Energy

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Energy is Eternal Delight. WILLIAM BLAKE

$E=mc^2$. ALBERT EINSTEIN

Energy is Information. DISCOVERY OF THE SCIENTIFIC-TECHNICAL REVOLUTION

Energy can be defined technically as the capacity to do work or to transfer heat. There are many common manifestations and forms of energy around us that we all recognize, such as the sun, a TV picture, the lights in the street, a moving car, air conditioning, a warm fire, to mention a few. There are also latent or potential forms of stored energy that can be liberated under certain conditions, i.e. the water behind a dam, a lump of coal, a bottle of alcohol, an apple or a car battery. For the most part, the energy used on earth originated at the sun, and also some minor contributions from nuclear and geothermal sources. Most importantly, solar energy sustains all life and powers the biosphere, its ecosystems and climatic variations.

Natural Ecosystems

Less than one percent of the energy from the sun gets fixed or stored by the plants through photosynthesis; the rest is briefly held by the biosphere and then released by reradiation to space. The plants in turn convert carbon dioxide to form breathable oxygen and supply the animal with food energy. An increasing fraction of fixed solar energy in the form of plant food and fuels as coal, oil and gas is being diverted to support man and his needs.

Green plants are the primary "convertors" of solar energy fixing it in organic compounds to maintain themselves and indirectly other living organisms which consume the plants and further convert the energy to flesh and work. The plants trap the sun's energy to build molecular structures such as sugars, starches, proteins, fats and vitamins. On land these are grasses, leaves, berries and nuts; in water the vegetation is plankton and sea weed. The consumers are animals, birds, insects, people and fish. Some consumers are herbivores such as cows and grasshoppers, others are carnivores that consume only animal matter such as cats and sharks, and some species called omnivores such as humans, get their energy both ways eating plants and animal flesh.

The chemical energy available for life processing decreases through the food chain. The plant itself uses roughly half the energy that it fixes from the sun for its own respiration. An animal eating the plant dissipates ninety per cent of the energy to maintain its own metabolism and muscular activity leaving ten per cent for conversion to weight if it is growing. A carnivore eating the animal would likewise be inefficient in converting the food to body weight. The plant and animal matter that does not get consumed as food ultimately dies and is attacked by decay organisms which extract the remaining energy and return the basic minerals and gases back to the biosphere at essentially zero energy state. The components are eventually recycled however, in new plants and animals by the infusion of solar energy thereby perpetuating the cycle.

