SUSTAINABILITY OF INDUSTRIALIZED CIVILIZATION EXAMINED

With the End in Sight for Fossil Fuels, is Man Doomed to a Cold, Dark and Bitter Future?

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Anthropologists inform us that Peking man was kindling fires in caves about 400,000 years B C. To him no doubt fire was magic--this new elemental force was something truly marvelous.

Nature by then had been building up its supplies of fuel for hundreds of millions of years; fossil fuel from vegetation, oil and gas from marine life, supposedly (although a recently advanced theory assumes that our carbohydrate deposits of oil and gas are even more ancient, dating from the time of the earth's agglomeration, which involved bombardment by meteors of organic composition, these meteors having struck at levels far beneath the present surface of the earth, with the oil and gas then eventually percolating upward).

Even until the last century man, far fewer in numbers, used fuels in relatively tiny quantities. The rate of usage posed no great threat to supply, which was enormous in relation, and no one then conceived such a thing as a threat to the environment.

We must leave to future historians the task of determining whether what happened to us with the dawn and development of the Industrial Age was a great blessing or an incredible curse. Certainly it brought us quickly and forcibly from a long-established sustainable pattern of life, developed over thousands of years, into a totally new and untried style of living, to which we continue to try to adapt.

For years, now, the names of James Watt, Robert Fulton, Alexander Graham Bell, Cyrus McCormick, Thomas Edison, Henry Ford, Orville and Wilbur Wright and a host of others have been recited almost with reverence, and with little wonder, for from crude beginnings the accelerating revolution has brought us goods, conveniences, pleasures, relief from poverty and drudgery. Industrialization, with its cheap machine horsepower, supplanted slavery--simply made it economically unsound. It was not a matter of humanitarianism, a matter of society's revulsion with the concept of bondage--it was a simple matter of economics: slavery became an obsolete practice.

The short term assessment of industrialization is, quite naturally, positive. Unquestionably, there is more wealth. We are living better, for the time.

Even so, in our headlong rush toward greater heights of industrialization for ourselves and the forcing of it upon the undeveloped or third world, it may be well to pause and ask where we are going--where this all may possibly end, for the end, assuming that we do not alter our course, already is in view.

Danger signs are flashing. Thus far the warnings are coming primarily from environmentalists. There is much that is legitimate in their approach which needs to be factored into our thinking, but this paper will not address the tremendous environmental impact of ever-accelerating industrialization.

Rather, let us direct our attention to a single and simple concept, that of "sustainability," usually an environmental topic only) in relation to our rapidly dwindling total reserves and resources of fuels. With fossil fuels a finite resource, undergoing rapid depletion, and with this fuel distributed unevenly throughout the earth, furthermore with our ever-increasing dependence on this fuel, we in the United States conceivably face a future shock the dimensions of which could well dwarf our ability to comprehend.

Our national problem has overtaken us rapidly. As recently as 1972, the U. S. Geological Survey claimed that there were 450 billion barrels of domestic oil and 2,100 trillion cubic feet of natural gas left to be found in the U. S.

Then, in less than 10 years, in 1981, the USGS itself characterized the earlier figures as four times too high. Soon, though, both government and industry experts viewed the amended estimates of 83 billion barrels of oil and 594 trillion cubic feet of gas as overly optomistic.

Recent estimates, made in 1989 in cooperation with Interior's Minerals Management Service, turned out to be the lowest ever made, and agreed roughly with private and industry estimates. The figure for oil remaining to be found in the US (technically called oil resources), had plummeted to a mere 35 billion barrels, with the new estimate for undiscovered natural gas reduced to 263 trillion cubic feet.

In existing oil fields we now have left in the US only about 51 billion barrels of recoverable oil.

Consider where this leaves us. Since the beginning of the oil industry in Pennsylvania about 100 years ago our nation has consumed 143 billion barrels of domestic oil.

The reserves and estimated resources appear massive until one considers that US usage is now close to 6 billion barrels of oil per year and is, naturally, increasing each year. Reserves and resources total 84 billion barrels, at present rates a 14 year or less supply--but keep in mind that the estimate of oil to be found includes Alaskan wildlife refuge areas and the promising offshore sites. It is not at all certain that the oil companies will be permitted to explore these promising sites. Furthermore, it takes time to discover oil, and still more time to place new fields in production. We should remember that Prudhoe Bay was not an easy find, for its 10 billion barrels were discovered only after 45 years of searching and 57 exploratory wells drilled along the North Slope.

Gentlemen, we are in trouble. The world may temporarily be awash in oil, but the US is not. Our reserves and resources are finite, perhaps an eight or ten year supply with production limitations stretching this out over a much longer period.

Currently about half the oil we use is imported. One hears much about cheap middle-east oil. Consider this fiction, even in times of peace. It is definitely not cheap. We keep, even in less disturbed times, a sizeable military presence there. Former Navy Secretary John Lehman stated in 1987 that the cost of our military presence to enforce the Persian Gulf oil supply lines was 40 billion dollars a year. Relating this to the amount of oil that we ship to ourselves, 800,000 barrels daily according to one report, the policing costs 137 dollars a barrel. Add to that the cost of the oil itself and transportation and the cost exceeds 160 dollars a barrel. This is not cheap oil--for us, anyway. Perhaps it is cheap oil for Europe and Japan, as they get more oil than we do, and normally do not share our military expense.

