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ENERGY SYSTEMS, HYDROGEN AND THE BIOSPHERE

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ABSTRACT

In the living of its life, every species has an effect on the environment. And it is the sum of all such effects, plus the characteristics of the physical environment, which ultimately define the biosphere. Recently, geologically speaking, human activities have begun altering ecosystems in ways and in magnitudes which are almost unprecedented and which are perceived to have lowered the "quality" of living systems.

Pollution is the word used generally to describe such deleterious effects on the biosphere but it does little to shed light upon why or how pollution occurs. What we must learn to accept is that man's impact on the environment derives primarily from his quest for and use of energy, either to feed himself or power his activities. His search for and production of materials also degrade selected ecosystems but since these activities would be impossible without usable energy, it is actually how we capture, store, transmit and utilize energy which determines how seriously the biosphere is affected by our actions.

Earth's serious environmental problems - air pollution, water pollution, thermal pollution, acid rain, CO_2 accumulation in the atmosphere, deforestation, desertification and so on and so forth - all result from "human/energy" interactions. This concept gives us a starting point for perceiving ways in which man's degradation of the environment can be diminished. It appears evident that most forms of pollution could be significantly ameliorated by reducing our dependence on fossil fuel resources. Movement away from hydrocarbon-based energy systems to systems characterized by the exploitation of non-fossil sources of energy, and in particular by the use of hydrogen and electricity as the prime energy currencies (energy carriers), is presented as an energy strategy which would produce distinct environmental benefits.

1. INTRODUCTION

All the lifeforms which inhabit Earth exert some influence on their surroundings. And it is the sum total of these

multitudinous effects, taken together with the characteristics of the physical environment, which conspire to define niches, communities, ecosystems and, ultimately, the biosphere.

The biosphere is analogous to the thin skin of a bubble, and it constitutes the fragile outer layer or covering of our planet. Compared with the size of Earth itself, it is rather insignificant, extending above the planet only a very short distance and penetrating only minimally into Earth's crust. But this thin-skinned phenomenon is remarkable indeed, for despite our most concerted efforts we have not yet been able to detect its like anywhere else in the universe.

It is difficult to grasp the fact that the biosphere is actually extremely limited because we live in it. In the way a small puddle represents the universe to a tadpole, we have difficulty seeing and appreciating the universe beyond because we are completely immersed in the swirling, seething mass of life we call the biosphere. We are, however, developing a greater and greater appreciation for the biosphere's uniqueness as we be begin to travel outside its boundaries and recognize it as an environment which appears to be completely unrepresentative of the rest of space.

Because we live in the biosphere, because we are used to the grandeur of nature's handiwork, and because we have all experienced the awesome power of "the elements" through natural disasters or catastrophes, we think of the biophere as "strong". We think of it as an entity with which we have to cope, not vice versa.

It certainly is all-encompassing - only a handfull of men have ever managed to venture beyond it - but the biosphere constitutes only the thinnest of coatings on our planet, and it is remarkable in that it has persisted at all over time, not for the fact that it seems incredibly resilient, and resistant to the rough handling it has received from the species Homo sapiens.

This is not to say that all species live in harmony with their environment in such a way that they never change it, and, by implication, that man and all his activities are bad because he and they do change the status quo. Indeed, as mentioned above, it is the very sum of multitudinous effects by innumerable individuals which actually define ecosystems. And one has only to think of the "oxygen revolution" that plants carried out 3.5 to 4 billion years ago to realize that, as a species, nothing we are likely to do short of instigating nuclear war is likely to have as profound an effect on the biosphere as did green plants and the (essentially) irreversible transformation they wrought with their chlorophyll molecules eons ago. This should not, however, be taken as an excuse to disregard our impact on the environment.

Plants "got away" with what they did - polluting the atmosphere with molecular oxygen - because, in the process, they transformed the environment in a way which enabled them to create their own food energy. They became independent. They became

autotrophs, species which are able to tap the never-ending supply of energy which falls on Earth in a continuous stream of radiation from the Sun. In doing so they created an environment which all other organisms must cope with if they are to survive.

Man, on the other hand, is as yet unable to directly tap an external (or extraterrestrial) source of energy to any significant degree and is therefore dependent upon the marvellous photosynthetic ability of plants to nourish his body with the energy it needs. He also depends upon natural planetary energy resources to supply his other energy needs. In other words, we are heterotrophs which depend absolutely on the proper functioning of Earth's various ecosystems so that the plants within them can carry out the primary production which is the essential first step in providing us, and all other heterotrophs, with food, with the energy we need to "run" our bodies.

