors, if the rate of fissions were to increase significantly, more heat would be produced. The heat would increase the energy of the neutrons in the fuel, and thus increase the proportion of neutrons escaping from the core and being caputured by non-fissioning atoms. The rate of fission would thus slow down. This effect is automatic and instantaneous, and is one reason why a nuclear reactor cannot possibly become a bomb. In a bomb, essentially pure fissionable material is required, much more than in the slightly enriched reactor fuel, and it must be rapidly compressed and held together for the chain reaction to increase to an intensity of a nuclear explosion.

The use of water as a coolant and moderator provides another built-in safety feature of today's power reactors. If the reactor were to exceed its designed power level, it would raise the temperature of the water, which would in turn decrease the water's ability to act as a moderator. This tends to reduce the reactor's power level.

In addition to these natural safeguards, many safety features are built as an integral part of any reactor facility. These are a defense in depth agains the release of radioactivity.

One such safeguard is a monitoring system for neutron intensity. Neutrons initiate the fission reaction, and the number of available neutrons is related to the reactor power level. Thus measurements of the number of available neutrons are made by several independent monitoring systems at various locations in the reactor core. These instruments are connected to a rapid shutdown system in case neutron intensity rises above a pre-set limit.

Reactor control systems are also designed for safety. Materials such as boron or cadmium are able to absorb neutrons and, by removing neutrons from the system, shut down a reactor, preventing new fissions from occurring. Common methods of using these control systems include the mechanical insertion of control rods into the core and the addition of liquid solutions of these neutron-absorbing elements to the water moderator. Most water reactors have both methods of control available.

Instruments constantly monitor what is happening in the core. Improper signals concerning temperature, pressure, or other unwanted conditions will immediately shut down the reactor. Each safety system has one or more backup systems in case there is a failure in the primary system.

Reactor designers assume that at some time, electric power to a nuclear plant may be shut off. To allow for this possibility, they usually design reactor systems that require no electric power to achieve safe shutdown. Those which may require power after shutdown, such as those which keep the coolant circulating, are equipped with emergency diesel generators and batteries so that they can operate when no outside power is available.

Although the nuclear chain reaction can be stopped immediately, radioactive fission products in the fuel rods continue to decay and give off heat. If for some reason there is a rapid loss of the coolant water to a nuclear reactor, it is conceivable that the core might melt due to heat from these fission products, even if the nuclear reaction has been stopped. This core meltdown could result in releases of dangerous amounts of radioactive material. In order to prevent the core from overheating due to a loss of coolant, several independent emergency core cooling systems are available to bring in water to cool the core. The network does not require an operator to get started.

In order to test the effectiveness of emergency core cooling systems, the Nuclear Regulatory Commission built a loss-of-fluid test (LOFT) reactor in Idaho. In December of 1978 this reactor had a planned loss of coolant, allowing the effectiveness of the emergency core cooling systems to be observed. The results of this experiment indicate that the systems of an actual nuclear reactor work even better than expected. Reactor temperatures never rose as high as predicted, nor did it take as long as expected for emergency cooling water to cool the radioactive core. Although more test are planned at the LOFT reactor, at this writing the preliminary experiments are confirming the efficiency and reliability of nuclear reactor safety systems.

In the event of an accident at a nuclear power plant, there are many barriers in reactor systems to guard against significant amounts of radioactivity escaping to the environment. There is, first of all, the ability of the fuel material to retain most of the fission products, even when they are overheated. There there is the fuel element cladding, through which fission products must pass to get into the reactor coolant. Next, there are the walls of the reactor vessel itself. Finally, there is the containment system, constructed to halt any release of radioactive material that gets past all the other barriers. The reactor building itself may be sealed off as a secondary containment system.

Several attempts have been made to determine the probability of a serious nuclear accident. One of the best known, WASH-1400, also called the Rasmussen report, was ordered in 1972 by the Atomic Energy Commission. For two years a staff of 60 people studied hundreds of things that could go wrong in a nuclear power plant and estimated the amounts of radioactivity that could be released under various weather conditions. They determined that the worst credible accident would kill 3300 people and cause radiation injuries to another 45,000. Severl thousand square miles of land would be contaminated and 290 square miles would be uninhabitable for a year or more. The probability that such an accident would occur was calculated to be extremely small–if there were 1,000 reactors in operation, such accidents would have the probability of occurring once every million years.

The Union of Concerned Scientists has produced a critique of WASH-1400. They believe that under the worst possible conditions, the immediate and eventual deaths from a nuclear accident might exceed 300,000, and such accidents have the probability of occurring about once every 50,000 years.

The NRC recently commissioned a group to review the Rasmussen study. Their findings, the Lewis Report, state that much of the data needed for calculations of reactor risks is still inadequate, and that WASH-1400 cannot be used to prove the safety of nuclear power. The authors were unable to say whether reactors are more safe or less safe than the figures in WASH-1400 suggest.

Nuclear power opponents argue that the consequences of an accident would be so catastrophic that any risk, no matter how small, is unacceptable. They contend that the accident at

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Three Mile Island, caused apparently by a combination of human errors and equipment failure, shows that no matter how many safeguards there are, in a systems so complex it is impossible to anticipate and provide for all things that can go wrong. The Three Mile Island accident will be discussed later in this section.

The Price-Anderson Act

When nuclear power began to emerge in the U.S., Congress was concerned with providing protection to the public and limiting the liability of the nuclear industry in the event of a major nuclear accident. To accomplish these purposes, the Price-Anderson Act was enacted in 1957 and renewed for the second time in 1976.

Price-Anderson is not unique in providing government liability protection. The federal government also provides deposit insurance for bank accounts, flood insurance, and disaster aid.

At present, a total of $560 million is available to cover liability claims for a nuclear accident at a licensed power plant or reprocessing facility, or during the normal course of transportation between such facilities. The act requires that a maximum amount of insurance be first purchased from a private source. This amount is currently set at $390 million by the American Nuclear Insurers. The federal government provides the rest of the insurance, up to the maximum of $560 million. Each utility pays a premium to the government for Price-Anderson coverage.

The Price-Anderson Act will be in effect until August, 1987. The entire responsibility for providing the $560 million liability protection, which includes both personal injury and property damage, will be gradually transferred to the utilities. Congress has also guaranteed further action if the liability exceeds $560 million.

Wastes from Nuclear Power Plants

As mentioned in the section on coal, waste heat is put into the environment in large amounts by both nuclear and fossil-fueled power plants. But one of the major concerns over nuclear power involves radioactive wastes.

Within the broad category of radioactive wastes, some system of subdivision is needed for clear discussion. Unfortunately, there are no clear-cut definitions in general use, and this has contributed to the confusion about these wastes.

One attempt at categorizing radioactive waste is to consider whether the radioactive materials in the waste are natural or man-made. In the production of nuclear power, natural radioactive materials occur in wastes from the mining, milling, refining, enrichment, and fuel element fabrication steps which lead up to the operation of the reactor. Although the decay of natural uranium eventually yeilds stable lead, there is a long series of intermediate radionuclides which account for more than 90 percent of the total radioactivity present in a sample of natural uranium ore. These daughter products are left behind in the tailings, which is the residue from the milling process in which the uranium is chemically extracted from the crushed and ground ore. These tailings are normally stored on the surface near the mill, graded and diked as necessary to prevent erosion by surface waters, and watered to prevent wind erosion. When addition to tailings to a particular pile has been completed, a vegetation covering can be added as additional wind protection. It is possible for radon, a radioactive gas, to diffuse through a tailings pile from decay of the uranium, and disperse into the air. The Residual Radioactive Materials Act of 1978 establishes

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joint federal-state programs to minimize the potential problems from these mill tailings. Other wastes containing naturally-occurring radionuclides which result from various other fuel handling steps present no significant disposal problems.

Man-made radioactive materials originate within the reactor during the fission process. Man-made wastes can be divided into two categories based on their method of disposition: some can be released to the environment, and some must have varying degrees of controlled storage. Most nuclear facilities generate gaseous and liquid wastes which are contaminated with radioactive materials. Under strict regulation, some of these wastes can be treated and released to the environment. The gaseous wastes can be filtered and are sometimes stored temporarily to permit the decay of short-lived radionuclides. Liquid wastes can be treated by evaporation, ion exchange, or precipitation, so that the remaining concentration of radioactivity in the liquid is very low. Release of these treated liquids or gases to the surrounding water or air must be carefully monitored to insure that only very small amounts of radioactivity are put into the environment.

The category of radioactive wastes which may not be dispersed to the environment can be further broken down into two sub-categories. One of these is solid waste for which relatively shallow burial is considered acceptable. The other is waste for which shallow burial provides insufficient isolation, or which requires greater or more extended surveillance than shallow burial affords. Wastes which fall into the first of these categories are shipped from nuclear facilities to burial grounds which are operated under licenses from either the Nuclear Regulatory Commission or certain states which operate their own radiation control programs under agreements with the NRC. These burial grounds are selected after studies of local soil and weather conditions have shown an acceptable probability that the buried radioactive materials will not be moved from the site by the action of groundwater.

This general class of wastes is frequently called "low-level solid radioactive waste," although the term is not precise. Almost all facilities in the fuel cycle send wastes to the burial grounds. Some of the types of waste involved are as follows: filters from the clean-up of gaseous wastes; ion exchange resins, precipitates, or evaporator sludges from the clean-up of liquid wastes; concrete or other solids made from small batches of radioactive liquid waste not practical to clean up; absorbent paper, swabs, plastic sheeting, and similar materials from contamination control or clean-up work; defective or obsolete piping, motors, instrumentation, or other equipment.

The annual volume of this general category of waste is a few million cubic feet per year. Even if this increases over the years, it will still be very small compared with other types of solid wastes.

The spent fuel rods are virtually the only waste from nuclear power plants that cannot be disposed of by shallow burial. They contain highly radioactive fission products as well as part of the original uranium-235 fuel and some plutonium-239 which was created in the fuel. The uranium and plutonium are potentially usable for fuel, but regulations banning fuel reprocessing preclude their use at the present time. The fission products are basically waste that needs to be disposed of. The final disposal of these spent fuel rods is a problem yet to be solved. It is a problem shared by wastes from the government weapons testing and nuclear-powered ship program. The amount of these defense wastes is many times larger than that from nuclear power reactors. The defense programs have produced about 500,000 tones of highly radioactive wastes and 65 million cubic feet of less radioactive solid waste. Nuclear power plants have so far produced about 5,000 tons of spent fuel and 16 million cubic feet of low-level waste.

The high-level waste from both sources is currently in temporary storage awaiting a decision on the best method of more permanent disposal. The weapons waste is stored in tanks and burial pits at three government reservations. The spent fuel is stored in pools of water on the power plant sites. This storage at the site allows the short-lived radionuclides to decay and thus reduces the radioactivity of the spent fuel. It will probably be the first step in any disposal plan.

Most experts believe that long-lived radioactive waste should be concentrated and put into solid form, then placed into protective containers and stored deep underground in suitable geologic formations.

Radioactive waste is being solidified into glass in France, and U.S. researchers are looking at the possibility of a ceramic form, which would be more resistant to leaching by groundwater.

Scientists are looking at geologic formations such as salt beds, basalts, shales, and granites to determine which might be more suitable for long-term storage. The storage site must be one where groundwater cannot easily reach, and where earthquakes are not likely.

A government task force called the Interagency Review Group on Nuclear Waste Management has been set up to study and report on the best methods for waste disposal. This group reports that a waste repository will probably not be available until 1988 to 1993. The interagency group believes that the radioactive wastes can be successfully isolated for a few thousand years, but after that point it is impossible to be sure of success. Most of the radioactive materials would be harmless long before that time, but materials containing plutonium-239 would remain dangerous for many thousands of years, since plutonium-239 has a half life of 24,360 years.

One of the key decisions affecting waste management is that of reprocessing. If the spent fuel is considered a waste, it would be encapsulated in some very hard material and disposed of. If on the other hand reprocessing is to take place, the spent fuel would be treated to remove useful fuel. The remaining material would be a highly radioactive liquid which would be solidified before disposal.

Since any type of commercial power plant has a useful life of roughtly 40 years, it is necessary to consider the disposal (or decommissioning) of a nuclear power plant. Except for the reactor vessel, most of the plant could be disposed of by conventional methods, with the materials being recycled or discarded. Many of the materials within the reactor vessle will have become radioactive. These materials and the reactor vessel itself would probably remain on the site for several years to allow the shorter half-lived materials to decay. They would then be dismantled and disposed of in a burial site.

The transportation of nuclear materials, including nuclear waste, is of concern to many people. Some states and municipalities have banned the transport of radioactive wastes through their area, thereby creating legal, logistical, and routing problems.

The federal Department of Transportation regulations require that nuclear wastes be packaged so that, even in the event of a severe transportation accident, there would be no significant release of nuclear wastes from the packages. Such accident-proof containers must be strong enough to withstand the types of impact, puncture forces, and fire effects that are encountered in severe accidents. In spite of these precautions, the movement of nuclear wastes is still a controversial area.

Health Effects of Nuclear Power Plants

As previously noted, all matter is made up of units called atoms. Each atom has a nucleus with an electrically positive charge. A cloud of electrically negative electrons surrounds the positive nucleus. Ordinarily, the number of negative electrons equals the number of positive charges in the nucleus. The atom is then electrically neutral. If energy is supplied to an electron, it can be moved to a position further from the nucleus; then the atom is said to be an excited state. If large amounts of energy are supplied, the electron can escape from the atom completely. When one or more electrons is separated from the atom, the atom is said to be ionized. The atom has a net positive charge since it is missing an electron. This positively-charged atom, taken with its separated negative electron, is called an ion pair. Radiation produced by nuclear reactions and by radionuclide decay can supply the energy needed to excite an atom or form ion pairs. Thus it is often called ionizing radiation.

When ionizing radiation passes through matter, it interacts with the electron clouds of the atoms in the matter. In this process the radiation loses its energy by exciting the atoms and/or producing ion pairs in the matter. This basic process is essentially the same for all kinds of materials--air, water, people, cement blocks, or steel.

The potential for injury or damage from any kind of radiation depends on the rate of energy loss as the radiation travels through matter. This rate of energy loss in turn depends on the type of radiation, its electrical charge, and its energy. The energy deposited by the radiation in the absorbing matter causes changes in the matter, such as the production of ion pairs. These changes can result in damage to the matter including disruption of the functions of cells of living organisms.

The most penetrating type of decay radiation is the gamma ray. High energy gamma rays can completely penetrate a person, a concrete block, or a sheet of lead.

Beta radiation, which is high energy positive or negative electrons, is capable of penetrating a piece of aluminum foil or several layers of a person's skin. In air, its range may be as much as a yard.

Alpha radiation, which is high energy helium nuclei, can sometimes penetrate a very thin piece of paper but cannot penetrate conventional aluminum foil. However, alpha particles are the most hazardous of all types of radiation if they enter the body as a result of swallowing or inhaling an alpha emitter.

Radioactivity [illegible] by several types of instruments. One of the simplest radiation detectors is ordinary photographic film, which darkens on exposure to radiation and is routinely used in film badges for measuring the cumulative amount of exposure received by people who work with sources of radiation. Other types of detectors such as Geiger counters, ionization chambers and proportional counters are used to detect the presence and measure the intensity of radiation. These instruments can detect the presence of extremely small amounts of radioactive materials. Radiation detection is also very sensitive in its ability to identify specific radioactive substances. This is possible because every species of radioactive atom has a characteristic pattern of radioactive decay.

The roentgen is the unit [illegible] ion pairs produced in air by X-rays and gamma rays. A roentgen is the amount of [illegible] radiation required to produce ions carrying a standard electrical charge in a standard amount of air. The roentgen can be measured directly since the electric current can be measured by an ammeter

The radiation absorbed dose (rad) indicates the amount of energy deposited in material by any type of ionizing radiation. It is a measurement of not only ion pairs, but of all energy deposited. A rad is a very small unit. For example, one rad equals the energy required to raise the body temperature by two-millionths of a degree Fahrenheit.

The roentgen equivalent man (rem) is the unit of dose equivalent. It is a measure not only of energy deposited but also the resulting biological effects.

For instance, suppose 500 rads of gamma rays produce a certain change in a tissue and 50 rads of alpha particle radiation produce the same change. We then would say that the alpha radiation was 10 times as powerful as gamma radiation in causing this change. In other words, the alpha radiation would have a quality factor of 10 when it is compared to the gamma ray.

We can use the formula rems = rads x quality factor to convert from rads to rems. In our example, the quality factor for gamma radiation is 1. Therefore, 500 rads multiplied by a quality factor of 1 gives 500 rems. For the alpha radiation, 50 rads multiplied by a quality factor of 10 gives 500 rems. The number of rems is thus the same for the two types of radiation which produced the same biological effect.

Since radiation protection deals with the safeguarding of people from unnecessary radiation exposure, regulations and recommendations are usually written in terms of rems, which take into account the biological effects of the radiation. However, it is often desirable to work with smaller units, so the term millirem (mrem), which is one thousandth (.001) of a rem, is often used. For example, the maximum permissible exposure allowed for a radiation worker is 5 rems, or 5000 mrem, per year.