The geographical incidence of present world oil and gas reserves is shown in the table you have. The tiny, hostile Persian Gulf area, where oil-bearing sand is a mile thick, contains nearly two-thirds of the world's oil reserves, almost one-third of the world's natural gas. They export 85 percent of the non-communist oil in world commerce.

To visualize the disturbing rate of increase in world use of oil, natural gas and coal, please refer to the chart on the rate of primary energy use. The increases in global use since, for example, 1940, are enormous and exponential for oil and natural gas, with perhaps only a doubling for coal.

Note that oil use rose from 4 million barrels a day in 1940 to 90 million barrels a day in 1985, with equivalent natural gas use rising in the same period from 4 million barrels to 30 million barrels a day.

The question arises: how much total fossil fuel remains in the earth? At first hearing the figure is reassuring, for the experts best estimate is the equivalent of 10 trillion barrels of oil, 170 years supply at the present rate of usage. From the chart it is glaringly obvious that usage will not continue at the present rate. A more reasonable expectation, extrapolating the world's frenzied ever-increasing appetite for energy, is that world supplies will be largely exhausted in about fifty years.

Assuming accuracy for this time frame, concern for man's future welfare should bring us directly to the question of "sustainability" of industrial and life patterns. Admittedly, for us, this ultimate concern is not related to our own life span. Still, we need to be good stewards and leave a decent world for those who follow--a world with heated homes, food, medicines, some means of transportation, some essential industrial capability--orderly, continuing, "sustainable" energy sources of whatever kind..

Think how sad it would be to permit the death of that intricate and benevolent industrial machine, which has dispensed such marvelous benefits for so long a time.

Certainly it could, in the absence of needed fuel, slow and eventually become silent, leaving twelve billion men and women to face staggering odds against survival of more than a small fraction of their number.

Fortunately, in recent years, factors have emerged which bring hope for a different scenario.

Let us examine briefly some possible solutions to the stated problem.

Basic to this approach is the knowledge that truly sustainable energy can be derived from a limited number of sources. Obviously the most important of these is solar radiation. A poor second is geothermal heat, which can be trapped from the earth's core. Third, and scarcely worth mentioning, is the energy generated by the moon's gravitational pull as manifested in tidal power.

To comprehend the enormous amount of solar energy available to us, compare the present annual world use of 12 terawatts of energy, this from all the various sources, to the solar radiation striking the earth each year, which is 178,000 terawatts, or 15,000 times the world's present annual energy supply. Admittedly, only a small portion of this can be trapped for usage. 30 percent is immediately reflected back to space; another 50 percent is absorbed, converted to heat and reradiated. The remaining 20 percent creates the wind, perpetuates the water cycle, and gives us the magic process of photosynthesis. This completely free solar radiation affords us the opportunity to establish, through innovative effort, truly sustainable energy supplies for the future. Among the approaches would be windpower, hydropower and biomass. In addition, direct solar power can be trapped by solar thermal electric plants, and by photovoltaic cells which convert sunlight directly into electricity.

With the exception of biomass, the remaining conversions to energy are essentially pollution free.

It is exciting to consider the potential in windpower. After all, what could be cheaper than power from the wind?

Man has drawn energy from the wind for centuries, applying it as motive power for ships, and capturing its force with windmills to grind grains, saw wood and pump water.

Although the wind is free, conversion to useful pipeline energy is not. Our newest coal-fired power plants produce electrical energy at a cost of 5 cents per kilowatt hour. As recently as 1981 wind turbines were far from competitive, producing electrical energy at about 70 cents per kilowatt hour.

Today, however, through varied economies including large scale production, design refinements, and increased scale efficiencies in transmission, wind turbines are producing electrical energy at 7 cents or less per kilowatt hour. Refinements contributing to lower cost were lightweight composite-material blades and microprocessor-controlled turbines.

Pacific Gas and Electric is now linked with the Electric Power Research Institute in Palo Alto and U. S. Windpower in Livermore to develop, build and test prototypes of a 300-kilowatt variable-speed wind turbine. The designers have as features blades and sophisticated electronic controls which will allow the rotor to turn at optimal speed under a very wide range of wind velocities, thereby increasing the efficiency of wind energy capture.

Projections have been made by the U S Department of Energy and industry analysts of cost-competitive electricity from windpower within twenty years, the targeted figure being 3-1/2 cents per kilowatt hour.

Even with greatly reduced cost, windpower suffers the disadvantage of being totally dependent on the vagaries of the wind, thereby posing the problem of matching an intermittent energy source to needs that are huge and very nearly constant. It now appears that a solution to this problem is emerging.