But man differs significantly from the rest of the world's heterotrophs in at least one very important way. We are unique in that we have need of energy in two distinctly different forms. We need **food** to power our bodies, and we need **energy currencies** (media of energy exchange which can be spent in return for work) to spend on doing the activities we do to provide ourselves with shelter and warmth, to power our communications and transportation systems, to supply ourselves with materials for the creation of the goods we require, and to enable us to manipulate ecosystems to provide us with our daily bread. In short, we need energy currencies to facilitate "human/energy" interactions.

It is our ever-increasing use of energy, however, which enables us to alter ecosystems and to pollute.

2. ENERGY SOURCES, CURRENCIES AND TECHNOLOGIES

Our energy systems can be divided into three different parts: (1) energy sources, (2) energy currencies, and (3) energy technologies. Each of these segments have their own peculiar effects on the environment and this breakdown gives us three potentially different ways of looking at how we can attack the problems resulting from our use of energy. **We must become more serious at developing and utilizing energy sources, currencies and technologies which are increasingly environmentally benign.**

Everyone knows what **energy sources** are. They are simply resources which can be developed and exploited for the production of utilizable energy. They range from fossil fuels to nuclear power, from ocean thermal energy to solar radiation, from tidal power to geothermal energy. There are, however, significantly varied perceptions as to which of these sources are most desirable for exploitation from an environmental point of view. Almost every energy form has its proponents and detractors.

There appears to be very little discussion over which **energy**

currencies we should be moving towards using, primarily because "energy currency" is neither a term nor a concept which is familiar to many. Energy currencies are are neither energy sources nor energy technologies. They are intermediaries between the source from which energy is derived and the point at which it is used. Most energy currencies have traditionally been called fuels. But the term fuel normally refers to combustible materials and therefore does not aptly describe electricity.

An energy currency is simply a medium of energy exchange which can be spent in return for work. Of course, according to the First Law of Thermodynamics, energy is neither created nor destroyed; therefore, we do not actually **use** energy for anything. We do, however, facilitate its transformation from one form to another, and in so doing derive work from it. It is this process, because of its present magnitude, that is directly or indirectly causing our environmental problems.

Nevertheless, we must use energy to maintain modern society. Therefore, we must concentrate to an increasing degree on developing ways and means of generating, storing, transporting/distributing, and using energy without engendering environmental havoc.

The term **energy technologies** describes those means we have of facilitating (or inhibiting) the transformation of energy from one form to another. For example, hydroelectric installations enable us to transform the energy of falling water into electrical energy, and nuclear plants enable us to transform the energy of radioactive elements into heat or electrical energy.

Since energy sources are not inherently naturally polluting, we must recognize that it is man's transforming of energy forms which generates pollution and environmental deterioration. Thus, one of the first steps we must take to reduce our impact on the biosphere will be to develop energy technologies which are (1) **non-polluting** and (2) **conserving in nature,** so that we can keep our energy transforming activities to a minimum.

We must also increasingly use those energy currencies available to us which pose the least threat to the environment.

And we must redirect our thinking to use those energy resources which are inherently least damaging to the environment upon exploitation, that is which can be used to produce desirable energy currencies and which will require the use of those energy technologies which are least environmentally disruptive.

3. POLLUTION AND THE USE OF ENERGY

The problems we are facing as a result of our violation of the biosphere are many. They range from local phenomena like the pollution of streams or lakes, to larger-scale problems such as the desertification of extensive regions of Earth (the Sahel in Afrika being a prime example), to global problems such as acid rain and CO_2 accumulation in the atmosphere.

In many of the world's freshwater lakes, streams and rivers, industries and energy-generating installations pour all manner of pollutants into the waterways - everything from heavy metals to organic wastes, from newly-systhesized, completely unnatural chemicals to energy-containing materials such as coal particulates and oil, from radioactive contamination to thermal pollution.

In the Sahel, the environment is suffering from a disastrous desertification problem. This has also been brought about by energy considerations. First, gleaning for firewood to produce **thermal** energy for cooking and keeping warm has literally denuded the countryside of vegetation and promoted the deterioration of the ecosystem to the point where it is now no longer capable of combating the various forces of erosion which act to destabalize dryland communities. Second, cattle husbandry is practised to an extent greater than the carrying capacity of the environment in order to generate **food** energy in the form of animal protein, or to produce economic gain enabling farmers to buy food other than meat. Overgrazing of the sparse vegetation cover very quickly produces an ecosystem unable to cope with diminishing supplies of rain, and leads inevitably to the exacerbation of desertification.

As far as pollution problems which have now become truly global in scale are concerned, it is obvious that these phenomena are directly related to man's manipulation of energy. For example, the Industrial Revolution was made possible by an exponential increase in the use of energy for the generation of heat and electricity and to provide motive power in the transportation sector. This feat was accomplished by combusting ever-increasing quantities of fossil fuels: coal first, then oil over the last fifty years and, most recently, natural gas. Billions of tons of carbon dioxide have been released to the atmosphere as a result of the oxidation of these fossil fuels and that enormous amount, combined with a roughly equivalent amount of CO_2 generated as a result of deforestation, has led to an increase in the concentration of CO_2 in the atmosphere of some 40 ppm.