To describe radiation exposure of groups of people the term person-rem is used. The person-rem indicates the total exposure of all members of a certain population. For example, consider a group of 50 people. If each of the 50 people receives one rem, the population dose is 50 person-rems. If 25 people receive one rem and 25 people receive no exposure, the population dose is 25 person-rems. If one person receives 25 rem and the rest receive no exposure, the population dose is 25 person-rems.

To summarize the units of radiation exposure, a roentgen refers to the ions produced in air by x-rays or gamma rays. A rad refers to the energy deposited in any material by any ionizing radiation. A rem refers to the results of that energy deposited in tissue, and the term person-rem indicates total exposure of a given population.

[illegible] of background radiation and radiation [illegible] man [illegible] both [illegible] equally split between these two with an average of [illegible] 100 [illegible] a year coming from each category.

[illegible] radiation dose increases with altitude [illegible] that people who live [illegible] more than those who live at sea level. Taking an airplane trip also increases exposure to cosmic radiation.

Another source of natural radiation [illegible] uranium and thorium are widely distributed in soil and rock. Because of this, people who live in houses made from stone or brick receive significantly more natural radiation than those who live in houses made from wood. Our bodies and the food we eat contain radioactive nuclides such as potassium-40 and carbon-14.

Table 5 shows the average dose from natural radiation in the U.S.

Table 5
U.S. Average Natural Radiation Dose

Source	Dose (mrem/year)
Cosmic radiation	40
Radionuclides in rock, soil, etc.	26
Radionuclides in the body	24
Total	90

Man-made radiation adds to the average dose that everyone receives. Most significant is the dose from medical and dental x-rays. A small amount of radioactivity is also received from fall-out from weapons testing and from nuclear reactors. Table 6 gives some examples of man-made radiation exposures that give an average of 100 mrem per year to everyone in the U.S.

Table 6
[illegible] Sources [illegible]

[illegible]	[illegible]
Environmental	
Nuclear [illegible]	
Consumer products such as [illegible] watches, microwave ovens	[illegible]
Nuclear reactors (living at site boundary)	[illegible] 0.3 mrem/y
Nuclear reactors (average person in the population)	0.01 [illegible]
Medicine and Dentistry	
Chest x-ray	[illegible]
Whole mouth x-ray	910 [illegible]
Breast mammograph	1,500 mr[illegible]
Pacemaker insertion [illegible]	132,000 [illegible]
Radiation treatment for [illegible]	5,000,000 [illegible]

[illegible] of various factors which [illegible] following paragraph[illegible]

[illegible] One should recall that the rate at which [illegible] determining its effect. This is because [illegible] as soon as [illegible] healing begins. Thus if a particular dose is delivered [illegible] it is possible that repair may keep up with the damage so that no detectable change would be produced. On the other hand, if the same dose is delivered all at once, the change may be noticeable.

Knowledge of the effects of radiation has generally resulted from data on large doses received in a short time. Data sources include Hiroshima survivors, victims of radiation accidents, and patients receiving radiation therapy. However, most humans are exposed to low doses and low dose rates. To see the biological effects of this type of radiation, one would have to observe large groups of people over many generations. Because of this difficulty, the general practice is to predict the results of the low doses and low dose rates on the basis of high dose and high dose rate data.

Furthermore, in order to be conservative in estimating radiation effects, one must assume that some injury results from any exposure to radiation. According to the International Committee on Radiation Protection (ICRP): "The objectives of radiation protection are to prevent acute radiation effects, and to limit the risks of late effects to an acceptable level. For purposes of radiation protection, any exposure is assumed to entail a risk of biological damange." There are certainly levels of radiation that produce no detectable effects: background radiation and routine diagnostic x-rays, for example. But the most conservative assumptions are used to insure maximum protection for the population.

The age of the exposed individual can greatly affect his/her sensitivity to radiation. When organs are developing before birth, sensitivity is high, because differentiating cells and cells undergoing rapid division are more easily damaged. Similary, from birth to maturity, high rates of cell division and possible further differentiation make a child more sensitive to radiation exposure. An adult is more resistant to radiation effects. Exposure, however, may give rise to genetic effects in the exposed adult's future children. For a person beyond the reproduction age, genetic effects are not important. Similarly, radiation effects which might appear only after a long time (for example, tumor induction) would not be as significant to older people as to younger people.

Some parts of the body are more sensitive to radiation effects than other parts. [illegible] if the upper abdomen is irradiated, the radiation effects are more severe than if a body area of similar size elsewhere were exposed to the same dose. This is because of the presence of vital organs in the upper abdominal area. Thus the relatively high doses from sources such as dental x-rays can be tolerated since they are confined to an extremely small area containing no vital body organs.

Irradiation of a small part of the body surface will have much less general effect than an equal dose delivered to the whole body, since the unirradiated portion can help the affected portions recover.

[illegible] 95 [illegible] of significant levels of radioactivity [illegible] the body [illegible] techniques. Radioactive materials move through the body in the same manner as nonradioactive materials. They are also eliminated in the same manner and, in addition, become weaker through radioactive decay.

[illegible] individual responses [illegible] single exposure killed half of a group of [illegible] within 30 days [illegible] 400 rads and some lived after 600 rads. Thus biological variations occur in radiation effects.

[illegible] ed only in the person who has been irradiated [illegible] of the person irradiated.

Somatic effects originate with the response of the irradiated cells. The first event in the absorption of ionizing radiation is the production of excited atoms and ion pairs. When these are produced in the chemical systems of a cell, new and possibly harmful chemicals are produced as the original chemical structure of the cell is disturbed by the radiation. Thus, toxic materials may be produced. Furthermore, if the radiation affects chromosomal material within the cell nucleus, cell division may be affected. Thus a cell may respond to irradiation in several ways: chromosomal changes, cell death before division, failure to specialize, failure to divide completely, or slowing its division rate. Some cells will be unaffected by the radiation.

The cellular response to radiation is determined by a number of factors. Among these are the cell's stage of specialization, its activity, and its division rate. These factors partially account for an embryo's great sensitivity to radiation. In the embryo, a small group of cells will eventually specialize or form an organ, so these cells are especially radiosensitive.

These factors also help to make radiation therapy possible. A patient with cancer, for example, receives a number of exposures, giving him/her a large total radiation dose. Through the phenomenon of repair following radiation exposure, the cells begin to repair the radiation damage between exposures. However, the rapidly dividing cancer cells have a greater chance of being destroyed because they are more frequently in the radiosensitive stages of cell division.

The radiosensitivity of organs and tissues depends on cell multiplication. In the lining of the gastrointestinal tract, for example, some cells are mature. These are continuously being discarded and replaced by new cells produced nearby. If a high dose of radioactivity is received, these rapidly dividing cells will be severely decreased in number. If the dose is not too high, the surviving cells will be able to replace those destroyed.

If a large dose is given to a small [illegible] the general [illegible] which organ is irradiated. For instance, a large radiation dose to an arm will very likely cause detectable changes in the arm, but it will not result in death or severely damage the blood making system, because the majority of this system was not exposed to the radiation. On the other hand, a moderate dose to the reproductive organs can result in temporary sterility.

A large, sudden whole-body dose of radiation produces the [illegible] syndrome: nausea, vomiting, general aches and pains, and possibly a decrease in the number of white cells. Localized phenomena, such as reddened skin or loss of hair, may be produced. Larger doses cause weakness, drastic depression of all blood elements, and possibly sterility. At still higher dose levels, death will probably occur.

It has been shown in animals [illegible] aging. It is obviously difficult to obtain such data [illegible] degree of life shortening may occur following high dose exposure.

[illegible] the effects [illegible] Instead, there is an increased frequency of disorders [illegible] environmental factors or which occur spontaneously with no known cause. For example, cancer and leukemia may be long delayed consequences of a single large exposure to radiation, and they may also follow chronic exposure, but they are by no means an inevitable result of any form of human exposure to radiation.

[illegible] effects [illegible] changes in the characteristics of an offspring [illegible]

Mutations occur in all living organisms. They may occur of their own accord, apart from any known alteration in the environment. Whatever their origins, most mutations are undesirable. Every individual has some of these undesirable mutations.

Radiation-induced mutations are divided into two classes: gene mutations and chromosomal abnormalities. Most radiation-induced alterations are gene mutations, which tend to be recessive. In other words, the effect of the mutation is not seen in the offspring unless the altered gene is carried by both parents. Even though the mutation may not be seen in first-generation offspring, it makes such offspring slightly less fit.

Chromosomal abnormalities include chromosome loss and chromosome breaks. These effects are severe, and usually result in the death of the embryo before birth. This type of genetic effect happens much less frequently than does gene mutation.

The increase in genetic damage to be expected from radiation is sometimes discussed in terms of doubling dose. This dose would eventually cause a doubling in the rate of gene mutations that occur spontaneously.

In the United States about 100 million children are born in a generation. Of these, about two percent will have detectable genetic defects as a consequence of spontaneous, unavoidable genetic changes passed on by all their ancestors. If a doubling dose of radiation were applied to present and future generations, it would eventually lead to a gene mutation rate of four percent. It would take on the order of 10 generations to reach the four percent rate. The doubling dose cited by the National Academy of Sciences report, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation*, is estimated to be 40 rads (40,000 mrads) per generation. In other words, if the average dose to the reproductive cells of all of the individuals of the population were a total of 40 rads from conception to age 30 or 1.3 rads per year above background for every generation, after about 10 generations the rate of impairing mutations would gradually increase so as to eventually double from two percent to four percent. This amount of radiation is far above that obtained from any current man-made source.

It should be pointed out that only [illegible] caused by environmental radiation. The bulk of all genetic changes is produced by other causes, including environmental pollutants.

[illegible] able to expect that a wide range of [illegible] would exist in this great variety. While radiation protection guides are written for the protection of humans, much of the data upon which such guides are based was derived from animal experiments.

[illegible] apply to all other life forms. However, there is a wide range of [illegible]. The more complex the organism, the more sensitive it is to radiation effect.

[illegible] An example is shellfish such as oysters and [illegible]. These organisms [illegible] certain radionuclides up to 100,000 times the levels found in the water in which they live. This does not appear to affect the well being of the animal, but people who use these shellfish as their major source of food could receive a significant fraction of their maximum permissible dose in the process. For this reason, edible shellfish living near nuclear plants are used as monitors for cross-checking radioactive discharges.

Under normal conditions, the amount of radiation the general public receives from a nuclear power plant is extremely small. What are the risks from such small additional amounts of radiation? The latest National Academy of Sciences study indicates, according to its chairman, "At low doses the risks are very small. There is a risk, but it's not the end of the world." Another member of the study panel disagrees somewhat: "We have no idea what the effects are from very low levels, and in any case they are undetectable."

This very fact of being unable to clearly detect any effect, accompanied by an unwillingness to say that there is no effect at all, has led to a dilemma. In order to avoid setting standards which would expose the public to unnecessary radiation, the National Council on Radiation Protection and Measurements has recommended exposure limits based upon the following cautious assumptions: (1) There is a single, linear dose-effect relationship for the effects of radiation, from zero dose with no effect to the known effects of high level doses. (2) There is no threshold of radiation below which there is no effect. (3) All doses received by an individual are additive—that is, their effect add up. (4) There is no biological recovery from the effects of radiation. Much of the available evidence indicates that several of these assumptions are probably too conservative, but in the interest of safety, we assume that they are true under the philosophy that it is better to be oversafe than to be sorry at some future date.

The radiation protection guide [illegible] permissible dose to the general population. The maximum is presently 500 mrem/year above natural background. This figure does not include an individual's radiation dose from medical procedures. The NCRP does not attempt to regulate or limit radiation exposure for necessary diagnostic and therapeutic purposes but it does recommend reductions in the exposure which does not contribute to treatment or diagnosis.

People are becoming more cautious about having [illegible] that might [illegible] In all cases doctor and patient must decide when benefits outweigh risks. This is particularly true with the large doses received in radiation treatment for cancer. Doctors know that such doses increase the risk of a second cancer but they also may lengthen the life of the patient.

The limit for radiation workers is 5000 mrem per year. To those that [illegible] there have been suggestions that this maximum exposure level should be reduced, perhaps by a factor of 10. Part of the controversy over this subject stems from a study done by Dr. Thomas Mancuso of workers at the government nuclear facilities at Hanford, Washington. He studied the causes of death of people who had received radiation exposures while working at Hanford and concluded that some of the cancer deaths could be correlated with low level radiation exposures. Other scientists, questioning Dr. Mancuso's methods of analyzing the data on the deaths, have concluded that there is no evidence of an increased death rate from cancer or any other cause in the Hanford workers.

[illegible] worker [illegible] nuclear power plant [illegible] permissible dose of 0.5 [illegible] per year.

Table 2 [illegible] general [illegible]

Table 7
Estimates of Annual Health Effects From the Operation of One 1,000 Megawatt Nuclear Power Plant

Procedure	Occupational Deaths	Occupational Injuries and Disease	Nonoccupational Deaths
Mining			
Accidents	0.005-0.2	1.8-10.0	
Disease	0.002-0.2		
Transportation			
Accidents	0.002-0.005	0.045-0.11	
Processing			
Accidents	0.003-0.2	0.6-1.5	
Disease	0.013-0.35		
Power Generation			
Accidents	0.01	1.5	[illegible]
Disease	0.003-0.1		
Total	0.035-0.945	3.7-[illegible]	0.01-0.16

[illegible] Mile Island

About 4 a.m. on Wednesday, [illegible] ...erable to the nuclear power [illegible] Mile Island Unit 2 nuclear plant near Harrisburg, Pennsylvania [illegible] had been in operation for one year. Figure 5 is a diagram of that plant.

The accident at Three Mile Island began [illegible] ...tion. This is the system that feeds water into the steam generator [illegible] have started automatically but it did not because some valves had been left closed after a test of the system in the days prior to the accident. This was a violation of NRC regulations. Without a water supply, the steam generators dried out, resulting in a rise in the temperature and pressure of the cooling water. The turbine shut itself down instantly, and within seconds the reactor's control rods automatically descended into the core and shut down the fission process. A relief valve released steam into the reactor containment vessel to relieve the pressure in the primary cooling system. This relief valve should have then closed; instead it [illegible] open. Unknown to the reactor operators, this allowed the continuing release of radioactive steam and water into the containment building, [illegible] the tanks that were supposed to hold it and [illegible] the floor of the building.

[illegible] high side [illegible]. Shortly afterward [illegible] the faulty gauge the operators [illegible]. They shut off these pumps because if the system were completely filled with water, as they thought was happening, they would have difficulty controlling the pressure. Around 5:30 a.m. they shut down the primary coolant pumps, which had begun to vibrate, apparently because they were pumping too little water. The operators feared that the vibration would destroy the pumps, and possibly cause a rupture in the primary coolant system. By the time the stuck relief valve was discovered and repaired, and the emergency core cooling system was turned on again, the coolant level had dropped so low that part of the core had been uncovered, resulting in substantial fuel damage.

Meanwhile the radioactive water from the containment building was being pumped into a storage tank in an auxiliary building. This pumping was done by sump pumps which operated automatically. When the storage tank was full, water spilled onto the floor and radioactive gases began to escape to the environment through the auxiliary building's ventilation system. This problem was discovered at about 9 a.m. The sump pump was turned off and the containment building was sealed off from the rest of the plant.

As the fuel heated, some of the fuel cladding [illegible] with the water, forming a hydrogen and steam bubble at the top of the reactor pressure vessel. Reactor operators were unaware of the extent of this problem.

The most serious problem confronting operators [illegible] was [illegible] the reactor to begin to cool the core. This was finally accomplished through the use of the emergency core cooling system and one of the main reactor coolant pumps could be started by 8 p.m.

[illegible] Utility officials held a news conference [illegible] morning saying that they had seen little fuel damage but later NRC officials reported that fuel damage was much worse than previously thought. Low levels of radiation continued to be emitted as plant personnel tried to control the radioactive water on the floor of the auxiliary building.

Friday, March 30, is called "Black Friday," by [illegible] 6:40 a.m. there was a series of small gaseous releases of radioactivity from the auxiliary building. There was a large release around 6:45 a.m. About that time a helicopter which was monitoring radiation levels directly above the plant reported a radiation reading of 1200 millirem per hour. NRC headquarters in Washington mistakenly thought this measurement was from ground level outside the boundary of the plant and they called the Pennsylvania Emergency Management Agency (Civil Defense) and told them that the area around the plant should be evacuated. The error was soon discovered and the evacuation order was replaced with a directive that people within a 10 mile radius of the plant should stay indoors.