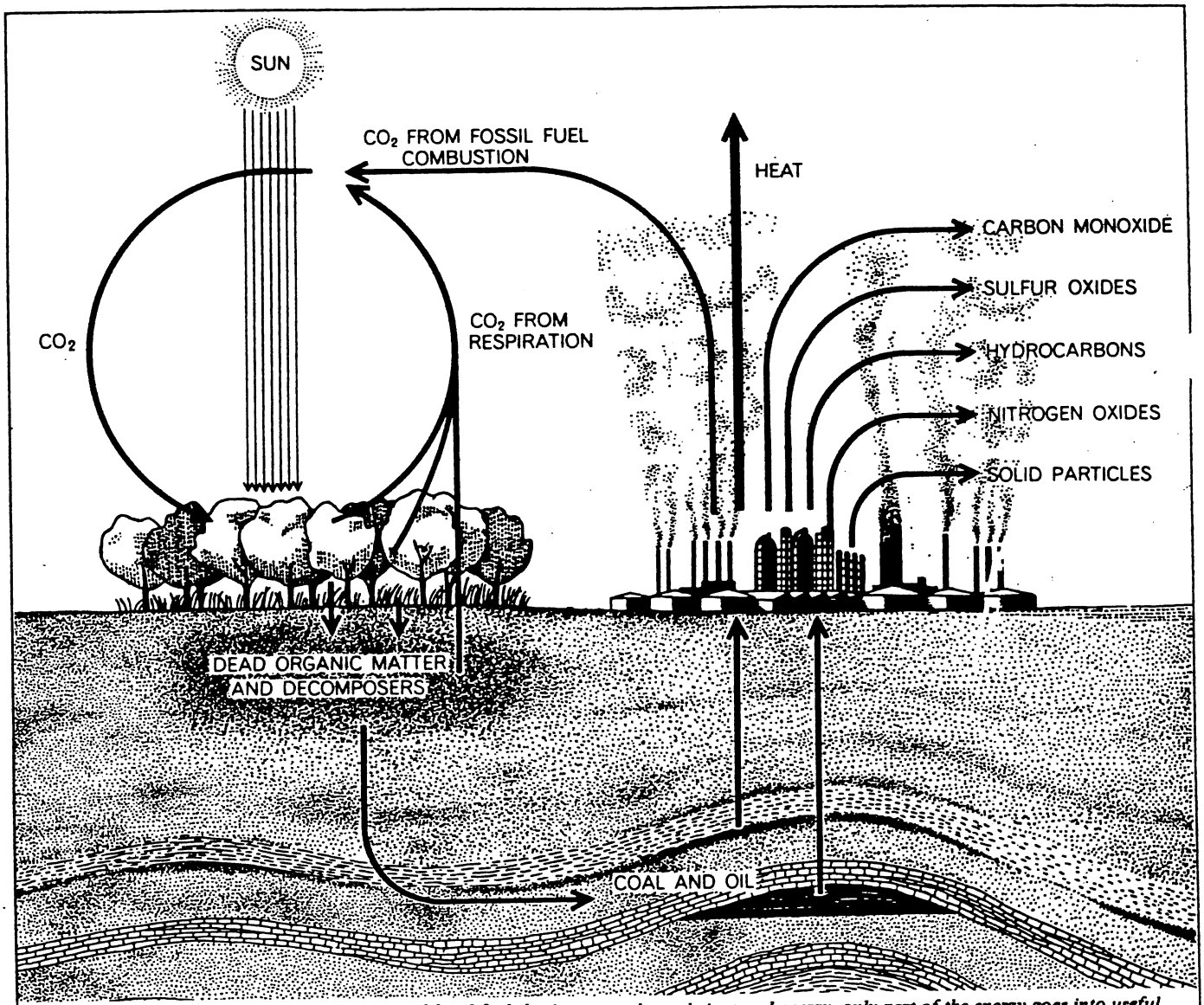
The natural ecosystems in the biosphere depend on the incident solar radiation which varies on the earth's surface because of the geometric planetary relationships and most importantly because of the local weather conditions which are in turn influenced by solar heating. Clouds, rain and humidity are due to water evaporation from the oceans, lakes and rivers. The 24 hour average of sunshine on the earth surface varies from 100 watts per square meter in the arctic regions to 250 watts per square meter in the tropics. Very little of the incident radiation gets diverted into the life-support processes of the biosphere, with only about a kilogram per square meter of dry organic matter being produced per year. The forests, which cover about a tenth of the earth surface, fix about

A loop prominence of the sun -- a result of strong magnetic fields. Sacramento Peak Observatory, 1979. Photograph courtesy of National Optical Astronomy Observatories, Tucson, Arizona.

half the energy; other land vegetation and the oceans convert most of the remaining energy. Lands cultivated by the human population fix about five per cent of the solar radiation, using an equivalent addition of energy from the fossil fuel reserves in the form of fertilizers and pesticides. The yield of agricultural lands can be increased many fold by the addition of external energy sources. Six to ten kilograms of plant growth per square meter is possible in the most productive agriculture with proper infusion of oil and gas for fertilizers, pesticides, irrigation and machinery.

