1976 Distinguished Teacher of the Year

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Energy and Mankind

We are all aware of the fact that the world's population increases at continually faster rates, and that more people on Earth will require more energy to keep their present standard of living. Moreover, this standard of living, which is ordinarily measured in economic terms, could well be measured in terms of energy consumption. In fact, the average energy demand per person for the world as a whole is approximately 3000 KWH per year. There are, however, wide differences in this demand from country to country. In the USA and parts of Western Europe it has reached 18000 KWH per person per year, whereas in India it is still around 300 KWH per person per year. Obviously, it will be the goal of the developing countries to raise their standard of living until the present disparities have been eliminated. This trend will cause the world energy demand to increase at rates that exceed the rates of increase of the human population.

Some concerned groups have been aware of this energy scenario for a few decades. However, it was not until 1973 that the general public became aware of our ever-mounting energy crisis through the "Arab Oil Embargo" and its more directly felt consequences, such as long lines at the gas stations and much higher utility rates brought by a quadrupling of imported oil prices. At this time, under pressure from their constituents, our legislators in Washington began a never-ending series of new laws concerning pollution control and energy consumption, all far too specific and which not only have not helped to improve the situation, but have rather aggravated it, since often one regulation works against the other. Part of the reason this has happened is that lawmakers are mostly lawyers and have employed legal reasonings in the structuring of their laws. Lawmakers should recognize that the essential difference between the laws of man and the laws of nature is the fact that the laws of man can be violated (subject to consequences), or they may be changed and modified, whereas the laws of nature not only cannot be violated, but also stand unmodifiable and unchangeable. Thus, what our lawmakers should do is define the goals we wish to achieve and let engineers and scientists choose the methods to achieve them.

Before we can attempt to formulate possible solutions to the problem at hand, we should understand the laws of nature that are concerned with the generation of mechanical energy. In economics, a poor man's dollar purchases exactly the same amount of goods as a rich man's dollar; that is, there is no such thing as quality of money. However, in engineering thermodynamics a curious paradox exists in that one BTU of energy at 1000^0F of temperature can be converted into 0.7 BTU of mechanical energy, whereas one BTU of thermal energy at 120^0F can only be converted into 0.20 BTU of mechanical energy – the remainder, in each case, being rejected to our large bodies of water or to the atmosphere. The second law of thermodynamics can help us understand this paradox. This particular law of nature separates thermodynamic processes from economic processes in that all real processes involving the generation of mechanical (or organized) energy from thermal (or disorganized) energy are irreversible. Entropy is a property that is derived from the second law of thermodynamics. Webster's Third International Dictionary gives the following thermodynamic definition of entropy: "A quantity that is the measure of the amount of energy in a system not available for doing work." However, in more general terms it also states "entropy is the ultimate state reached in the degradation of matter and energy in the universe." It also says that "entropy is the general trend toward death and disorder." This almost philosophic concept of entropy has sparked more than its share of discussions amongst science and engineering students, most of them to be forgotten too soon.

However, to the practicing engineer, the second law of thermodynamics requires that all heat engines operating in cycles must exchange heat with two bodies, one at a higher temperature, called the heat source, and one at a lower temperature called the heat sink. A heat engine that violates the second law of thermodynamics is an impossibility and is usually referred to as "a perpetual motion machine of the second kind." (I am sure that several of these machines can be credited to the now "not so famous" Rube Goldberg.) Thus, in order to produce mechanical energy from thermal energy we must have both a heat source and a heat sink, and the efficiency with which we can convert the thermal energies of our heat sources into mechanical work will depend, mostly, on the temperature difference between the source and the sink. To optimize this efficiency, we choose the heat sink at the lowest available temperature; physically this means that we must use our large bodies of water or the atmosphere to accept the heat rejected in the energy conversion process. The efficiency of the process is then determined by the temperature of the heat source; the higher the temperature of the source, the more thermal energy being converted into useful work and the less heat being rejected to our oceans and atmosphere. This characteristic of energy transformation processes seems to indicate that we should take a hard look at our energy needs and divide them into high-quality energy needs, such as electricity and transportation, and low-quality energy needs such as heating of water and space, and that we should aim towards supplying the high-quality energy needs from high-quality energy sources such as fossil fuels and radioactive materials, and meeting the low-quality energy needs from low-quality energy sources such as solar and aeolian energy.

Unfortunately, the solution to our energy problems is not that simple, for there are many factors that influence our decisions in this field; in particular, in order to satisfy our ever-increasing high- quality energy needs, we must develop new sources of energy through newer technologies, such as nuclear energy, and old sources of energy must be looked at with an open mind; for example, the use of mineral oil may soon have to be reserved mostly for the products that are derived from it (such as plastics), while coal could be used to meet our energy needs provided that we are willing to pay the price demanded for the development, fabrication and use of new, improved pollution prevention equipment. Incidentally, the coal reserves of the United States of America are more than adequate to meet our energy demand for the next two or three centuries.

The entire energy scenario must be looked upon subject not only to the laws of nature, which control all energy transformation processes, but also subject to rather stringent pollution controls and, of course, economic constraints. It is in the field of economics where the concept of irreversibility of energy processes must be made to interact with the economic laws of supply and demand in the process of establishing the cost of energy. Dr. Nicholas Georgescu at Vanderbilt University has been looking into the economics of non-reversible processes and is revolutionizing economic thought through some of the theories presented in his book *The Entropy Law and the Economic Process*. In addition, the eventual solution of our energy problems must also include the development of a comprehensive energy conservation program, which should include tax incentives designed to encourage owners of existing buildings and homes to insulate their property to produce energy savings, as well as educate the consumer to pay the higher prices associated with the energy-saving versions of devices, appliances and dwellings.

Finally, I must ask you to have faith in your classmates, student, and/or colleagues pursuing careers in science and engineering to bring forward progress in this critical area of energy production, for they are not only trained in understanding the basic laws of nature and in the optimal process involved in converting the Earth's energy resources into useful mechanical energy, but are also concerned about our environment and the effects of our fabrications upon the quality of life on this planet.