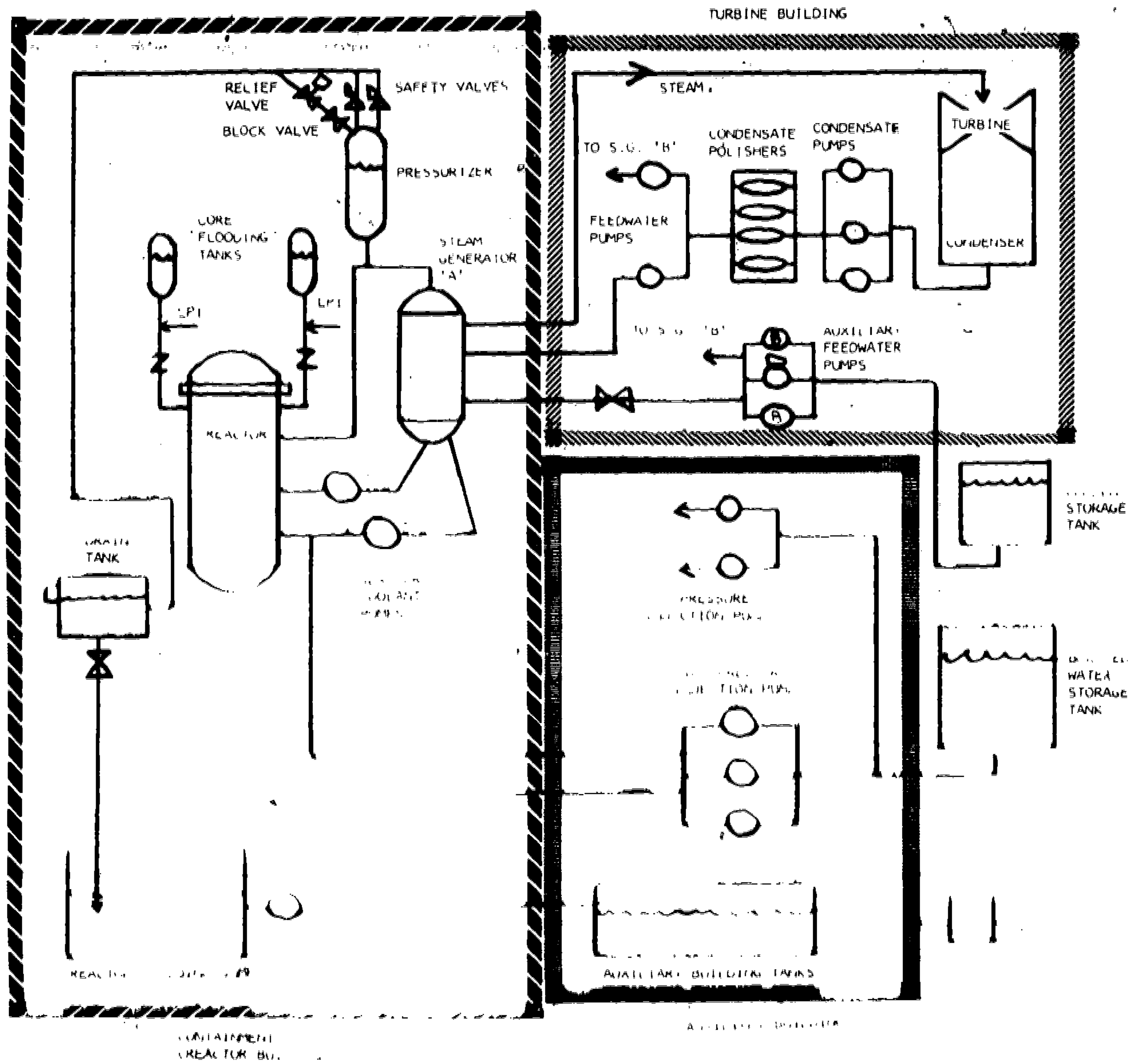
[illegible]

[illegible] plant. NRC [illegible] than [illegible] in the primary containment. Also about [illegible] the 23 schools in a five mile radius of the plant [illegible] pregnant [illegible] children in that five mile radius to leave the area. As it turned out, most of the significant radiation releases that would take place during the incident had already occurred. Utility officials discounted

FIGURE 5

SCHEMATIC OF PRESSURIZED WATER REACTOR

MAJOR SYSTEMS INVOLVED IN THREE MILE ISLAND ACCIDENT



[illegible] to steam generator [illegible]

[illegible] The [illegible] 5,000 [illegible] President Carter ordered the [illegible] the White House, NRC headquarters and the nuclear plant

[illegible] was [illegible] stable [illegible] the fuel temperature was [illegible] fear that if the system cooled down very much, the bubble would expand and restrict the flow of cooling water through the damaged core, possibly exposing the core again.

NRC personnel, using a "worst-case scenario", postulated that there could be a hydrogen explosion which could possibly breach the containment building and release serious amounts of radioactive materials to the environment. **In actuality, there was never a danger of such an explosion because there was no oxygen in the reactor vessel.** The chemical reaction which produced the hydrogen had consumed the oxygen from the water by oxidizing the fuel cladding

About this time, an NRC official at the scene remarked to the press that there was real possibility of a core meltdown. In the midst of the confusion Harold Denton arrived to take control of the NRC staff and began the coordination of news releases

NRC officials debated about whether they should recommend a general evacuation of the area around the plant. They also considered taking over operation of the crippled plant, but finally concluded that they did not have enough qualified operations staff to run the plant. Thus as "Black Friday" closed, the nation believed that a catastrophe was eminnent

Saturday arrived with continued tension and confusion [illegible] leak from the plant. Governor Thornburgh told the people living near the plant that it was no longer necessary to stay indoors, but still advised pregnant women and preschool children to avoid coming within five miles of the plant. Plans were being prepared for the evacuation of everyone within 20 miles of the plant

The core was stable, but some hot spots remained in the core. The utility reported that the bubble was decreasing but NRC reported that it was growing, increasing the possibility of an explosion. NRC advised the governor to evacuate the people up to 10 to 20 miles around the plant, but the governor decided such an evacuation was unwarranted. However, many who had remained up to this time decided to leave, and it is estimated that over the weekend 80 000 of the 200 000 people living within 20 miles of the plant left their homes

At 8:27 p.m. the Associated Press quoted an unnamed [illegible] bubble was so volatile it might explode at any minute. Harold Denton reported at 10:00 p.m. that this was false, and that the bubble had started to decrease. At about the same time, the governor was advised that President Carter would visit the plant the next day

Sunday, April 1, was a better day [illegible] water and the bubble was thought to be slowly shrinking. Gases were being [illegible] the primary coolant water and vented to the containment. Hydrogen [illegible] the hydrogen and some of the containment oxygen into water.

[illegible] of the [illegible] safety of the people in the area

Monday, April 2 [illegible] slightly reduced [illegible] reported [illegible] it had gone [illegible] possibility of an evacuation was now remote

Harold Denton told the press that the possibility of the hydrogen bubble exploding was never great. He also began recruiting some 200 nuclear experts from around the world to assist in the subsequent evaluation of the system.

By Tuesday, April 3, some schools in the area opened. Governor Thornburgh declared an end to the threat of an immediate catastrophe.

Joseph Califano, then head of the federal Department of Health, Education, and Welfare, stated that the maximum dose anyone might have received was about 80 mrem, or about the same as a couple of chest x-rays.

Some radiation was reported to be escaping from the plant, primarily from opening systems to take water samples.

In subsequent days, the pressure and temperature of the system remained stable and the fuel temperature slowly decreased. The pressurizer was occasionally vented to the containment to avoid possible return of the bubble. The hydrogen recombiners continued to lower the hydrogen content of the containment building. By April 9, the dissolved gases in the primary coolant were essentially eliminated, and Governor Thornburgh lifted his advisory that pregnant women and preschool children stay out of the area.

Finally, on April 27 [illegible], a month after the accident, cold shutdown was achieved. The primary pumps were shut off and the reactor was kept cool by the natural circulation of water between the core and the "A" steam generator. The massive clean-up job remained to be done.

There were several assessments of the radiation exposure to the population around the plant. The normal background radiation in the area is about 125 mrem per year. The maximum dose that anyone in the public could have received occurred at the bridge on the north side of the plant boundary as it connects to the mainland. It was computed that if someone had stayed at that point 24 hours a day during the incident, that person would have received a total dose of about 85 mrem. The maximum actually received by any individual was less than this value.

The Department of Health, Education and Welfare calculated that the [illegible] persons within 50 miles of the plant was about 3[illegible]00 person-rems. The National Academy of Sciences estimates that this exposure could cause an additional one to ten cancer deaths in the population of 100,000 people living within 10 miles of the plant. The same population would normally be expected to have 4[illegible]000 cancer cases over the next 20 years.

[illegible] be less [illegible] that [illegible] real [illegible]

[illegible] the safety systems and the training and operating stress pertain to a sudden large break in the primary coolant line. They were not prepared for events which occurred over a period of time and involved relatively small leaks.

[illegible] problem. It also showed a need for better radiation monitoring [illegible]

A survey on the social and economic impacts of the accident was commissioned by NRC and conducted in the summer of 1979. The survey showed that the cost to people near the site was $18.2 million in evacuation expenses and lost wages. Two out of every three children under five years of age and three of every four pregnant women in the area left during the emergency. Twenty-two percent of those responding to the survey said that some member of their family suffered extreme emotional upset during the emergency period.

The complete effect of the accident on the future of nuclear power is not known, but it has certainly increased the apprehension of many people about this energy source. On the other hand, supporters of nuclear power say that if lessons learned from the accident are properly applied, nuclear power can be made safer, and it should continue to supply an increasing amount of our electricity.

Nuclear Power: Future Prospects

Nuclear power has thus far had a good safety record. Electricity produced by nuclear [illegible] is generally less expensive than that produced by coal or oil. This has resulted in major savings for consumers, while at the same time helping the U.S. decrease its dependence on imported oil. And the unique ability of nuclear power plants to keep operating during severe weather conditions such as the frozen coal piles and barges of 1977 and during a national coal strike in 1978 helped to avert major power outages in those years.

Despite this performance, there were [illegible] nuclear [illegible] plant [illegible] orders from 1975 to 1977, resulting in a net reduction of 14 large plants since 1975. There were two new orders for nuclear plants in 1978. Delays have occurred in building the plants already ordered, and in completing the plants under construction. There are many reasons why electric utilities are not ordering nuclear power plants. One is the fact that the growth in electrical consumption did slow down for a while. According to a DOE study, another principal reason for the lag in nuclear plant orders is the perception by utilities that the executive branch of the federal government, though endorsing the use of light water reactors in the National Energy Plan, has not supported nuclear power by carrying out the federal responsibilities for licensing, spent fuel storage, waste isolation, and fuel enrichment. Another major problem faced by utilities is the long and uncertain schedules for completion and the rapidly escalating costs when construction delays occur. These delays often result from the difficulty in obtaining the necessary licensing. Hearings for various licenses become battles between the utilities and opponents concerned about safety, plant siting, waste heat, storage and transportation of nuclear waste, decommissioning, and the possibility of fissionable materials being diverted for use in bombs. Some question the need to increase energy supplies in any form. Another factor has been the difficulty in securing outside financing to support construction costs because of uncertainty and spiraling prices resulting from delays, changes in plant design, and changes in government regulations after construction has started.

[illegible] it is still anticipated that [illegible] will [illegible] demand for electrical energy grows.

[illegible] U.S. [illegible] Japan, the Soviet Union and other [illegible] commitments to the [illegible] of nuclear power. These commitments include not only increasing conventional reactor capacity but also reprocessing, breeder reactor development, and radioactive waste storage. In mid 1978, 22 countries had licensed 220 reactors, and an additional 320 reactors were under construction or on order. This has not been without some controversy, since increasing opposition to nuclear power in many countries has come in the face of its continued growth.

ELECTRICITY

In 1977, about 27 percent of the primary energy consumed in the U.S. was used to generate electricity. This percentage is expected to increase because some of the energy sources that are expected to be available to us in the future are best suited for producing electricity. Because of its importance in our day-to-day lives, electricity is included in this section on energy sources.

In 1977, an estimated two trillion kilowatt hours of electricity were generated, with coal contributing 47 percent, oil 17 percent, gas 14 percent, nuclear sources 12 percent, and hydroelectric sites 10 percent.

This electricity was used by the consuming sector as follows: residential 32 percent, industrial 41 percent, commercial 23 percent, and other 4 percent.

When the electricity is generated at the power plant, it [illegible] through a large transformer, where its voltage is stepped up in much the same way as a pump builds up water pressure in a hose. When the desired voltage is reached, the electricity enters the transmission system to be carried where it is needed. Electricity travels at nearly the speed of light, so it is used at almost the same instant it is produced. The high voltage transmission lines are usually placed above ground. There is some loss of electricity as it passes through the lines. Step-down transformers further reduce the voltage to the proper level for consumers. The lower voltage distribution lines can be buried underground.

[illegible] companies [illegible] are financed by private investors. [illegible] produced by [illegible] government-owned utilities. Because of the major investment in generation and transmission equipment, a utility is permitted to provide exclusive service in a particular geographic area. The rates of investor-owned companies are regulated by federal and state agencies.

[illegible] embargo [illegible] 15 [illegible] percent and in 1977 it was [illegible] percent.

[illegible] about 15 percent [illegible] about 30 percent [illegible] environmental [illegible] by environmental groups have increased the time that it takes to complete a power plant so that it now takes on the average nearly 10 years to build a large coal plant and about [illegible] years to build a large nuclear plant. Oil or gas fueled plants could be built relatively quickly, but the fuel would have to be imported, increasing [illegible] supply interruptions and adding to the economic problems. The combination of plant cancellations and long construction times could be the source of severe electrical shortages if the demand for electricity grows at a higher rate than expected. Some people believe such shortages will begin in the early 1980s, possibly causing economic recession and unemployment. On the other hand, utilities cannot afford to have too much excess generating capacity, since it is expensive to build and maintain whether it is being used or not.

Another problem in electrical generation is that there are presently no good, economically feasible ways to store electricity. Batteries are expensive and have limited lifetimes. Pumped hydroelectric storage is being used at some power plants equipped with hydroelectric capability. In this system, electricity generated at off-peak times is used to pump water into a reservoir. Then at peak times, this water can be used to operate hydroelectric generators to produce extra electricity. This storage method has limited application, however, since few suitable sites exist.

This lack of a good method of storing electricity is a significant problem, because demand for electricity varies greatly from day to night anf from season to season. Since electricity has to be generated as it is used, the generating capacity must be large enough to accommodate the peak demand, while in off-peak periods only about 50 percent of the generating capacity might be needed. Since the generating equipment is very expensive, this unused capacity adds greatly to the cost of electricity.

It is possible that "time-of-day" metering will soon appear on a wide scale. It is being tested in some areas. Under this system, electricity used at peak demand times will cost more than electricity used at other times. This system would hopefully encourage people to even out the demand for electricity. This could mean more industrial work done on a night shift, and residential activities such as running dishwashers and washers and dryers done in the evenings to save money.

ENERGY: POLICY AND PROSPECTS

PRINCIPLES OF ENERGY ECONOMICS

Many aspects of economics are routinely discussed in newspapers, magazines, and television. Some of those aspects which arise in considering energy economics include competition, monopoly, cartel, windfall profits, supply and demand, environmental effects, and scarcity itself. We can better understand our present energy problems and our future possibilities if we have some feeling for the meaning of these terms.

Economics is simply the science of allocating scarce resources. If any kind of useful good is truly abundant, it does not need to be rationed or allocated, and it will be free–if anyone tried to charge for some of it, people would be able to get it from another source. Only scarce resources command a price, or need to be allocated. The price of a scarce good represents what a buyer has to give up when he gets the good, and what a seller has to receive before he parts with the good. But the price also serves as a signal to both the buyer and the seller--when a good becomes suddenly scarce, for whatever reason, the price normally goes up until buyers want enough less, and sellers provide enough more, that no other kinds of rationing or allocation is necessary.

Competition exists whenever real or potential producers have the opportunity to make more profit by lowering their price enough to sell more goods (though at a lower profit on each). If gasoline stations buy gas at 60¢, and are all independent, they tend to sell their gas for about 65¢,

55

because the stations need about 5¢ per gallon to stay in operation. Suppose a station sells 50,000 gallons per week, servicing about 700 cars per day. Then 5¢ per gallon yields the station $2500 each week to pay its rent, wages for the attendants, other operating costs and owner's profit. If the station lowers its price to 63¢, it needs to sell 83,333 gallons to get the same $2500; if it raises its price to 67¢, it can get $2500 by selling only 35,741 gallons. Whenever there is true competition, a station which raises its price too high will lose enough sales that even at the higher price, its total profits drop. If a single station raises its price to 80¢, it could make 20¢ on each gallon, but it probably would not sell the 12,500 gallons it needs to make $2500 if other stations were still willing to sell at 65¢.

Monopoly exists when a seller sets a price without losing sales to competition. If a gasoline station is the only one in town, it will be able to charge more for gas, up to the point when one of three things happens: (1) its customers use less gas; (2) they find another town where they can buy gas; or (3) somebody opens a competing gas station because it is such a profitable business. Monopolies are usually undesirable because they can earn an unfair profit, and because they restrict the availability of their goods. Fortunately, either real or poetntial competition usually prevents excessive monopoly power. However, some activities (notably water, natural gas, electric, and telephone utilities) are such that once one firm has installed the necessary pipes or wires, it is both expensive and undesirable to have another firm go into competition with them. Such a "natural monopoly" is often regulated by the government. If the only problem with a monopoly were that it makes too much profit, a tax on that profit would be the easiest and best way to solve the problem. But the main effect of the monopoly is that by setting too high a price, it sends an incorrect price signal and forces people to use too little of its own good, and too much of other substitute goods. For instance, a gas station that is a monopoly might force people to take time to drive to a cheaper but distant gas station. Regulation tries to prevent problems like these.