Technological Man

Agriculture is but one area where modern man has intervened in the natural energy flow of the earth's ecosystems in order to maximize real time benefits in



ENERGY CYCLE involved in the combustion of fossil fuels begins with solar energy employed in photosynthesis millions of years ago. A small fraction of the plants is buried under conditions that prevent complete oxidation. The material undergoes chemical changes that transform it into coal, oil and other fuels. When they are burned to release their stored energy, only part of the energy goes into useful work. Much of the energy is returned to the atmosphere as heat, together with such by-products of combustion as carbon dioxide and water vapor. Other emissions in fossil fuel combustion are listed at right in the relative order of their volume.

terms of human well being and material goods. The human intelligence has learned that man is not constrained by the limits of his own body to convert energy to achieve his ends. Other converters of a biological nature such as animals and plants as well as mechanical devices of his own fashion can be used to accelerate and concentrate energy flow to produce food, clothing and shelter. Technological man's needs far exceed the basic biological requirements for subsistance. Human nature however, has not yet allowed for an equitable distribution of these material benefits which accounts for existing starvation and suffering in the world.

The amount of solar energy falling on the earth is immense and far exceeds man's ability to convert it; the amount of heat that falls on one-and-a-half square miles is equivalent to the 20 kiloton atom bomb dropped on Hiroshima. Man's ability to convert radiant energy however is very limited and requires a high initial investment. For the most part man depends on and has depended on plants and other natural earth systems such as hydro and wind to harness the power from the sun. Industrialized society today is very dependent on fossil fuels which originated by photosynthesis millions of years ago. This stored and compacted form of solar energy conveniently packaged for distribution around the globe is relatively cheap since there is no cost of conversion from the incident radiation, just drilling and pumping costs. However, the fact that it is exhaustible and not equitably distributed on the earth surface is responsible for much of the political unrest in the human world today. In addition, its concentrated form permits exaggerated and localized liberation of combustion products and heat which tax the biosphere's ability to absorb the products in the environment.

The massive conversion of energy by man has taken place in a relatively insignificant time period -- 100 years -- compared with the millions of years of life in the biosphere. It is inevitable to question if this accelerated release of energy might not, in fact, affect the life cycles themselves. At one time all human beings depended on organic energy produced by green plants for survival and well being. The primitive societies of the past and very few today live by means of food gathering and hunting which is completely in a harmonious, yet very vulnerable, coexistence with the natural cycles of the biosphere. Slightly more advanced energetically are the food cultivators which through agriculture grow their food and related by-products. Much of the world's population now is in this stage of early development with a very limited control over their own destinies. These low energy societies are to some extent self perpetuating inasmuch as a critical balance between the in and out flow of energy exists. The institutions and energy use patterns tend to be stagnant because a surplus of energy is required for change to occur. Modern technology for improved conversion cannot be easily introduced because the investments generated by the surplus are not available.