In addition, burning fossil fuels and smelting sulphur-containing ores has released billions of tons of acid rain precursors - sulphur dioxide (CO_2) and nitrogen oxides (NO_x) - to the atmosphere producing acid rain. Acidic precipitation has now become a modern-day malaise which no longer plagues industrialized nations alone. It has spread worldwide, even recently being detected in the fogs of the Arctic.

Similarly, and paradoxically, a large portion of the energy we require for the "human/energy" interactions referred to earlier is used for activities which are carried out to provide our bodies with food energy - agriculture and the food processing industry in general use prodigious amounts of energy. This is perhaps the clearest example of how the simple transformation of wind, water, electrical, nuclear, geothermal, or whatever energy form to food energy for man contributes greatly to the contamination of the environment.

In fact, the cause of the biosphere's ills can all be traced directly or indirectly to our quest for, and/or our manipulation and use of energy. We must therefore admit that none of these problems would exist if we weren't either searching for or "using" large quantities of energy.

We must understand that it is the process of transforming energy from one form to another on an ever-increasing scale which is causing our environmental ills. In fact, the one "sure-fire" way of ending pollution by man would be to deprive him of his energy supplies. Without them he wouldn't be able to do anything to damage the biosphere.

4. ENERGY AND ENVIRONMENTAL DETERIORATION

The more energy we process through our energy systems, the more damage we do to the environment. This is done in two ways: via the generation of material pollution through the manipulation of matter; and via "pollution" with energy itself, usually in the form of thermal pollution, but also existing in such forms as extremely low frequency (ELF) electric fields from electric transmission lines (Marino and Becker, 1978), or radioactive contamination.

The term pollution usually refers to an excess of some man-made material in a specific location (mercury in freshwater rivers and lakes, excess carbon dioxide in the atmosphere, oil on the seas and in estuaries, and so forth) and does not conjure images of such environmental problems as deforestation and desertification. But the corruption of the biosphere is now truly a global phenomenon and looking from the vantage point of outer space it is not difficult to accept the image of man damaging the planet through the indiscriminant use of energy.

Unfortunately, the use and control of greater and greater amounts of energy has become increasingly dangerous in that we have begun interfering with the normal functioning of natural biogeochemical cycles, the cycles in which elements such as carbon pass through biological and non-biological compartments in an endless recycling process.

Except for green, photosynthetic plants, no species has ever before had the power to remove itself from and independently alter such cycles. In burning fossil fuels on a large scale over the last one hundred years or so, we have released to the atmosphere a quantity of carbon that natural processes took millions of years to lay down and, in the process, we have significantly perturbed the carbon cycle. This rapid turning back of the carbon clock may very well turn back the meteorological clock as well, leading to a climate which has not existed on Earth for millions of years.

Man developed the ability to manipulate the environment with energy over a very long period of time. At first small quantities of energy were used when he discovered fire. Then he domesticated beasts of burden, harnessing their energy for

agriculture and transportation. Next he discovered coal, then moved to the use of petroleum and more recently to the burning of natural gas, the latter 30 years or so seeing a parallel development of nuclear power take place.

Surprisingly, during this evolution he actually moved in the direction of using cleaner and cleaner fuels - from wood, to coal, to petroleum, to natural gas. This was undoubtedly done more for convenience that for cleanliness, but the direction has been towards fuels (or energy currencies) with decreased carbon content and increased hydrogen content. If one looks at the hydrogen-to-carbon ratio of these fuels, one finds that it is a ratio that is continually increasing. The logical extention of this trend is to move to pure hydrogen produced from a variety of energy sources alternative to fossil fuels, probably most notably via the electrolysis of water.

In 1980/1981 a Special Committee on Alternative Energy and Oil Substitution of the Canadian House of Commons did a study of alternative energy options in the Canadian context and produced a widely-acclaimed report entitled **Energy Alternatives** (Canada 1981). While working for this committee a seven point pnilosophy was iterated to be used in the formulation of environmentally-responsible energy policy. The points were made in connection with establishing a new energy order for a world in which the use of fossil fuels would slowly be diminished. This goal was desired because fossil fuels are an exhaustible resource and because there are unacceptable environmental risks associated with the continued and increasing burning of carbon-containing energy resources.

The report stated: that we should make every effort to reduce energy demand by practicing **conservation**; that in the long term, energy should be derived primarily from **renewable** and/or **inexhaustible sources of energy**; that the production of the primary energy we require should be achieved **with as little environmental disruption as possible**; that we must achieve greater **diversity** in our energy mix; that we must recognize **regional differences** in energy resources and in energy requirements; that we must address **strategic concerns** in formulating energy policy, and; that we must adequately consider the **social implications** of bringing about major changes in energy systems.