A cartel exists when independent sellers band together to act like a monopoly. If a town has only two or three gasoline stations, they would ordinarily be in partial competition–this is called an oligopoly. If they agree *not* to compete, they can charge a higher price and split the full monopoly profit among themselves. Some nations approve of selected cartels (usually on the grounds that they lead to more economic stability), but in the U.S. such an agreement would be termed collusion and would violate anti-trust laws. A cartel or trust has most of the economic characteristics of a monopoly. OPEC (Organization of Petroleum Exporting Countries) is clearly a cartel. It must be recognized that while a cartel can and does charge too high a price, that price is limited by demand for the cartel's product, for the cartel attempts to maximize its total profit. The more that higher oil prices lead to conservation, the less incentive an OPEC cartel has to raise its prices.

Windfall profits are usually taken to mean unexpected or unearned profits–especially those that exceed the profit a supplier needed to count on before he went into business. When OPEC placed an embargo on oil in late 1973 and raised oil prices dramatically, U.S. oil and gas were automatically wroth much more than they had been. In a freely competitive market, oil and gas prices would have risen quickly to signal for less consumption and more production. (Germany and Japan dealt with their energy crisis in this way.) But in the process, existing oil and gas supplies would also command the same higher price, and the suppliers would thereby make windfall profits. Since these profits are usually make by large companies at the expense of people who depend on fuels for heating and transportation, their unfairness has led the U.S. to maintain various kinds of price controls. Many vexing political and economic problems center around this kind of issue–whether or not to allow prices to perform an efficient job of allocation, at the expense of inequitable costs and profits.

Supply and demand are simple concepts, yet are widely misunderstood. A shortage of fuel does not mean that people are using more fuel than is produced—it means they *want* more than they are using. Strictly speaking, no "shortage" can last very long before people's wants are translated into higher prices—any continuing shortage of a market good must be due to some form of price controls.

Environmental effects are called "externalities" by the economist, and refer to goods which are not incorporated in the market. If you and I both keep all our trash on our own property, or both dump our trash into a truly bottomless pit, no externality is involved in our trash disposal. But if only one of us has access to such a pit, or if the trash causes a problem for someone else, the whole logic of the marketplace is distorted. The producer should charge his customers enough so that he can pay his suppliers for all the materials he uses. But suppost that one of the things he uses is clean air, in the sense that he puts out a lot of dirty smoke for every item he makes. If he does not have to pay for the air he has dirtied, he will charge his customers too little, they will buy too many of this items, and he will make the air too dirty. Note that we said above that price controls were at the root of every continuing shortage of a market good. For non-market goods (external or environmental effects) a physical shortage is, in fact, quite possible. We can be confident that the world will not truly "run out" of copper, or coal, or oil—as they become really scarce, they will become expensive enough so that they will be saved for their most vital uses, and substitutes will be found for the less important uses. They become expensive because they are each *owned* by someone who sells them to other people, and who charges a higher price when his good becomes scarce. But clean water, fresh air, a healthy environment—these could be used free, and could therefore be used up excessively.

The economic rationale for most conservation and rationing programs is based on ideas like these. Policy-makers judge that generally higher prices would hurt low-income and fixed-income groups, and selectively higher prices would be inequitable, so they try to discourage the energy uses that would be dropped if prices were higher. These uses probably include electric heat, fuels for indoor temperatures higher than 68 degrees in the winter or lower than 80 degrees in the summer, gasoline used for speeding or for some weekend travel, and so forth.

The important thing to understand is that higher prices would resolve our energy problems rather quickly, but at a cost which seems unfair to many. Conservation programs help prevent us from making choices which will cost society—all of us—more than they are really worth.

THE NATIONAL ENERGY POLICY

"The diagnosis of the U.S. energy crisis is quite simple: demand for energy is increasing, while supplies of oil and natural gas are diminishing. Unless the U.S. makes a timely adjustment before oil becomes very scarce and very expensive in the 1980's, the nation's economic security and the American way of life will be gravely endangered. The steps the U.S. must take now are small compared to the drastic measures that will be needed if the U.S. does nothing until it is too late." These are the opening words from the first National Energy Plan from the Executive Office of the President, Energy Policy and Planning, in April of 1977.

Shortly after President Carter proposed this National Energy Plan, the Department of Energy began operations. This federal agency is responsible for administering the national energy plan.

The National Energy Plan was an attempt to deal with many of the energy problems faced by our nation. After its proposals were put forth by President Carter, Congress deliberated for nearly a year and a half before passing the National Energy Act on October 15, 1978. It enacted some of the President's proposals, rejected others, and passed some in a revised version. The National Energy Act is composed of 5 bills. They deal with the following major areas: conservation, use of alternate fuels for gas and oil, regulation of public utilities, natural gas pricing, and energy-related taxes and tax credits. We will briefly discuss the provisions of each of these.

The National Energy Conservation Policy Act of 1978 (NEPA) provides a program which requires utilities to help their residential customers identify various energy conservation possibilities within their homes and estimate their costs and savings. Utilities must also help arrange for installation and financing of such measures if the customer desires. The act provides grants for insulating low income homes, and loans for homeowners and builders for purchasing solar equipment. It provides loans for home energy conservation measures, and grants to improve the energy efficiency of schools and hospitals. The conservation act calls for energy audits in public buildings, and sets energy efficiency standards for major home appliances. It also provides for fines on auto manufacturers who fail to meet set fuel economy standards.

The Power Plant and Industrial Fuel Use Act of 1978 prohibits the use of oil or natural gas in new electrical generating facilities or large industrial boilers. It also requires existing large boilers that can burn coal to do so. Existing gas-fueled power plants cannot increase the amount of gas they burn, and, with certain exceptions, must stop using natural gas by 1990. The act provides a loan program to help utilities raise funds for pollution control. It also funds several programs to reduce the negative impacts of increased coal production.

The Public Utility Regulatory Policies Act of 1978 includes voluntary standards on rate structure and other utility practices for consideration by state regulatory authorities and non-regulated utilities. It provides for rules favoring industrial cogeneration facilities, and establishes a loan program to aid development of small hydroelectric projects. The act seeks to expedite the issuance of permits for crude oil transportation systems, and establishes a natural gas transportation policy.

The Natural Gas Policy Act of 1978 provides for a series of maximum prices for various categories of natural gas, including gas sold in both the interstate (between states) and intrastate (within the same state) markets. Previously, only the interstate rates were federally regulated. Price controls on newly discovered gas and some categories of high cost gas will be lifted as of 1985. Another provision of the act establishes protection of residential gas consumers by first passing through part of the increased gas prices to industrial users. The President was given the authority to allocate gas supplies to insure that in the event of a natural gas shortage, the best possible use is made of gas supplies.

The Energy Tax Act of 1978 provides for an income tax credit for residential insulation and other energy conservation methods, and for installation of solar or wind equipment. It establishes an excise tax on "gas guzzling" cars, and exempts "gasahol" from federal excise tax. The act gives incentives for the development of geothermal resources in the form of investment tax credit and special depletion allowances. It gives business tax credits for industrial investment in alternative energy equipment, and denies tax benefits for purchase of new gas and oil burners.

It is estimated that these measures in the National Energy Act will save more than 2 million barrels of oil per day by 1985.

In May of 1979, President Carter sent to Congress the National Energy Plan II. It is an attempt to deal with issues, notably oil pricing, not covered in the National Energy Act, and to further emphasize conservation and the development of new domestic energy sources and technologies.

The National Energy Plan II proposes an energy strategy to deal with the different problems that can emerge in three time-frames: the near term (from now to 1985), the mid-term (from 1985 to 2000), and the long term (2000 and beyond). This strategy is quoted here:

"As an immediate objective, which will become even more important in the future, the Nation must reduce its dependence on foreign oil and its vulnerability to supply interruptions.

In the mid-term, the nation must seek to (1) keep imports sufficiently low to protect U.S. security and to extend the period before world oil demand reaches the limits of production capacity and (2) develop the capability to use new higher-priced ("backstop") technologies as world oil prices rise.

The Nation's long-term objective is to have renewable and essentially inexhaustible sources of energy to sustain a healthy economy."

The major portion of National Energy Plan II deals with the near term strategy by phasing out price controls on domestic oil to encourage production and discourage consumption. Under the current price control system, most U.S. oil falls into one of two categories: "old" oil, which is defined as production equal to the amount an existing field was pumping in 1972, and "new" oil, which is production from oil fields that exceeds the 1972 level or oil from wells drilled after 1972. Prices of both categories have been held well below the world price set by OPEC. For example, in April of 1979, "old" oil sold for about $6 a barrel; "new" oil about $13, and OPEC oil for more than $14. Because of this system, some old wells have been capped even though they have not run dry, because the controlled cost is relatively low. Also, exploration costs have risen more rapidly than the controlled price for "new" oil, so that domestic production has continued to decline.

These controls were set to expire automatically in 1981, but the President had the authority to abolish them at any time after June 1, 1979. President Carter chose to decontrol the oil prices in stages to lessen the immediate impact on the economy. Decontrol began on June 1, 1979, and will be complete by October 1, 1981.

The Department of Energy predicts that lifting the controls will quickly boost production from older U.S. fields and bring on a new round of exploration. It is also expected that the higher oil prices brought about by decontrol will cause many oil users to switch to other energy sources. Decontrol of domestic oil prices will cause gasoline prices to jump sharply, along with all transportation costs. Home heating oil prices will also increase. Food production costs will rise, bringing food costs up. All these things will add to the country's inflation woes. But President Carter felt the steps were necessary to halt our growing dependence on whate he called "a thin line of oil tankers stretching halfway around the earth ... to one of the most unstable regions in the world."

Higher oil prices will add considerably to oil company profits. President Carter has asked Congress to pass a windfall profits tax aimed at keeping these profits down. Under the President's proposal, half of the profits the oil companies would get from rising prices would go to the federal government. Added to existing taxes, this would leave the oil companies about 30 percent. The new tax would produce an estimated $1.6 billion in 1980, $4 billion in 1981, and $5.8 billion in 1982.

Some of the tax money would be used to help low income families cope with rising energy costs. Part would be channeled into mass transportation, including rehabilitation of railroads. The rest would be used for other energy projects such as the development of new energy technologies.

The President's proposals ran into opposition in Congress, and as of this writing they have not been acted upon.

In the National Energy Plan II, President Carter again stressed conservation, calling it "our cheapest and cleanest energy source." His new plan proposes a variety of voluntary measures, such as strict adherance to the 55 mile per hour speed limit, the use of car pools and mass transit, and thermostats set at 65 degrees in the winter and 80 degrees in summer. If such voluntary conservation does not occur, President Carter plans to ask Congress for passage of mandatory measures. He has already asked for the authority to order weekend closing of gas stations, and has ordered federal executive agencies to cut energy use by 5 percent.

The President is also allowing some relaxing of environmental standards. He has postponed a regulation which would have required refiners to reduce the lead content of gasoline, and has opened the way for emergency use of high-sulfur fuel when the prices of low-sulfur oil get too high.

In the area of nuclear power, the administration policy is that "the nation needs to develop safeguards that will allow light water reactors to continue to meet an increasing share of electrical energy needs." Research and development on breeder reactors will be continued, but demonstration will be deferred pending further study.

The federal energy policies and programs of the National Energy Plan II can be briefly summarized as follows:

Conservation:	Encourage conservation to reduce the rate of growth in energy demand and to improve the productivity of energy use through improved efficiency
Oil:	Paise domestic oil production and encourage conservation through decontrol of prices. Tax windfall profits and use revenues for relief for the poor and energy-related projects and research. Continue stocking the Strategic Petroleum Reserve, ultimately to one billion barrels.
Natural Gas:	Encourage domestic production by financial incentives
Coal:	Enough use in place of oil and gas wherever economically and environmentally feasible
Nuclear:	Use light water reactors to generate an increasing share of electricity. Work toward resolving nuclear waste management issues, and streamlining licensing without sacrificing safety.

Other energy sources scheduled for research, development, and/or demonstration:

Coal liquefication
Coal gasification
Breeder reactor
Fusion
Solar energy
Geothermal energy

International cooperation: Meet commitment with other member nations of the International Energy Agency to cut energy consumption 5 5 percent by the latter part of 1979

In a speech given on July 15, 1979, President Carter made some additions of his energy proposals and policies. At that time, he ammounced the re-imposition of quotas to limit the amount of imported oil to no more than that imported in 1977. He also set a goal of cutting imports in half by 1990. President Carter said that he would propose "the most massive peacetime commitment of funds and resources in our nation's history" to develop new energy sources. He called for the creation of an Energy Security Corporation and a Solar Bank, financed by the proposed windfall profits tax on decontrolled oil prices. To speed major energy projects through government red tape, the President proposed creation of an Energy Mobilization Board.

In another recent speech, President Carter said that he wants Americans to be as familiar with the facts about energy as they are with the daily weather report. Although both might at times be dull or depressing, it is our responsibility to inform ourselves on the energy situation and to act accordingly.

WORLD-WIDE PERSPECTIVE ON THE ENERGY PROBLEM

No country, however large or wealthy, can now view the future of its citizens independent of the rest of the world. National monetary systems are not independent, but are part of an international monetary system. National economies are increasingly dependent on the international flow of resources. One small region, the Middle East, controls the lion's share of the world's known petroleum reserves. North America controls a large share of exportable grain supplies. Interdependence among countries is so great that the size of automobiles and level of thermostats in the United States are influcence by oil production and export decisions in the Middle East. Food supplies in the Soviet Union and Japan are strongly influenced by U.S. agricultural export decisions.

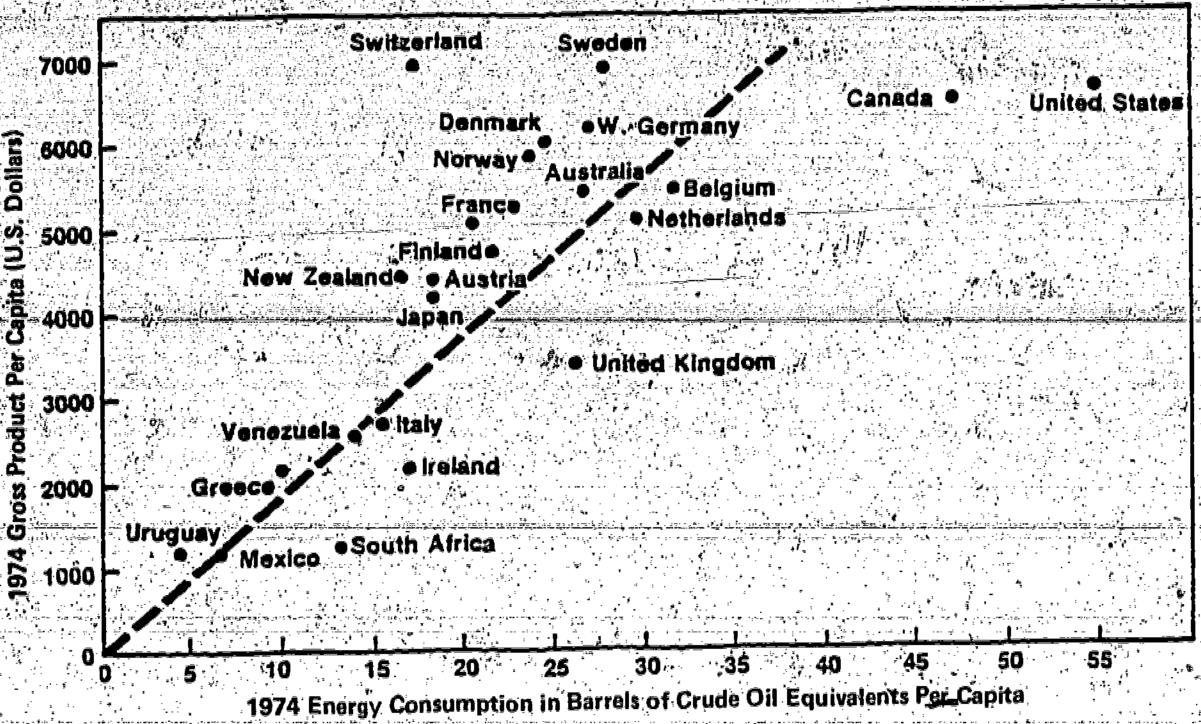
It is therefore important to understand something about the energy situation in the rest of the world, and how world-wide energy consumption is likely to change.