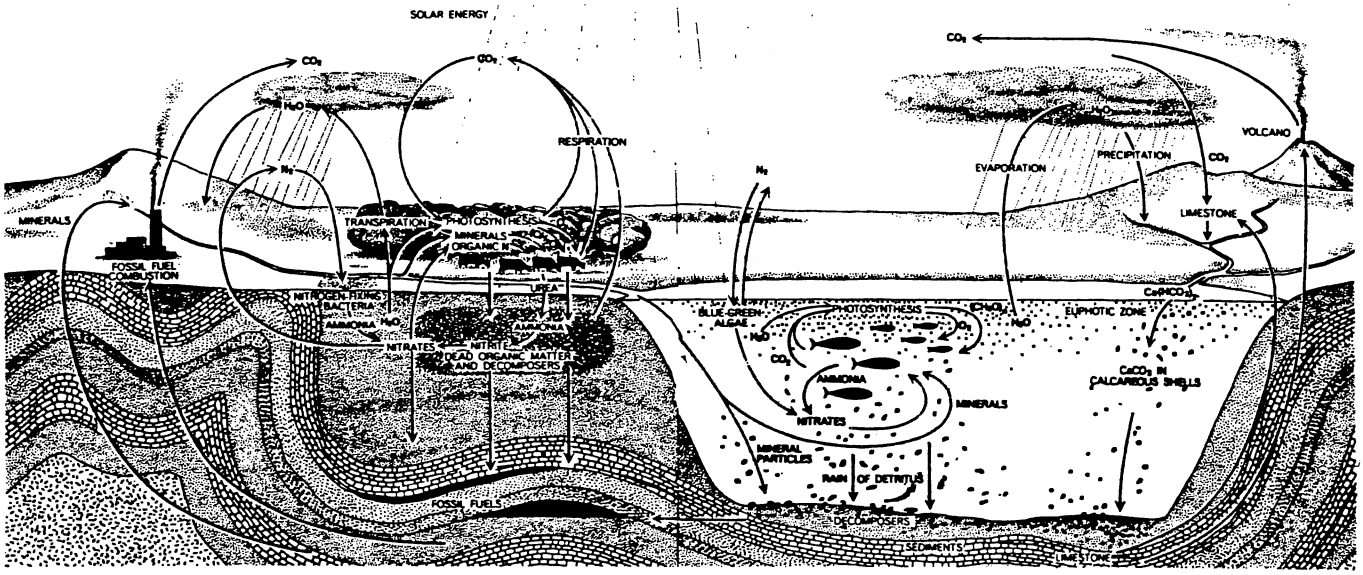
Energy Impact

The organization of the human species into economic and political units has been historically influenced by man's knowledge and capabilities to harness the energy available in the biosphere. In the last 100 years oil, gas and coal and the inventions of steam and combustion engines have greatly magnified human capabilities to construct buildings, transport man and materials and in general alter the environment. Modern man requires and utilizes orders of magnitude more energy for his external environment than he needs to keep alive. The accumulation of energy wealth and associated technology is the source of political and economic power which often results in serious world conflicts and divisions.

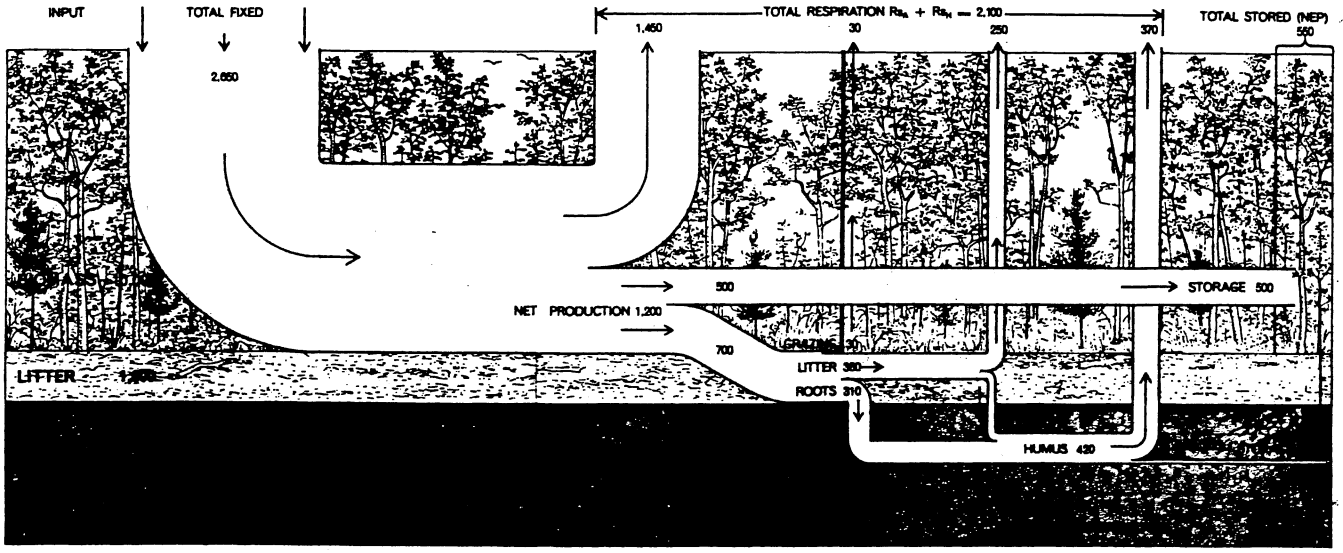
Before the era of fossil and nuclear fueled technology, the human race depended almost entirely on renewable solar energy. The lower level of energy availabilities, however, did not relieve the quest for individual accumulation or ameliorate the distribution of benefits. Animals and human slaves were used as energy convertors from Roman times until recently. Water power and wind were used to transport ships and grind grain. The sea powers of Europe dominated the world economically and politically. The new knowledge in using fossil and nuclear fuels has unleashed the industrial revolution and changed the economic institutions and organizations of man. The human condition has in general benefited and the limits and constraints of the biosphere have been expanded. Managed agriculture has increased the yield of crop production feeding a greater population; controlled and designed environments have provided for comfort and leisure regardless of the natural climatic conditions. Outer space beyond this biosphere is now accessible. The effects of this concentrated and localized release of energy and by-product pollution on the natural ecosystems are not clearly understood and remain a consideration for future generations to resolve. However, it is inevitable that the feedback systems of the biosphere will ultimately control our destiny.