In short, we should be thinking about establishing energy systems which are flexible, diverse, environmentally benign, strategically and socially responsible, and essentially conserving in nature. That is undoubtedly easier said than done. But we have an abundance of resources on Earth and the technological capability to build such an ecologically responsible energy system. All we have to quibble about is whether we are willing to pay the price.

5. HYDROGEN AND ELECTRICITY

It is the thesis of this paper that a significant array of our environmental ills derive from the continued and expanded use

of energy and, in particular, from the combustion of the fossil fuels: coal, oil and natural gas.

Oil spills, black lung disease, carbon dioxide pollution, acid rain, open pit mining, carbon particulates, the despoiling of terrain or water bodies in the search for and the delivery of hydrocarbons all result from our "addiction" to carbon-containing molecules laid down in warmer times millions of years ago. We must gain a greater appreciation for the fact that the "menu" of energy sources available to man is extensive and that we should begin tailoring our energy systems to make use of regional energy resources to meet local energy requirements and not force all our activities into the mould of having to conform to the requirements of an oil-based technological system.

All of Earth's energy sources should be used where most appropriate to produce a diverse energy system which would nevertheless be cohesive and universally acceptable through the generation and use of the energy currencies hydrogen and electricity. Developing such a system would be ecologically responsible and would simultaneously free us from the fundamental error or having the entire planet's energy system based on one single depleting and nonrenewable energy source.

Hydrogen and electricity represent ideal energy currencies because they are of themselves non-polluting and because they are **renewable.** Hydrogen is produced from water via the process of electrolysis and it combines with oxygen to reform water upon combustion. Similarly, electricity is generated via the separation of charge and it returns to charge neutrality upon being "used".

Hydrogen and electricity also make perfectly compatible energy currencies because they are interconvertible. Hydrogen can be converted to electricity via fuel cells, and electricity can be converted to hydrogen via electrolysis cells.

And lastly hydrogen and electricity make perfect energy currencies because the are complementary. Hydrogen can meet all our requirements for **chemical** energy, such as is required for the transportation sector. And electricity can satisfy all our needs for **electrical** energy where chemical energy would not suffice, such as in running electrical appliances or computers.

Electricity and hydrogen are ideal energy currencies (or fuels) because they contain no carbon and produce no pollutants when used. But it would certainly not benefit us greatly if we converted to environmentally benign energy currencies while generating them from environmentally damaging energy sources. We must make a planned and controlled effort to use clean energy currencies, and to generate them in a clean and conserving manner from those energy sources which are most appropriate in any specific location.

6. CONCLUSION

The environmental problems Earth is suffering from today are anthropogenic. Nature does not pollute. All the ills the biosphere is suffering from exist as a result of man's manipulation of matter and, more specifically, energy. None of the pollution problems which trouble us so greatly would exist if we did not use energy to concentrate materials in a location where they would not occur naturally. And none of the forms of pollution such as desertification, the destruction of the ozone layer, the accumulation of carbon dioxide in the atmosphere, the extinction of species, the introduction of new life forms, or the synthesis of new and unrecognizable chemicals would be possible without using large quantities of energy. Directly or indirectly, our search for and development of, our distribution and/or transportation of, our storage of and our "use" of energy conspire to affect our biosphere in ways which always seem to be detrimental.

Our energy systems can be broken down into three components: (1) energy sources, (2) energy currencies, and (3) energy technologies. This factoring enables us to judge more easily where we should make improvements to the energy system to reduce mankind's effect on the biosphere. It means we must look at all kinds of energy sources, currencies and technologies to produce the energy we need, not just blindly adhere to the oil-based system which has evolved.

First, we should make every effort to practice conservation. By limiting our use of energy we will automatically reduce our impact on the environment. Second, we should strive to utilize inexhaustible or replaceable sources of energy. Third, the production of the primary energy we require should be achieved with as little environmental disruption as possible. Fourth, we should strive for diversity in our energy mix. Fifth, we must recognize and make allowances for differences in regional energy requirements and energy resources. Sixth, energy systems which are resiliant and independent must be strived for in order to address the strategic concerns associated with dependence upon energy supplies. And seventh, all attempts at changing our energy systems must only be made while simultaneously taking all the many and varied social implications they will mean into account.

Which energy sources to exploit and how to do so will remain a question to be answered while taking the specifics of each situation into consideration. But it does seem that an expanded use of the energy currencies hydrogen and electricity would permit a diversification of our current energy system, would give us the opportunity to develop and utilize less polluting and more energy-conserving energy technologies, and would allow us to use energy currencies or fuels which are themselves environmentally benign.

7. REFERENCES

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