A country's standard of living is closely related to its use of energy. Those countries with a higher per capita (per person) income generally have higher per capita energy consumption. As might be expected, the United States leads the world in energy consumption. Furthermore, the United States uses more energy per capita than other countries with similar standards of living. Part of this excess energy is used to grow food and manufacture products which are then exported to other countries, but a great deal of it is energy that we could conserve and in fact badly need to be conserving. Figure 6 shows the relationship between energy consumption and gross national product (a measure of standard of living).

The less developed countries of the world use very little energy per-capita. These countries, where most of the citizens live in poverty, have 50 percent of the world's population; they consume only 2 percent of the world's energy. It is estimated that by the year 2000, they will consume no more than 4 percent, with 55 percent of the world's population. The developing countries of the world are expected to show the sharpest rise in per capita energy consumption. Smaller rises in per capita consumption in the U.S. and other industrialized countries will hopefully bring these countries' share of the world's energy consumption more into balance.

FIGURE 6

Energy Consumption Per Unit of GNP



Source of Data: U.N. Statistical Yearbook, 1975

ENERGY: IS THERE ANOTHER WAY?

The following section describes some alternative sources of energy. Some are in limited use today, while others can make no contribution to energy supplies for many years. Some may never prove to be feasible.

OIL SHALE AND TAR SANDS

Oil shale is a finely textured rock that contains a tarlike material called kerogen. When melted, kerogen gives off vapors that can be converted to shale oil. This shale oil can then be refined into oil, gasoline, and other petroleum products. Oil share deposits are located primarily in Colorado, Utah, and Wyoming. These deposits are estimated to contain the equivalent of several times the estimated recoverable oil in the United States.

There are two general ways of recovering shale oil. The one that has already been demonstrated is above-ground retorting, where the shale is collected and heated, distilling the vapors to produce the shale oil. The other process which is being studied is in-situ retorting. This involves breaking up the shale underground by hydraulic pressure or an explosion. Some of the shale oil would be burned in place to provide the heat to liquify more of the shale oil so it could be pumped from the ground. In-situ retorting has many unresolved problems; control of the explosion and underground fire are among the largest. But it is being studied because above-ground retorting has two tremendous drawbacks. One is the strip mining that an above-ground operation would entail, and the other is the disposal of wastes. Even high-grade shale is about 87 percent rock or inert materials, and these wastes swell up to almost twice the volume of the original shale when they are removed from the ground. Nothing will grow on these wastes without large quantities of water, in areas where the water is simply not available.

Union Oil is expected to soon begin producing shale oil on an experimental basis in Colorado. The oil will be expensive, and proposals for a $3 per barrel tax break or a loan guarantee are before Congress, along with the synthetic fuel bill which would provide price supports for fuel made from shale and other substances.

Tar sands consist of sand particles coated with a tar called bitumen. This bitumen can be extracted and refined into fuels. Tar sand recovery is more difficult and expensive than oil shale recovery, and U.S. tar sand resources are smaller than oil shale resources, so the future use of this material is uncertain.

MAGNETOHYDRODYNAMICS

One long-term possiblity for the more efficient and relatively non-polluting use of coal is magnetohydrodynamics (MHD). In this process, a fuel and preheated air are fired in a burner at very high temperatures. The resulting combustion gas is "seeded" with potassium or cesium salts, producing an electrically-conducting hot gas. This gas passes through the MHD generator, which is surrounded by powerful magnets, and produces an electric current. The hot gases can then be used in a conventional gas or steam turbine to produce more electricity.

An MHD research program is being carried out jointly by U.S. and Soviet scientists and engineers in Moscow. Natural gas is being used as the fuel in this experimental work, but because of supply considerations, coal is envisioned as the fuel to be used in any commercial application in the U.S.

In addition to the joint U.S.-Russian venture, DOE also has its own MHD research program. Commercial operation of MHD plants will probably not occur until early in the 21st century.

An important hurdle in the MHD program is the development of a suitable coal combuster for MHD requirements, which are different from those for conventional coal combusters. Another important task is to find suitable materials for th MHD generator. This is difficult because of the very high temperature that this material must withstand.

The MHD process has a potential efficiency of 50 percent or more, considerably higher than the 30 to 35 percent efficiency of current steam generating systems.

Pollution should also be less of a problem with MHD generators. The seed material used to increase electrical conductivity reacts with the sulfur in the combustion gases to form a solid substance that can be recovered. Thus MHD generators should be virtually non-polluting as far as sulfur is concerned. It is also hoped that the combustion process can be controlled in such a way as to keep the formation of nitrogen oxides and particulates to acceptably low levels.

GEOTHERMAL POWER

Beneath the earth's survace are vast amounts of heat, caused by the decay of natural radioactive elements, chemical reactions, and friction. This geothermal energy can sometimes be tapped to provide usable energy. Theoretically, such energy could be obtained anywhere on earth by drilling deeply enough and extracting the heat. In most parts of the world, however, the hot areas are too deep to reach with present drilling methods. But in some areas, including many places in the western U.S., large areas of heat lie relatively close to the surface. This occurs primarily in volcanic regions and along geologic faults.

The four major types of geothermal resources are dry steam, wet steam, hot dry rock, and geopressurized zones.

Dry steam, the scarcest type of geothermal energy, is the only type that is well understood and used to any extent today. It occurs when hot water boils in an underground reservoir and dry steam (not mixed with liquid water) comes near the surface where it can be tapped to run a turbine and generate electricity. There are presently three dry steam geothermal plants in operation in the world–one in Larderello, Italy (the first to come into service), one in Japan, and one in Northern California. The largest of these is the one in California, known as The Geysers. Here, the steam is collected from a number of wells, filtered, and passed through turbines that drive electric generators. The total electrical capacity at The Geysers is now about 500 megawatts, with a projection of adding about 100 megawatts per year for several years. This will bring the capacity up to the amount of electricity now used by the city of San Francisco. Additional large dry steam sources are not now known, although some may exist in Yellowstone National Park.

The second type of geothermal reservoir is the wet steam or hot water well. In wet steam fields, which are about 20 times more abundant than dry steam, water is heated by surrounding rock to well above its normal boiling point, but instead of turning to steam it remains a liquid because of high underground pressure. As it approaches the surface, the pressure drops and a mixture of steam and water is produced. Wet steam fields are sometimes characterized by geysers, hot springs, and naturally-occurring steam vents called fumaroles. (Technically speaking, there are no geysers at The Geysers plant–the energy is produced from fumaroles.) Among the most famous examples of wet steam fields are the hot springs and geysers at Yellowstone National Park. Production of electricity from wet steam fields is more complicated than for dry steam fields because the steam must be separated from the water before it can drive a turbine. In addition, the water is usually a highly corrosive brine (very salty water) which must be safely discharged or reinjected into the earth. There are only a few fields currently producing electricty from wet steam, none in the United States. There are some wells that produce hot water with no steam. Only limited use has been made of these resources.

The third, and probably the most abundant, geothermal resource is hot dry rock that has not come into contact with underground water systems. Energy might be recovered from these areas by pumping water into a drilled shaft connected to the hot rock and bringing it back to the surface as hot water or steam. The first water pumped into the shaft would break up the rock, creating a network of cracks and fissures to act as a reservoir. Extensive research remains before energy can be extracted from hot dry rock.

The final type of geothermal resource, geopressurized zones, is probably the least understood. Such zones have been found during oil exploration along the Texas and Lousiana coasts. They contain highly porous sands saturated with high-temperature, high-pressure brine or hot water. The energy potential of these areas is not limited to recovering their heat. The high pressures of these waters might make possible the use of hydraulic turbines, and dissolved methane in the water is another potential energy source. The size and productivity of these reservoirs need to be determined along with other information on their possible use.

Geothermal energy systems, at least as known today, are not without their environmental effects. Such systems are usually located in remote areas, and their environmental effects are mostly confined to their immediate locality. Air pollution from hydrogen sulfide and ammonia in the hot water, and noise from the steam venting process are very real problems. In addition, pollution of surface or ground waters can result from the disposal of water after the heat has been removed. Land subsidence is another problem–the withdrawal of large quantities of water from beneath the earth can cause the surface to settle and craters or holes to form. More research is needed to understand the impact of large-scale use of geothermal power.

Optimistic predictions would have less than one percent of the U.S. total electric generation coming from geothermal sources by the year 2000. Although geothermal energy apparently cannot satisfy our overall energy needs, it can be of local importance in the West and Southwest and possibly along the Gulf Coast, if the needed technology is developed.

SOLAR ENERGY

Solar radiation is the source of almost all energy on earth. The solar energy received by the earth every 10 days equals the world's total known fossil fuel reserves. The average amount of solar energy falling on an area 9 feet by 9 feet during one day would be roughly equivalent to the amount of energy contained in one gallon of gasoline. The idea of harnessing this abundant, inexhaustible energy supply is attractive indeed. But solar energy is variable–factors such as season of the year, cloud cover, and geographic location can affect the amount of solar energy received. Solar energy is also a diffuse form of energy, necessitating a system for collecting and utilizing it.

There are two basic ways to utilize solar energy: using it directly for solar heating and cooling, and converting it into electricity.

Solar energy for space heating (heating of buildings) and water heating is feasible in some parts of the country. Solar space heating systems can be classified as either active or passive. In an active system, solar energy is received by solar collectors, usually on the sloping roof of the building facing the sun. The "flat plate" solar collector is the most common. It is a large air-tight box covered with one or more layers of glass or plastic. ~~Radiant~~ energy passes through these layers and is absorbed by a metal absorber plate. Heat energy is then transferred from this plate to water (or air) being circulated through the collector, and is thus carried off for immediate use in the heating system or for storage. Water can be heated to between 150 and 180 degrees Fahrenheit in such a system. Several refinements improve the efficiency of the collector system. More than one layer of glass or plastic over the collector permits sunlight to eneter but helps to keep the heat from escaping. The metal absorber plate is painted black or specially coated so that it absorbs the maximum energy. A layer of insulation between the absorber and the roof helps prevent heat loss.

In a solar heating system, a heat storage system is necessary to provide for nights and cloudy days. Water in an insulated tank is most often used for storing the heat, although crushed rocks or pebbles are sometimes used. When heat is needed, it is delivered to the house through a conventional hot air or hot water circulating system.

In contrast to these mechanized systems to collect, store, and release heat, passive solar heating systems release heat from materials that are integral parts of the building itself. Such passive use of the sun's energy is of course not a new idea. Research has shown that the structure of Indian puebloes in the southwestern portions of the United States was carefully designed to use solar energy and other climatic elements of the region. A study of the Ocoma tribe's pueblo, located near Albuquerque, New Mexico, showed that the construction of buildings was planned to maximize the entry of sun in the winter and minimize it in the summer. Furthermore, the thick adobe walls stored heat for release on cold nights.

Passive solar design is typified by large areas of south facing glass, massive structural elements such as thick concrete walls or floors, and energy conserving insulation techniques. Passive solar systems tend to cost less than active solar systems for the same total energy delivered to the building, and, in some cases, cost is no more than conventional building design. There is also a minimum likelihood of operational malfunctions.

Hot water for household use can also be provided by solar energy. In fact, companies marketing solar water heaters did a good business in California and Florida for many years before low-cost natural gas came on the scene. The water is heated by being piped through a solar collector, and then is stored in a tank. Solar water heating can be used by itself or in conjunction with a solar space heating system.

Solar energy can also provide cooling. The solar heat is used to evaporate a refrigerant in a closed chamber, causing some cooling. The evaporating refrigerant is picked up by an absorber solution which promotes faster evaporation, which in turn promotes cooling. As the absorber picks up the refirgerant, it rejects heat to the outdoors. Thus indoor heat is absorbed and radiated outdoors, cooling the house. Solar cooling units of this type require temperatures of 200 degrees Fahrenheit, higher than can generally be produced by current flat plate collectors. Thus some kind of concentrator is required.

The combination of a heat pump and a solar system is also being explored. A heat pump is a device which moves energy from one place to another. It is reversible, so it can pump heat into a building in the winter and out of a building in the summer. Thus solar collectors can warm water which can be drawn out with a heat pump.

At first glance, the widespread use of solar energy for heating and cooling looks extremely attractive--the "fuel" is free, non-polluting, and available to all. But of course this rosy view must be tempered with realism.

First of all, the cost of a solar heating and cooling system is initially much higher than that of a conventional system. This cost differential will undoubtedly decrease, as mass production techniques are already bringing down the price of solar components. In most areas of the country, solar collectors cannot yet economically provide all the heat required for a building, so a solar system must be backed up by a conventional heating system. Furthermore, current storage systems cannot store enough heat for more than a day or two, so a back-up system must be called upon for long periods of cloudy days. This causes a serious problem for utilities if this backup heat is electric, as it often is. Utilities must provide enough generating capacity for everyone at these times of peak use, but the expensive generating equipment would be idle or inefficiently used at other times.

In addition to its use in heating and cooling, solar energy can also be converted into electricity. There are two basic ways in which this can be done--by using the sun's heat to generate electricity and by using solar cells to generate electricity directly from sunlight.

The process for generating electricity from the sun's heat is called solar thermal conversion. Solar heat is used to make steam or to heat air, which is then used to turn a turbine to generate electricity.

One type of solar thermal system is called the central receiver system. In this system, sometimes called a "power tower," a field of mirrors called heliostats are aimed to reflect the sun's rays to a receiver mounted on top of a tower. The solar energy is absorbed by water or some other fluid in the receiver and generates steam to turn a turbine. One such experimental plant under construction will concentrate the sunlight by a field of more than 1500 heliostats. These heliostats will be multi-faceted glass mirrors each about 45 square feet in area. Their angle will be individually computer controlled to continuously direct the sun's energy onto the central receiver. The receiver will be a cylindrical collection of tubes mounted on a 283-foot tower. The plant will generate 10 megawatts of electricity by steam turbines.

The focusing of a whole field of mirrors on one receiver produces a large concentration of energy—up to 1000 times as great as the normal sunlight. Thus the steam temperatures should be high, which allows for efficient generation of electricity.

In contrast to the central receiver system is the distributed system of thermal conversion. In this type of system, the solar energy falling on a field of collectors is converted to heat at the collector. The heat is then conducted to a central location where it is used to provide steam to generate electricity. The major advantage of the distributed collector system is that it can produce some energy from indirect light, while the central receiver works only in full sunlight. But the resulting temperatures are significantly lower than with the central receiver system and are thus less efficient for power production.

Generating electricity directly from the sun depends on the photovoltaic effect, which is the process that occurs when light hits certain sensitive materials and creates a flow of electrons. This effect is used to generate electricity through the use of solar cells. Solar cells are clean, safe, and have no moving parts. All that they need to generate electricity is a supply of sunlight.

Solar photovoltaic cells are often made from silicon. Silicon itself is abundant and inexpensive, but its crafting into solar cells is so exacting that it requires much careful handwork by highly skilled technicians, making solar cells expensive. The manufacturing of solar cells also uses large amounts of energy.

A typical solar cell is 2 centimeters by 2 centimeters in area. Its power output is very small, so that many cells must be connected electrically to get a significant amount of electricity. For example, 40 cells provide enough electricity to charge a 12-volt automobile battery. Many sizes and shapes of solar cell modules are available from over a dozen different companies now manufacturing solar electric products. They are finding a wide variety of applications where power requirements are reasonably small. For example, they power Coast Guard buoys in Long Island Sound, and backpack-mounted two-way radios used by the Forest Service. Solar cells are the major source of power in space vehicles.

In the future, solar cells may generate electricity in central power plants or for individual buildings. They may also be used in conjunction with solar heating and cooling systems.

A proposal put forward by Peter Glaser of Arthur D. Little, Inc., calls for a Satellite Solar Power Station. A satellite would be built with two wing-like panels of solar cells, each about 3 miles on a side. The satellite would be in a synchronous orbit—that is, it would be fixed above the same spot on the earth, about 22,000 miles above the surface. Since it would always be in the sunlight, it would receive much more solar energy than any earth-based panels. The electricity produced by the solar cells would be converted to microwave radiation and beamed to earth where it would be collected by a 36 square mile antenna and reconverted to electricity. Solutions such as this are obviously far in the future.

Economic factors remain a serious barrier to the widespread use of solar cells. Electricity from solar cells cost 15 to 20 times as much as that produced from nuclear or fossil generation. It is hoped that mass production techniques and improved technology will reduce this cost.

There are several problems common to both types of solar electrical systems. One is the universal bane of solar energy–the sun does not always shine, and good, economical long-term energy storage systems are not currently available. Another factor to be considered is that not all areas of the country receive the same amount of solar radiation. The southwestern portions of the U.S. receive the most; in the Midwest and Southeast, the direct solar radiation received is about one half the values of the Southwest, while in the Northeast and Northwest it is about one-third. Thus solar electric plants, and particularly thermal conversion plants which depend on direct sunlight, can most economically be used in the Southwest. But a concentration of such plants in the Southwest, with transmission of electricity to other areas, would pose two major problems: there is an inadequate amount of cooling water available there for such plants, and such a concentration of plants in one area would make for an unreliable power supply.

A tremendous amount of land area would be required for widespread solar electric generation. It is estimated that a 1000 megawatt solar electric plant operating in the Southwest would require an area of 10 to 20 square miles.