Human Needs

The basic necessities of human life go far beyond the energy to supply food, and they include shelter, clothing, health care, transportation, communications, education, recreation, and security. Although only about 40% of the population on earth today enjoys all of these benefits, in 1900 only 1% of the society was so privileged. The availability of fossil fuels and related technology for



MAJOR CYCLES OF THE BIOSPHERE are indicated in a general way in this illustration. The operation of the biosphere depends on the utilization of solar energy for the photosynthetic reduction of carbon dioxide from the atmosphere to form organic compounds on the one hand and molecular oxygen on the other. The cycling of certain other vital elements is also indicated.



ENERGY RELATIONSHIPS were worked out for an oak-pine forest at the Brookhaven National Laboratory. Of the annual gross production of 2,650 grams of dry matter per square meter, some 2,100 grams are lost in respiration, leaving 550 stored as new plant growth, litter and humus. The animal population is not increasing appreciably. This is a "late successional" forest in which 80 percent of the production is expended in respiration.

Energy

conversion to useful products and services is primarily responsible for this growth in the standards of living. Energy consumption has grown from 11 to 83 trillion kilowatt hours since 1900. A major problem facing the world today is how to get enough energy to satisfy the 100% of the population with an equitable distribution of benefits yet minimize the disturbance of the natural biological systems of the biosphere.

The magnitude of the problem is made more acute when one considers how the population and its growth rate have grown in recent times. 250 million people were alive during the time of Christ. By 1650, the population increased to 500 million and doubled again in 200 years, so that it was 1 billion by 1850. In 1930 the population doubled to 2 billion and then reached 4 billion by 1975. The doubling rate is now 35 years and programmed to double again early in the next century.

The complexity of the energy resource expansion problem is further aggravated by societies' dependence on non-renewable and finite reserves of oil, gas, coal and uranium. All estimates show that at current usage patterns these free stored energy sources will be depleted within the next century. To what extent these predictions are to become reality depends on the modifications that society can adopt in both the supply of energy and demand for its use.

The energy crisis and shortages of the seventies were just a prelude to a new era of necessary adjustment. The scarcity of supply has increased prices and motivated a significant improvement in efficiency of use through conservation. Consider that the overall energy consumption in the United States has not changed in the ten year period from 1973 to 1983. Although the available fossil fuel reserve has not changed radically, the perception of an energy crisis no longer exists; oil and gas energy supplies are now apparently more stable because of increased production and present political considerations. The motivations for improved efficiency in energy use have consequently diminished. The underlying issues of continued population growth, limited resources and environmental pollution have not changed for the long term, however, and must ultimately be dealt with.

The biosphere is an automated system which will function with or without the human intelligence. However, some sound and critical human thinking, vision and planning can make for a more harmonious integration of societies' needs within the natural systems of the biosphere yet provide adequate energy for man's needs both in the present and the future.

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