The energy costs in building and operating solar plants must be considered. The energy requirements for solar thermal power plants are primarily for the heliostats, which are made from steel, aluminum, copper, and plastics. Studies have shown that such a plant in the Southwest will "pay back" its energy requirement in less than 5 years of operation–that is it will take 5 years to generate as much energy as was required to build the plant. (Similar studies for fossil and nuclear power plants showed energy paybacks of 2 to 3 years.) Five years appears to be an acceptable payback period, but if the same plant were built in another area of the country, the payback period might be excessively long.

Very large amounts of energy are required to process the silicon crystals for use in photovoltaic cells. Thus the payback period for such a system would also be long.

Solar energy needs to be looked at as a total system, from mining of materials to final energy production, in order to be wisely evaluated.

Just how much of the nation's energy requirements will be met by solar energy and how soon this will happen, is open to different opinions. Many experts believe that a 10 to 20 percent contribution to total energy needs by the year 2000 "would be a tremendous accomplishment."

WIND POWER

The windmill is one of the earliest machines, with its origins thought to be in Persia around the 7th century. Windmills were first used to pump water for irrigation.

In the United States, wind power was a major source of electricity, particularly in rural areas, until 1930, when the Rural Electrical Administration began to make centrally-generated electrical power available to farms. Thus by 1950, small-scale windmills were rare.

Wind power is really a form of solar power, since wind is caused by alternate heating and cooling as solar radiation reaches the earth.

A windmill is basically a shaft containing a number of blades designed to turn in the wind. This provides energy which can be used to turn a mill, pump water, or turn a generator to produce electricity. The power output of a wind machine depends on wind speed and on the length of the machine blades. Thus a wind machine needs to have blades that are as long as practical, and also needs to be as tall as practical since wind speed and constancy generally increase with height.

Near Sandusky, Ohio, NASA has been experimenting with a wind generator that can produce up to 100 kilowatts with an 18-mph wind. It has two 62.5 foot long blades, for a diameter of 125 feet, and it is on a 125 foot tower.

The major disadvantage of wind power, in the absence of a suitable energy storage system, is the variable nature of the "fuel source." When wind speed falls below 6 mph, efficient generation is impossible. Also, winds that are too strong can damage the apparatus, particularly the blades. This has been a problem with some of the recent experimental wind generators.

Some advocates of wind power have suggested building a network of [illegible] 300,000 large windmills (about one every square mile) across the Great Plains to generate 189,000 megawatts of electricity. Large "wind farms" covered with a grid of identical wind generating units could then be built with more economical mass production techniques. The large areas of land required for such a network should still be usable for farming or grazing. If the wind generated electricity could be fed into a large multi-regional electrical system, the variations caused by changes in the wind could be somewhat evened out, and existing steam generating plants could also help handle the electrical demand.

Another [illegible] winds. Such systems [illegible] in the [illegible] along the [illegible] objections on esthetic grounds, however, from those who would not like to see the landscape dominated by the many large towers that would be necessary.

Small scale use of wind power is practical [illegible] companies are producing wind generators to provide electricity for homes [illegible]

ENERGY FROM THE OCEAN

[illegible] ocean thermal [illegible]

[illegible]

[illegible] through turbines [illegible] the turbine through the [illegible] generating [illegible]

[illegible] operating tidal plant [illegible] U.S.S.R. It appears that the only possible [illegible] at [illegible] Alaska bay and several at [illegible] has been a project proposed for many years on one of these [illegible] Passamaquoddy [illegible] and studies are still being conducted on that site and the Alaskan site. With such a limited number of suitable sites and the large investments required to build the plants, it does not appear that tidal power will make a significant contribution to the total energy supply.

In Great Britain, studies are being done on extracting energy from ocean waves. This would be done by using strings of specially-shaped vanes which would be turned by the waves to generate electricity. It is not yet known whether the project will be successful.

The third method for getting energy from the ocean is called ocean thermal energy conversion (OTEC). Enormous quantities of solar energy are collected and stored in the oceans. An OTEC power plant would utilize the energy that can be made to flow between the sun-warmed surface of tropical and subtropical oceans and the colder deep water. A fluid such as ammonia or propane that vaporizes at relatively low temperature can be vaporized by the warm surface water. The pressurized vapor would then turn a turbine, and the cycle would be completed by using the cooler deep water to condense the gas back to a liquid.

Small-scale OTEC plants have been built in Cuba and off the Ivory Coast but they closed down because of damage by waves and current.

The corrosiveness of seawater on plant components and the possibility of marine growth fouling the system must be considered. The plants must also be built strongly enough to withstand storms.

One important advantage of OTEC [illegible] that the solar energy stored in the water is always available, whether or not the sun is shining or the wind is blowing. But one disadvantage is the fact that the best sites for OTEC plants are in tropical and subtropical seas far from the areas where the electricity is most needed. Thus the electricity would have to be transmitted through undersea cables or used at the site to create products that can be transported by ship or barge.

More study needs [illegible] on climate of a change in the temperature [illegible] must be considered. Also, pumping large quantities of cold water to the surface would change the ecological balance. The change might be beneficial if it allowed the establishment of fisheries around the plant but the impact needs to be carefully studied.

[illegible]

[illegible]

[illegible] floating plant [illegible] plant [illegible] of time and money. Plants under study [illegible] sunflowers, water hyacinths, and giant sea kelp. Such fuels would either be burned directly or converted to liquid or gaseous fuels.

Energy farms would have to compete with agriculture for land area and water resources. As the world's need for food increases, this could be a serious consideration.

Another biomass possibility is recovering energy from forestry, agricultural, and animal residues. For example, the residue from the sugarcane industry–the plant material remaining after the sugar has been extracted–is often burned to provide energy for the sugar mill. Similarly, the forest products industry often uses their residue to fuel lumber plants.

Animal wastes can be converted to methane. A large facility is being built at an animal feedlot in Colorado to provide methane, and as a byproduct, a high protein feed supplement for the animals.

Such uses of biomass may never provide a large share of our energy, but if they are [illegible] where they are feasible as in the sugarcane and forestry industries, valuable fuels will be saved for other uses.

ENERGY FROM THE [illegible] GARBAGE

Nearly [illegible] tons of solid waste is generated each [illegible] The collection and disposal of garbage is a large and expensive [illegible] plants to produce electricity is an attractive alternative to other disposal methods.

Several waste-burning electric power plants are in operation today, [illegible] of these plants the waste is the only fuel, but in most it is mixed with larger amounts of coal or oil. The wastes are collected by regular garbage collection systems and brought to the plant. Metal and glass are recovered from the garbage and sold for recycling. The rest of the waste is dried and then burned.

The [illegible] economical only when the garbage must be collected and disposed of anyway. In sparsely populated areas the cost of collection and transportation of sufficient quantities of garbage would be too high. It is most suitable for large urban areas. Even in urban areas burning garbage is not expected to save much money or generate a significant amount of electricity. But it can conserve other valuable fuels while helping to alleviate disposal problems.

[illegible]

[illegible]

[illegible]

[illegible]

Fuel cells were used for spacecraft power on the Apollo space flights and in the early 1970's provided electric power to a number of buildings on an experimental basis. A demonstration unit is expected to begin operation in New York City in 1979 in order to determine the effectiveness and the environmental and social acceptability of a power plant in a densely populated area.

The widespread use of fuel cells is dependent on a number of developments to reduce cost of the equipment and to allow the use of a wider variety of fuels. Fuel cells now in use depend on naphtha or natural gas, so their use is limited from a fuel supply standpoint. The currently-available fuel cells also require an expensive catalyst, such as platinum, for their operation. Thus electricity generated from fuel cells is currently too expensive for general use

Research is underway on a new type of fuel cell which operates at a much higher temperature than current fuel cells Because of the higher operating temperature, no expensive catalyst is required This newer fuel cell should also prove adaptable to other fuels, particularly to low BTU fuel gas made from coal

One major advantage of fuel cells is their flexibility They can be [illegible] units, then stacked together to form whatever size installation is needed

Unlike large combustion plants, fuel cells operate equally efficiently at [illegible] They also require no lengthy warm-up period, generating electricity from the moment they are turned on

Since fuel cell operation does not involve a combustion process, emissions are significantly lower than conventional plants and are well within EPA requirements Some heat is generated in the cells, but it is expected that they can be air cooled with fans, eliminating the need for the large quantities of water required for cooling conventional plants Fuel cell operation is also quiet so overall they appear environmentally desirable

Fuel cells could find a wide variety of applications [illegible] ing power systems peak load capacity, since their quick [illegible] full capacity make them especially suitable. They could also supply electricity for small communities or for remote sites Fuel cell systems could serve individual buildings or groups of buildings Having the fuel cell near the point of electrical use could reduce transmission losses and expense

FUSION

[illegible]

[illegible] energy [illegible] generat[illegible] [illegible] electrical power [illegible] could [illegible] make a single helium atom and [illegible] neutron [illegible] separate [illegible] would be "burned" [illegible] In order for fusion to [illegible] the deuterium and tritium gas must be heated to extremely high temperatures 50 to 100 million degrees centigrade. At these temperatures the gas becomes a plasma consisting of free positive ions and negative electrons The deuterium and tritium must be held together for a long enough time to allow them to fuse time ranging from a fraction of a second to a second The plasma must also be dense enough to [illegible] large [illegible] deuterium and tritium in a small enough space to permit [illegible] reaction Obviously no ordinary container can [illegible] holding this tremendously hot [illegible] Two [illegible] are being studied [illegible] containment and inertial confinement

Since the plasma consists of particles with electrical charges, it can be contained within a magnetic field. In 1967 the Russians announced the development of the tokamak, a donut-shaped machine in which the plasma was heated by running an electric current through it, and was contained in a magnetic field. But high enough temperatures could not be achieved. In 1978 Princeton University and the Department of Energy announced that the New Jersey laboratory had achieved a record 60 million degree centigrade plasma temperature, well above the temperature estimated to be needed. However, many complicated problems remain to be solved.

In inertial confinement, sometimes called laser fusion, a solid pin head sized pellet of deuterium and tritium would be heated very rapidly so that fusion would occur in less than a millionth of a second, before the pellet had a chance to expand and thus lose its density. This heating would probably be done with a powerful laser beam or ion beams. This form of fusion is less advanced than magnetic confinement

Some radioactivity will be produced in fusion [illegible] radioactive waste will be produced. Overall there seem to be no unsolvable environmental or safety problems

Because of the tremendous technical and engineering problems remaining [illegible] fusion [illegible] expected to contribute importantly to our energy supplies until well into the 21st century

[illegible]

[illegible] the energy we use. This can be accomplished in three ways: [illegible] efficiency of building, vehicles and industrial equipment, by substituting [illegible] goods and services for energy intensive ones, and by curbing our demands for energy

There are many benefits of conservation. It can help to [illegible] environmental health and safety problems associated with energy use and it can [illegible] the consumer

[illegible]

[illegible] and other conservation [illegible] less energy than those built in 1973. Large home appliances [illegible] These beginning steps need to be continued. To aid you personally [illegible] a home energy audit is included at the end of this section. It will help you to identify conditions that cause energy waste and to decide which ones to correct to maximize energy savings

[illegible] been [illegible] EPA tests. The estimated mileage [illegible] increased 40 percent between 197[illegible] and 1978. This even though there are more cars, their consumption of fuel has been growing slowly because the newer cars are more efficient. Savings of oil as well as several thousand fewer auto deaths each year have resulted from the 55 miles per hour speed limit. The use of mass transit systems has been growing gradually in recent years. Gasoline shortages and high gasoline prices will undoubtedly help continue this trend.

The industrial sector is actually using less energy now than it was in 1973. This reduction has come about primarily through improved efficiency. Lower output during part of the period and a shift away from some energy-intensive products also played a part, but energy savings have been realized by more careful energy management and by improving industrial processes.

One method of industrial conservation has been cogeneration, which is the use of energy (usually steam) from a single facility for two or more processes. Plants can be constructed which will produce steam for electricity and make the spent steam available for manufacturing processes. Increased fuel costs have and will continue to make this practice more attractive to industry, since it increases efficiency and thus lowers costs. Cogeneration may reduce operating costs of the facilities involved from 22 to 31 percent compared to the cost of fuel which would be required for separate operation.

An example of a cogeneration [illegible] company and the city of Eugene, Oregon. Boilers produce steam which is used to generate electricity for the city and the spent steam is used in lumber processing operations.

It would appear that a beginning has been made in energy conservation [illegible] beginning. What we must learn to do is to stop and think about our use of energy. We can no longer afford to use it as if it were limitless. This "conservation ethic" is something each American needs to develop.

HOME ENERGY AUDIT

This home energy audit will enable you to make a survey of your home and identify those conditions which are wasteful of energy, and thus wasteful of money. After identifying these energy-wasting conditions, you will be able to decide which ones you may wish to correct first, which ones have a lower priority, and which ones you can practically do nothing about.

To use the audit, answer each applicable question. Then consult the rating sheet that follows to assign a conservation value of -5 to +5 to each item. You will then be able to make decisions according to the following scale:

-5 to -2	High energy wasting condition. Correcting such conditions should be given first priority
-1 to +1	Energy wasting condition. These should be corrected after the high priority items
+2 to +3	Satisfactory condition
+4 to +5	Energy saving condition
N	Condition which has [illegible] little or nothing

[illegible] narrative at the [illegible] [illegible] wasteful conditions

[illegible]

[illegible]

[illegible]

a [illegible]
b Cinder block
c Brick
d Wood
e Alum[illegible]

W[illegible] the co[illegible]
a Light colored
b Medium colored
c Dark colored

W[illegible] the color of [illegible]
a Light colored
b Medium colored
Dark colored

[illegible] roof of your [illegible]
a Little or none
b Paritally
Most or [illegible]

[illegible] be most of [illegible]
a Sand [illegible]
b Grass or other veg[illegible]
Ashphalt bare soil [illegible]

B. Inside your Home

6. What daytime temperature do you maintain in your home during the winter?
   - a. 55-58
   - b. 59-62
   - c. 63-65
   - d. 66 68
   - e 69-72
   - f 73 75
   - g 76 77
   - h Over 77

7 What night time temperature do you maintain in your home during the winter?
   - a 55-58
   - b 59-62
   - c 63-65
   - d 66-68
   - e 69 72
   - f 73 75
   - g 76 77
   - h Over [illegible]

[illegible] was you[illegible]
   - a Never
   - b More than 12 months ago
   - c Within the last 12 months
   - d I don't know

If your house is air conditioned [illegible] summer?
   - a Under [illegible]
   - b 67 68
   - c 69 70
   - d 71 72
   - e 73 74
   - f 75 76
   - g 77 78
   - h 79 80
   - i [illegible]

[illegible]
[illegible]
   - a [illegible]
   - b [illegible]
   - c 69 70
   - d 71 72
   - e 73 74
   - f 75 76
   - g 77 78
   - h 79 80
   - i [illegible]

11. How many of your windows have storm windows or more than one layer of glass (e.g. "Thermopane")?
a. None
b. Less than half
c. Half
d More than half
e All

12 How many of your exterior doors are equipped with storm doors?
a None
b Less than half
c Half
d More than half
e All

13 How many of your windows and [illegible] to prevent air leakage?
a None
b Less than half
c Half
d More than half
e All

How many of your [illegible]
a None
b Less than half
c Half
d More than half
e All

[illegible] ...es?
a Regularly
b Sometimes
c Never

How many of [illegible] to keep out the sun [illegible]
a None
b Less than half
c Half
d More than half
e All

W[illegible]
a None
b Less than half
c Half
d More than half
e All

[illegible]
a Yes
b No

[illegible]
a Yes
b No

20. Is your attic equipped with windows or vents that provide air circulation?
   a. Yes
   b. No
21. Is your attic equipped with an exhaust fan?
   a. Yes
   b. No
22. How much insulation is in the floor of your attic?
   a. None
   b 1-2 inches
   c 3-4 inches
   d 5-6 inches
   e. 7-8 inches
   f. 9-10 inches
   g 11-12 inches
   h Over 12 inches
23 What does the surface of the [illegible]
   a None present
   b Unknown
   c Loose particles
   d Blankets or batts
Do you have a basement?
   a No
   b Partial
   c Full
About how [illegible] of the base[illegible]
   a None
   b Less than half
   c About half
   f About three-quarte[illegible]
   e Nearly all
W[illegible] part of your basement [illegible]
[illegible] family room)
   a None
   b Less [illegible]
   c Half
   d More [illegible]
   e All
[illegible]
   a [illegible]
   b [illegible]
[illegible] have a [illegible]
[illegible]
   a Yes
   b No
[illegible]
   a None
   b One
   c Two
   d [illegible]
   a Yes
   b No
A[illegible]

Rating Sheet: Home Energy Audit

1. N for all responses.

2. a. +3
b. 0
c. -3

3. a +3
b. 0
c 3

4 a +2
b +1
c +3

a +3
b +1
c 3

a 0
b 0
c 0
d 5
e 0
f 2
g 3
h 5

a 0
b 0
c 5
d 5
e +4
f 2
g 3
h 5

c 2
c 2
d 5

a 3
2
d 1
e 5
f 2
g 3
h 4
i 5

10. a. -5
b. -3
c. -2
d. -1
e. 0
f. +2
g +3
h +4
i +5

11 a 5
b 3
c 2
d +3
e +5

a 5
b 3
c 2
d 3
e +5

a [illegible]
b 4
c 2
d 1
e 5

a 5
b 1
c 2
d 3
e 5

5
5
5

b 3
c 2
d 3
e 5

b 3
c 2
d 2
e 5

18. a. +5
b. -5

19. a. 1
b +2

20 a +5
b 5

21 a +5
b 5

a 5
b 4
c 3
d +2
e +3
f +4
g +5
h +5

[illegible]

[illegible]

[illegible]

+5
b +3
c 1
d 3
e 5

5

5
5

Explanation of the Audit Questions

1. Exterior Construction

This is an example of a difference which will affect your total energy use, but about which you can economically do little or nothing in an existing home. Stone, cinder block, and brick, contrary to common belief, are not good insulators. The usefulness of any material as an insulator is described by its R-value, which is a numerical index of its resistance to heat passing through it. The greater the R-value of a material, the greater its thermal insulating capability. The R-value of some common building materials are:

4-inch stone: 0.80
8 inch concrete block: 1.70
4-inch brick: .80
Wood: .94
Aluminum: Almost zero. Aluminum [illegible] conductor of heat
Fiberglass batting: 3.71 per inch. This means that 1 inch of fiberglass (which comes in four or six inch thickness) has the same insulating capacity as 4½ inches of stone or brick. So 4 inches of fiberglass in your walls will provide the same insulating capacity as 18 inches of stone or brick. These facts should be kept in mind during new home construction.

[illegible]

[illegible] wall [illegible]
[illegible] heat away [illegible]

[illegible] Color

[illegible]

[illegible]

[illegible]

[illegible]

8. **Heating System Maintenance**

Heating systems should be cleaned and serviced annually to avoid costly breakdowns and maintain efficiency.

9. & 10 Inside Temperature in Summer

Excessively cool summer temperatures are obviously costly (both in energy and money) to maintain

11 **Storm Windows**

All windows should have storm [illegible] should [illegible] investments in storm windows will save enough energy to pay for themselves in [illegible] to 3 years in many areas

[illegible] Storm Doors

Storm doors [illegible] of the exterior walls. For example, [illegible] R value of [illegible] exterior walls consisting of drywall, 4 inches of insulation and wood siding will have an R value of at least 15. Storm doors will significantly increase the R value of [illegible] door, while closing out chilling drafts which might enter around the door. Energy savings from the installation of storm doors will eventually pay for the door

Weatherstripping

[illegible] present of [illegible] average home. Weatherstripping [illegible]

[illegible] Windows

[illegible] sources [illegible] These should [illegible]

[illegible]

Relative Humidity

relative humidity [illegible] plants [illegible] allowing [illegible] proper relative humidity [illegible] relative humidity will also [illegible]

[illegible]

[illegible]

17. **Shade**

Shading, obviously, will keep your home cooler in the summer. Trees will also serve as wind breaks in winter.

18. Attic or Crawl Space

An unheated attic acts as insulating air space between your ceiling and the outside. There should be at least 6 inches of insulation above your ceiling.

19. Permanent Attic Flooring

Permanent flooring in an unheated attic makes it difficult [illegible] to determine if insulation exists under the floor. In such a case, the attic ceiling may be insulated instead.

21 Attic Ventilation

[illegible] attic ventilat[illegible] This lightens the load on your [illegible] and [illegible] energy costs.

23 Attic Insulation

[illegible] glass fiber, rock wool [illegible] insulation [illegible] attic, the better the insulating factor.

[illegible]

[illegible]
[illegible]

[illegible]

[illegible]
[illegible]
temperature [illegible]
to insulate [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

28. Crawl Space Ventilation

Crawl spaces should be adequately ventilated, allowing the free passage of outside air. This will also help to remove moisture.

29. & 30. Fireplaces

The modern home fireplace in operation may produce an overall heat *loss* to the home. Heated room air may escape up the chimney at a faster rate than the heat from the fireplace enters the room. Several heat pipe devices are available to increase fireplace efficiency. In any case, glass fireplace doors and a closable flue will help eliminate excessive heat loss.

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WHERE TO WRITE FOR MORE INFORMATION

In Pennsylvania:

Carnegie Mellon Institute
4400 Fobres Avenue
Pittsburgh, PA 15213

Coal Mining Institute of America
416 Ash Street
California, PA 15419

Energy Conservation Research
9 Birch Road
Malvern, PA 19335

The Franklin Institute
20th Street and Benjamin Franklin Parkway
Philadelphia, PA 19103

The Governor's Energy Council
State Street Building
6th Floor
Harrisburg, PA 17120

Gulf Oil Corporation
Gulf Building
Pittsburgh, PA 15730

Keystone Bituminous Coal Association
660 Boas Street
Harrisburg, PA 17101

Pennsylvania Department of Commerce
Fourth Floor - South Office Building
Harrisburg, PA 17120

Pennsylvania Department of
Environmental Resources
Evangelical Press Building
3rd and Reily Streets
Harrisburg, PA 17105

Pennsylvania Electric Association
800 North Third Street
Harrisburg, PA 17101

Philadelphia Electric Company
2301 Market Street
Box 8699
Philadelphia, PA 19103

Pennsylvania Environmental Council
225 South 15th Street
Philadelphia, PA 19102

Pennsylvania Gas Association
State Street Building
Harrisburg, PA 17101

Pennsylvania Power and Light Company
Information Center
Two North Ninth Street
Allentown, PA 18101

Philadelphia Gas Works
1518 Walnut Street
Philadelphia, PA 19102

Solanco
Box 64
Quarryville, PA 17566

U.S. Environmental Protection
Agency, Region III
Curtis Building
6th and Walnut Streets
Philadelphia, PA 19106

Elsewhere in the U. S.

American Enterprise Institute
National Energy Project
1150 7th Street, N.W.
Washington, D.C. 20036

American Gas Association
1515 Wilson Boulevard
Arlington, VA 22209

American Nuclear Society
244 East Ogden Avenue
Hinsdlae, IL 60521

American Petroleum Institute
1801 K. Street, N.W.
Washington, D.C. 20006

Atomic Industrial Forum, Inc.
475 Park Avenue South
New York, NY 10016

Center for Energy Information
340 East 51st Street
New York, NY 10022

Center for Environmental Education
1621 Connecticut Avenue, N.W.
Washington, D.C. 20009

Conservation Foundations
1250 Connecticut Avenue, N.W.
Washington, D.C. 20036

Consumer Action Now
317 Pennsylvania Avenue, S.E.
Washington, D.C. 20036

Consumer Federation of America
Energy Policy Task Force
1012 14th Street, N.W.
Suite 901
Washington, D.C. 20005

Council on Environmental Quality
721 Jackson Place, N.W.
Washington, D.C. 20006

Critical Mass Energy Project
Box 1538
Washington, D.C. 20013

Edison Electric Institute
1140 Connecticut Avenue, N.W.
Washington, D.C. 20036

Energy 80
Enterprise for Education
10960 Wilshire Boulevard
Suite 2134
Los Angeles, CA 90024

Environmental Action Foundation, Inc.
DuPont Circle Building
Room 720
Washington, D.C. 20036

Environmental Defense Fund
1525 18th Street, N.W.
Washington, D.C. 20036

Environmental Policy Center
317 Pennsylvania Avenue, S.E.
Washington, D.C. 20003

Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Exxon Corporation
1251 Avenue of the Americas
New York, NY 10020

Federal Energy Administration
12th and Pennsylvania Avenue, N.W.
Washington, D.C. 20461

Federal Power Commission
825 North Capitol Street
Washington, D.C. 20426

Ford Foundation
Energy Policy Project
Box 23212
Washington, D.C. 20024

Friends of the Earth
620 C Street, S.C.
Washington, D.C. 20003

International Solar Energy Society
12441 Parklin Drive
Rockville, MD 20852

League of Women Voters of the U.S.
1730 M Street, N.W.
Washington, D.C. 20036

Mobil Oil Company
150 East 42nd Street
New York, NY 10017

National Academy of Science
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

National Association of Electric Companies
1140 Connecticut Avenue, N.W.
Washington, D.C. 20036

National Audubon Society
950 Third Avenue
New York, NY 10022

National Coal Association
1130 17th Street, N.W.
Washington, D.C. 20036

National Petroleum Council
1625 K Street, N.W.
Washington, D.C. 20006

National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Natural Resources Defense Council
917 15th Street, N.W.
Washington, D.C. 20005

Resources for the Future
1755 Massachusetts Avenue, N.W.
Washington, D.C. 20036

Senate Committee on Energy
and Natural Resources
3106 Dirksen Senate Office Building
Washington, D.C. 20510

Sierra Club
1050 Mills Tower
220 Buch Street
San Francisco, CA 94104

Solar Action
1028 Connecticut Avenue
Suite 1100
Washington, D.C. 20036

Solar Energy Institute
1001 Connecticut Avenue, N.W.
Suite 632
Washington, D.C. 20036

U. S. Department of Commerce
Washington, D.C. 20230

U. S. Department of Energy
Washington, D.C. 20434

U. S. Department of the Interior
18th and C Streets, N. W.
Washington, D.C. 20240

U. S. Department of the Interior
Bureau of Mines
Washington, D.C. 20241

U. S. Department of Transportation
200 7th Street, S.W.
Washington, D.C. 20590

U. S. House of Representatives
Committee on Science and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

FOR FURTHER STUDY

Alternative Sources of Energy, The Seabury Press, 815 Second Ave., New York, NY 10017.

Consider the Process of Living, W. H. Eddy, Jr. et. al., Conservation Foundation, 1717 Massachusetts Ave., NW, Washington, DC 20036.

Critical Mass: Alternative to Energy Famine, Jacque Srouji, Aurora Publishers, Inc., 118 Seventeenth Ave. South, Nashville, TN 37203.

Direct Use of the Sun's Energy, F. Daniels, Ballantine Books, 201 East 50th St., New York, NY 10022.

Economics of Energy, L. E. Grayson, Darwin Press, Inc., Box 2202, Princeton, NJ 08540.

Energy, Ecology, Economy, Gerald Garvey, W. W. Norton & Co., Inc., 500 Fifth Ave., New York, NY 10036.

Energy for Survival: The Alternative to Extinction, W. Clark, Anchor Press, 245 Park Ave., New York, NY 10017.

Energy from Coal, Tetra Tech, Inc., Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Energy from Source to Use, Edited by Howard S. Stoker, Scott, Foresman & Co., 11310 Gemini Lane, Dallas, TX 75229.

The Energy-Saving Guidebook, George S. Springer, Technomic Publishing Co., Inc., 265 Post Road West, Westport, CT 06880.

Energy: Use, Conservation, and Supply, AAAS Publication Sales, Dept. Q, 1515 Massachusetts Ave., NW, Washington, DC 20005.

Hidden Waste: Potentials for Energy Conservation, D. B. Large, Conservation Foundation, 1717 Massachusetts Ave., NW, Washington, DC 20036.

The National Energy Act, Department of Energy, Office of Public Affairs, Washington, DC 20585.

The National Energy Plan, U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830.

Nuclear Power: The Unviable Option, John Berger, Ramparts Press, Palo Alto, CA 94303.

Oil from Prospect to Pipeline, Robert R. Wheeler and Maurine Whited, Gulf Publishing Co., 3301 Allen Parkway, Houston, TX 77001.

FREE 16mm FILMS

General Energy Topics

Challenge of the Future
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

We are entering a new age when energy will be more expensive and less abundant. This film's purpose is to look at the problem and detail the options that face the nation.

Energy
American Gas Association, 1515 Wilson Blvd., Arlington, VA 22209

This film traces energy sources from the first primitive fires through the fossil fuel era to atomic energy, outlines problems, and proposes possible solutions. For environmental uses, it is a good throught provoker.

Energy: The American Experience
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film's purpose is to show the development of different forms of energy under the unique conditions of the American experience. We see the sixty-year changing cycles of energy sources from wood to coal to oil and gas.

Electricity

World Behind your Light Switch
U.S. Department of Energy, Bonneville Power Administration, P. O. Box 3621, Portland, OR 97208

This film tells in a general way the story of how electricity is produced, transmitted, and distributed.

Ecology

No Turning Back
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film visits some of the technicians involved in government studies at laboratories and sites across the country, such as arid land ecology, a tropical forest study, river ecosystems, industrial impact on natural waterways, and pollution patterns in layers of atmosphere.

Economics

Don't Cut Us Off
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film documents the activities of four communities to solve a common national problem—the high cost of energy as it affects the poor and elderly across the country.

Energy, Economics, Environment
Modern Talking Picture Service, Inc., 2323 New Hyde Park Road, New Hyde Park, NY 11040

This film shows the interrelationship among energy, economics, and the environment. The problems are shared and solutions must come from mutual endeavors.

Coal

Coal Connection
Utah Power and Light Co., 1407 West North Temple St., Salt Lake City, UT 84110

This film documents electrical generation methods with emphasis on coal as a primary fuel. It shows how generated heat is used to produce steam to spin turbines.

Coal–the Other Energy
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film reviews the technologies now available to permit coal to be burned more cleanly and efficiently with concern for the environment where it is mined and used.

Energy vs. Ecology
Modern Talking Picture Service, Inc., 2323 New Hyde Park Rd., New Hyde Park, NY 11040

Coal is the most abundant source of energy in this country. This film indicates how we can utilize this valuable source without disrupting our environment.

Oil, Gas, and Hydroelectricity

Focus on Energy
American Gas Association, 1515 Wilson Blvd., Arlington, VA 22209

This film reviews our dependence on energy with an emphasis on natural gas. It describes possible solutions to the current supply problem.

Offshore: The Search for Oil and Gas
Modern Talking Picture Service, Inc., 2323 New Hyde Park Rd., New Hyde Park, NY 11040

Before the end of this century, more than half of the world's petroleum supply will hve to come from the oceans. This film tells of the intensive search and the painstaking effort to preserve the ocean environment.

Reserved for Tomorrow
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film shows the sites in Louisiana and Texas where the United States will store one billion barrels of crude oil in underground salt domes by 1985.

Water
Modern Talking Picture Service, Inc., 2323 New Hyde Park Rd., New Hyde Park, NY 11040

This film explores both the aesthetic and practical use of water. It covers the hydroelectric cycle, water chemistry, pollution, irrigation, conservation, and industrial and domestic use of water.

Nuclear Power

Introducing Atoms and Nuclear Energy
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film introduces atomic structure and explains how energy is released from a nucleus. It defines basic terms and demonstrates uses of nuclear energy.

Now that the Dinosaurs are Gone
Atomic Industrial Forum, 7101 Wisconsin Ave., Washington, DC 20014

This film presents the story of nuclear energy as the next step in man's use of resources. In non-technical language, it answers basic questions often asked about nuclear energy.

Nuclear Power and the Perry Environment
NUS Corporation, 4 Research Place, Rockville, MD 20850

This film is a documentary of environmental issues regarding nuclear plants. The emphasis is on nuclear plant siting.

A Sea We Cannot See
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

Almost everything in nature can be seen or felt–wind, light, cold, texture–that is everything except radiation. This is the sea we cannot see.

Energy Policy

Energy–A Family Album
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

A brief history of energy in America is followed with some details of the nation's plan to keep ahead of energy demands, alternative sources of fuel, geothermal, and solar power.

Energy Update
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

With the President's energy message of April 19, 1977, as a backdrop, the film describes a number of situations in which people try to cope with energy problems and seek solutions now. The film touches on coal, solar, nuclear, and other energy sources.

Conservation

Conservation–Investing in Tomorrow
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film shows some of the ways we can save energy now: more efficient machines and industrial processes, improving the transmission of electric power, new autos, making homes and buildings energy efficient.

John Denver on Conservation
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

The internationally-known singing star John Denver appears in this short film, shot entirely on location in Colorado and California. The film showcases a portion of Mr. Denver's "Red Rock" outdoor concert coupled with a personal message from Denver on behalf of energy conservation.

Running on Empty–The Fuel Economy Challenge
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

Through citizen participation over a 90-mile road rally, the film illustrates various driving and fuel economy techniques. It shows how average drivers, driving average cars, can practice ways to achieve maximum savings in gasoline and money while traveling city streets, country roads, and major highways.

Up the Power Curve
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film shows the practicality of energy conservation. It covers a wide range of energy saving ideas and the dollar savings to be achieved from each.

Alternative Energy Sources

Coal–Taking the Lumps Out
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

This film shows the research that is underway to convert coal to liquid or gaseous fuels at affordable prices.

Geothermal–Nature's Boiler
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

Natural heat energy stored in and under the earth's crust can be put to work just as the Geysers now supply half the electricity for San Francisco's needs. These resources may heat, cool, and light homes and factories across the country.

Here Comes the Sun
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

In this film solar systems are shown on the roofs and on the ground working in four states. Collectors warm the air and water for swimming pools, dishwashers, and storage tanks.

Power from the Earth
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

We need new sources of electrical power. In this film, scientists, engineers, and managers explain the various problems of obtaining thermal energy from the earth.

Putting the Sun to Work
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

Three leading solar experts explain the current schemes for harnessing solar power. Emphasis is on home and industrial usage.

Struggle for Power
Modern Talking Picture Service, Inc., Catepillar Film Library, 1687 Elmhurst Road, Elk Grove Village, IL 60007

This film documents what is being done to supplement dwindling fossil fuel supplies. It covers shale oil extraction and coal gasification processes.

Tidal Power
Department of Army, New England Division, Corps of Engineers, 424 Trapelo Road, Waltham, MA 02154

This film documents a study made by the U.S. and Canada on the economic feasibility of harnessing tidal power for electrical energy. It includes a tour of project sites.

To Bottle the Sun
Department of Energy Film Library, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830

The fusing of atoms releases large amounts of energy. In this short film, two scientists explain the fusion process in the attempt to generate electricity.

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FREE BOOKLETS TO SEND FOR

The following are available in single copies or classroom quantities from the U.S. Department of Energy, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830.

General Energy Topics

Energy in Focus: Basic Data

Statistics on U.S. energy production, imports, consumption, and prices that reflect energy situations over the past quarter century. Essential background for an understanding of the trends that have led to the current status of energy supplies.

Energy History of the United States 1776-1976

3 x 4 foot color chart and user's manual.

Energy Technology

Describes the research needed to locate, recover, develop, store, and distribute various energy forms in a clean, convenient, and economical way.

Oil and Gas

Enhanced Recovery of Oil and Gas

Discusses the potential contributions of enhanced recovery to increasing our energy supply and explains some of the methods, including the use of water, steam, chemicals, and combustion.

Oil

Basic information about the use of oil to provide power and the developments in technology that will be needed to use it more effectively for the benefit of mankind.

Oil

Explains how oil is produced, transported, and used.

Nuclear Power

The First Reactor

Dramatic story of the first controlled nuclear chain reaction.

Inner Space: The Structure of the Atom

History and present-day knowledge of the principles and concepts of atomic structure.

Nuclear Energy

Tells how nuclear energy generates electricity.

Nuclear Power Plant Safety

Describes the three levels of safety incorporated into the design of reactors.

Safeguarding of Nuclear Materials

Describes the basic components of the nuclear system, including facility protection and inventory control.

Shipping of Nuclear Wastes

Tells how radioactive wastes are packaged and transported, including the safety precautions employed.

Energy Policy

The National Energy Plan

The plan submitted to Congress in April 1977 for energy management, production, research, pricing, and conservation into the mid-1980's.

Conservation

Gas Mileage Guide for New Car Buyers

Lists the estimated fuel economy potential of 1978 cars and light-duty trucks and the engine combustion designs that meet emission standards of all states.

How to Save Money by Insulating your Home

Clearly illustrated instructions for insulating home walls, windows, doors, and attics.

How to Understand your Utility Bill

Popular guide to reading electric and gas meters and checking utility bills, so that householders may know how much energy they use and how effectively they conseve it.

Sixty-five Ways to Save Natural Gas

Offers money-saving methods to save natural gas in homes.

Tips for Energy Savers

Offers practical and simple ways to save energy in the kitchen, workshop, garden, and car. Includes energy-saving considerations when buying appliances and other household merchandise. (A Spanish language edition is also available.)

Tips for the Motorist: Don't Be Fuelish

Lists 30 ways to make gasoline go further, ranging from tips on improving driving skills to car maintenance checkpoints.

Alternative Energy Sources

Fuel Cells: A New Kind of Power Plant

Explains how fuel cells produce electricity, and features experimental demonstrations for utilities.

Fuels from Biomass

How biomass (vegetation, animal wastes, etc.) can be processed to produce methane gas or fuel oil.

Fusion

Explains a process, similar to that by which the sun generates energy, that could be used for future electrical energy production.

Ocean Thermal Energy Conversion

How the difference in temperature between warm surface water and cooler water beneath the sea is used to generate power.

Solar Electricity from Photovoltaic Conversion

Tells how solar cells, composed of silicon and similar materials, are used to generate electricity directly from the sun's rays.

Solar Energy

Basic information about the use of solar energy to provide electrical power and the developments in technology that will be needed to use it more effectively for the benefit of mankind.

Solar Energy for Heating and Cooling

Describes how solar heating and cooling systems operate, and tells how solar energy can be used as an alternative energy source.

OTHER FREE MATERIALS FOR TEACHERS

From American Petroleum Institute, 1801 K Street NW, Washington, DC 20006. **Looking for Energy? A Guide to Information Resources**

From National Coal Association, Coal Building, 1130 Seventeenth St., NW, Washington, DC 20036. A bibliography of publications on coal.

From National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC 20009. **Energy and Education**, a bi-monthly newsletter, gives information on educational materials, workshops, and up-to-date topics related to energy and education.

From Sea Grant Communications Office, 1800 University Ave., Madison, WI 53706. **The Household Energy Game**, a game designed to experience budgeting energy in the home.

From Standard Oil Company, Public Affairs, MC 3705, P. O. Box 5910-A, Chicago, IL 60680. **Amoco Teaching Aids**, describes films, low-cost teacher aids, and free teacher materials.

From Mr. David O. Schantz, Charles Edison Fund, 101 South Harrison St., East Orange, NJ 07018. Teacher's Aid Kit contains 10 booklets, mainly experiments and projects relating to various aspects of energy.

All of the following are available from U.S. Department of Energy, Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830.

Award Winning Energy Education Activities for Elementary and High School Teachers. Contains brief descriptions of prizewinning entries in the National Science Teachers Association Teacher Participation Contest conducted in 1976. The contest sought ideas that would fit easily into standard (science and nonscience) courses of study at various grade levels to further student understanding of important energy issues.

Energy Conservation in the Home: An Energy Education/Conservation Curriculum Guide for Home Economics Teachers. This resource book will help home economics students conserve energy in their homes and lives.

Energy History of the United States. Charts the growth of Amercian energy use and traces the history of the major sources of energy (coal, wood, and oil) in the United States.

How a Bill Becomes Law to Conserve Energy. Study units include "Case Study of a Bill," which describes how the 55 mph national speed limit became a law and takes the student through the lawmaking process; and "A Congressional Hearing," in which students play typical roles at a hearing on a national speed limit bill in a simulation game. (See also **U.S. Energy Policy–Which Direction?**)

Mathematics in Energy. This packet is designed to infuse energy concepts into junior high math classes. The unit deals with a wide range of energy math including conversions, statistics, and the manipulation of energy units.

Organizing School Energy Contests. Outlines procedures for conducting school and community energy projects from the planning state to issuing publicity and presenting awards for winning entries.

U.S. Energy Policy–Which Direction? This unit, which is a companion to **How a Bill Becomes Law to Conserve Energy**, concentrates on the Executive Branch of the Government and the various forces that go into making energy policy.

Fact Sheets on Alternative Energy Sources, a series of 19 fact sheets on various alternative energy sources.

Energy Films Catalog, describes more than 190 motion pictures that are available for free loan.

GLOSSARY

Acid Precipitation	Acidic rainfall caused by the oxides of nitrogen or sulfur present in the atmosphere as pollutants being removed by rainfall.
Alpha Radiation	A flow of positively charged particles (alpha particles) emitted by certain radioactive materials. Identical with the nucleus of a helium atom.
Anthracite	"Hard" coal, which contains the highest carbon content. It is easy to handle, burns cleanly, and contains little sulfur.
Barrel	A liquid measure. A barrel of oil contains 42 gallons.
Beta Radiation	An elementary particle emitted from the nucleus of an atom in one type of radioactive decay. Identical to the electron.
Biomass	Plant material in any form usable for fuel.
Bituminous	"Soft" coal. The coal stage between lignite and anthracite. Has an energy content 25% lower than anthracite. Often has a high sulfur content.
Boiling Water Reactor	A nuclear reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam can be used directly to drive a turbine.
Breeder Reactor	A special type of nuclear reactor in which the core is surrounded by a blanket of fertile material (uranium - 238 or thorium 233). The fertile blanket captures neutrons and decays into fissile fuel material. Breeder reactors could extend our nuclear fuel supplies indefinitely.
BTU	The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. (British Therma Unit) Four BTU's equals about 1 calorie.
Calorie	The heat required to raise the temperature of 1 gram of water one degree Celsius. The [illegible]lorie (note upper case C) is called the kilocalorie and is equal to 1000 calories. One Calorie is about 4 BTU.
Cartel	A worldwide monoply.

Chemical Energy	The energy released in chemical reactions due to the position of electrons.
Coal	Carboniferous remains of dead plant material. Coal is America's most abundant domestic fossil fuel resource. The basic composition of coal is carbon, hydrogen, oxygen, nitrogen and sulfur.
Coal Gasification	The production of a gaseous fuel from coal.
Cogeneration	The double use of high energy steam. The steam is used to produce electricity, then the lower energy steam is used for industrial processes.
Combustion	The rapid oxidation (burning) of fuel or any other burnable substance.
Coolant	A substance circulated through a nuclear reactor to remove or transfer heat, some collants are water, heavy water and air.
Decontrol	Removal of governmental controls of prices.
Deuterium	A heavy isotope of hydrogen in which the nucleus consists of a proton and a neutron, giving it an atomic weight of 2.
Electromagnetic Energy	The production of electromognetic waves which radiate from a source at the velocity of light. Produced by electrically charged particles moving in magnetic fields.
Electron	An elementary subatomic particle with a unit negative charge and a mass of 1/1837 that of the proton. Electrons surround the positively charged nucleus and determine the chemical properties of the atom.
Energy	The ability to do work (the movement of matter from one point to another).
Fertile Material	A material, not itself fissionable by thermal neutrons, which can be converted into a fissionable material by irradiation in a reactor. There are two basic fertile materials, uranium - 238 and throium - 232, which can be converted into plutonium - 239 and uranium - 233, respectively.
Fission	The splitting of a large atomic nucleus into two or more smaller nuclei. Large amounts of energy are released in this process.

Fluidized Bed Combustion	A method of burning coal with a low release of sulfur. Particles of coal and limestone are suspended in a stream of air directed upward through a very hot bed of ash and limestone. As the coal burns the sulfur in the coal combines with the calcium in the limestone. The calcium sulfide is removed with the ash.
Fossil Fuel	Any fuel derived from the remains of once living organisms. Examples are coal, oil and natural gas.
Fuel Cell	A device in which chemical energy is converted directly into electrical energy without the combustion step necessary in the steam generator.
Fusion	The formation of a heavier nucleus from two lighter nuclei, with the attendant release of energy.
Gamma Ray	High energy, short wave electromagnetic radiation originating in the nucleus. Similar to x-rays.
Gas Cooled Reactor	A nuclear reactor which uses a gas (possibly air) to remove excess heat.
Gasohol	Gasoline with up to 20% ethyl or methy alcohol as an extender.
Gasoline	A petroleum component used extensively as a motor fuel.
Geothermal Power	The use of the earth's interior heat in volcanic regions or near geologic faults to produce steam for electricity.
Gravitational Energy	A form of potential energy due to position.
Greenhouse Effect	The retention of the sun's heat by the water vapor and carbon dioxide of the earth's atmosphere.
Heat Energy	The energy of the motion of molecules.
Hydroelectricity	Electricity produced by allowing stored water to fall, turning turbines. High head hydro consists of allowing a small amount of water to fall a great distance; in low-head hydro a large volume of water is made to fall for a short distance.
Ionization	The process of removing or adding electrons to atoms or molecules, thereby producing charged (ionized) particles.
Ionizing Radiation	Any radiation capable of displacing electrons from atoms or molecules. Examples: alpha, beta, gamma radiation, ultraviolet light. May produce severe skin or tissue damage.

Kerogen	The petroleum-like substance found in oil shale.
Kerosine	A petroleum component used for lamps and other fuel use. Kerosine is less volatile and does not burn as violently as gasoline.
Kilowatt	One thousand watts.
Kinetic Energy	The energy of motion.
Light Water Reactor	A nuclear reactor which uses regular water as a coolant and moderator.
Magnetohydrodynamics	A method of extraciting electricity twice from a hot gas.
Maximum Permissible Exposure	That dose of ionizing radiation established as an amount below which no reasonable expectation of risk to human health occurs. Presently 5 RE per year. The lifetime dose = (N - 18) x 5 Where N = age in years.
Mechanical Energy	The form of energy acquired or released by moving objects.
Megawatt	1,000 watts
Methane	A natural gas produced by the decay of organic material. May be used as a fuel.
Millirem	1/1000 of a REM.
Moderator	A material such as ordinary water, heavy water or graphite, used in a reactor to slow down high speed neutrons, this increasing the likelihood of further fission.
Monoply	The sole seller of any good or commodity.
Neutron	An unchanged neutral subatomic particle with a mass slightly greater than that of the proton.
Nuclear Energy	The energy released in nuclear reactions such as fission or fusion.
Ocean Thermal Power	Also called Ocean Thermal Energy Conversion (OTEC). A device designed to use temperature differences at the surface and depths of the ocean to produce electricity. Most efficient in the tropics.

Oil Refining	The separation of crude oil into its various components by fractional distillation. Some components are gasoline, kerosine, fuel oil, light oils and heavy oils.
Oil Shale	A finely textured rock which contains a tarlike substance called kerogen. The kerogen can be driven off by heating, and then refined into petroleum fuels and other products.
OPEC	Acronym for the Organization of Petroleum Exporting Countries, an internation cartel which controls most of the world's oil.
Peat	Essentially an accumulation of dead plants in the early stages of decomposition. Peat is usually formed in swamps and bogs where the dead vegetation is covered with water, which blocks bacterial action, slowing the rate of decay. Thus, most of the carbon is retained.
Person REM	A theoretical measure of the exposure received by the entire population. Person Rem = Dose in REM's x No. of Persons.
Petroleum	Naturally occurring compounds of carbon and hydrogen formed from the remains of minute marine animals and plants which died and settled at the bottom of ancient seas where it was covered with silt. Various forces converted this material to petroleum and natural gas.
Photosynthesis	A process whereby green plants store the sun's energy in chemical compounds such as sugars.
Plutonium	A heavy, radioactive, man-made metallic element with atomic number 94. Plutonium - 239 is fissionable and is suitable for use in reactors or weapons.
Pnenmoconiosis	"Black Lung" disease of coal miners, characterized by the development of fibrous masses in the lung following years of exposure to coal dust.
Potential Energy	Stored energy due to position or condition.
Power	The amount of energy used or produced in a given amount of time. The watt is defined as .00948 BTU per second.
Pyrolysis	Removal of tars and other impurities from biomass by heating in the absence of air.
Quad	A measure of energy equal to 1 x 10^{15} BTU.

R-Value	A numerical comparison of the insulating value of various materials.
RAD	Acronym for radiation absorbed dose. The absorption of 100 ergs of radiation energy per gram of absorbing material.
Radiant Energy	Energy which radiates through space from a central point.
Radioactive Waste	Equipment and materials from nuclear operations which are radioactive and for which there is no further use. May be high-level or low-level wastes.
Radionuclide	Any radioactive isotope.
Reactor	A device designed to contain the nuclear fission reaction and to extract usable heat from the reaction. This heat is used to convert water to steam. The steam is used to turn turbines to produce electricity.
REM	Acronym of roentgen equivalent man. The unit dose of any radiation which produces the same biological effict as the unit of absorbed dose of x-rays.
Respiration	The opposite process to photosynthesis, whereby living cells release usable energy by the controlled oxidation of carbohydrates.
Rock Oil	Petroleum
Roentgen	A unit of exposure to ionizing radiation.
Solar Energy	The use of the sun's rays.
Solvent Refining	A process used to remove chemical impurities from coal. Coal is dissolved in a light oil at high temperature and pressure. Ash and insoluble matter settle out and can be removed. Produces a brittle, shiny, tar-like solid which can be remelted and transported by pipeline.
Stack Gas Scrubber	A method of cleaning the gaseous emissions caused by burning fossil fuels. Limestone is brought into contact with the flue gas in a cleansing tank. Most of the sulfur is removed.
Tailings	Waste materials left from materials from a mine after the desired material has been removed.
Tar Sands	Sand particles coated with a tar called bitumen. The bitumen can be extracted and refined into petroleum fuels.
Tidal Power	The harnessing of tides to produce eletrical energy.

Tokamak	A Russian-invented device to produce and contain the plasma in a fusion reaction.
Uranium	A naturally occurring radioactive element with an atomic number of 92 and an average atomic weight of approximately 238. The two principle isotopes are uranium - 235 (0.7% of natural uranium), which is fissionable, and uranium - 239 (99.3% of natural uranium) which is fertile.
Wave Power	Devices designed to convert the motion of ocean waves to rotary motion driving. The Japanese ship "Kaimei" was the first operational floating plant.
Windfall Profits	Excessive profits made by a company. Unexpected or unearned profits.
Windmill	A machine designed to convert the movement of the wind into rotary motion by means of rotating blades.