Solar electricity can produce hydrogen electrolytically by splitting water into its constituent atoms, thus storing the energy in hydrogen, a form of energy capable of being stored and used steadily, as required. Furthermore, hydrogen can be transported by pipeline at lower cost that electricity over wires, presuming a lifetime cost basis.

Please observe the map which shows wind-generation potential broken down by states. Note the statement that four million 500-kilowatt wind turbines spaced half a kilometer apart over 10 percent of the U S, where wind is favorable, (as in the plains states) could satisfy all present U S electricity demand.

A second approach to trapping of solar energy is that of solar thermal electric generation. Briefly, in this approach, mirrors are mounted in long parabolic troughs, creating solar reflective collectors. These devices, with analog controls, track the sun, thereby concentrating solar heat and light on a tube of circulating fluid mounted at the parabolic focal point. The heated fluid (oil, in the existing systems), is used to create steam which in turn drives a turbine generator. Between 1984 and 1988 plants having a total capacity of 275 megawatts were installed in California's Mojave Desert. By 1994 additional plants will be installed at Harper Lake in southern California with a capacity of 380 megawatts.

Initially, these thermal generators produced electricity at 23 cents per kilowatt hour, but cost has been reduced to about 10 cents per kilowatt hour. Further cost reduction is predicted.

Perhaps the most intriguing of the categories of solar conversion to useful power is one which converts sunlight directly into energy with no moving parts. Photovoltaic (PV) electricity is produced when photons (individual particles of light) are absorbed in a semiconductor. Because no water is required, these generating panels can be installed in the desert.

The cost of PV electric generation has been reduced dramatically since 1970. In that year the cost per kilowatt hour was $60.00. By 1980 the cost was only $1.00, and today the cost has been further reduced to 20 to 30 cents per kilowatt hour.

Research now promises a new class of solar cells based on extremely thin films of semiconductor material. One to two microns in thickness (one fiftieth the thickness of a human hair), these modules require minute amounts of active material, and should when perfected permit manufacture of solar cells at one-tenth the current cost.

In their desire to examine the prospect for large-scale PV electricity generation, Pacific Gas and Electric created a government-industry partnership called the Photovoltaics for Utility Scale Applications project. The object is to get PV R & D into commercial applications.

As a nation, we are not alone in this venture. All the major Japanese utilities are involved in PV projects. The largest West German utility is evaluating several of the PV technologies at an installation which eventually will generate one megawatt of electricity. The governments of Italy and Spain are funding freestanding systems for homes and for remote areas where the cost of power line installation is prohibitive.

A third source of energy derived from solar radiation through photosynthesis is "biomass," and today's most interesting application is found in Brazil's alcohol program.

Brazil's interest in alcohol production arose as an innovative response to the oil crisis in the seventies. Brazil determined to substitute pure ethanol (ethyl alcohol) and gasohol (mixtures of ethanol and gasoline) for gasoline in automobile engines. Ethanol, it should be noted, has a higher octane rating as well as some other advantages over gasoline.

In what amounted to technological leapfrogging Brazil, a developing country, established an entire fuel cycle--from an energy source (sugarcane) to end-use devices (alcohol-fueled automobiles), a tremendous leap that has no counterpart in other industrial countries. The cost of ethanol (the Russians call it vodka) is only 70 cents per gallon, and could be even less if modern gas turbines rather than low pressure steam turbines were used to burn the bagasse, since the current generated would be only one-tenth as expensive.

While this process for deriving ethanol from sugar cane "biomass" holds great promise for us, we continue our own pork barrel venture, a heavily subsidized one involving the manufacture of ethanol from corn, which is far more costly and inherently impractical. Too, with government actions assuring artificially high prices for domestic sugar producers, there is little incentive to process sugarcane into a less profitable product.

Because of our national love affair with the automobile (actually, this is a world-wide love affair, with 500,000,000 vehicles now motoring over the earth), our citizens should welcome a recent announcement from the American Academy of Science. Dr. Roger Billings, president, informed the scientific community of a breakthrough in hydrogen technology which will make it cheaper to operate a car on hydrogen then on gasoline, the cost being given as 46 cents per gallon equivalent to gasoline. His new device, which he has named the LaserCel, is an improved fuel cell.

Invention of the LaserCel came about through years of searching for less expensive ways of producing hydrogen. Quoting the inventor, "Since hydrogen must be synthesized from water, a process which consumes great quantities of energy, no simple solution could be found. The solution finally came when we began to address the problems by better utilizing the fuel."

According to Billings, 2/3 of gasoline's energy is wasted through hot exhaust gases and heat dissipated by the radiator. After one hundred years effort, no greater efficiency could be achieved. Again quoting Billings, "With hydrogen, however, we have very good news. With our new hydrogen fuel cell...sixty to eighty percent of the hydrogen put into the cell comes out as electricity."

The fuel cell transforms hydrogen and air into water and electricity. It has no moving parts, it is very quiet, and it doesn't wear out. A former drawback for electrically powered vehicles, the vehicle's limited range, has been doubled by the LaserCel, from 150 miles to a far more practical 300 miles.

Because the LaserCel operates in reverse, as an electrolyzer, the vehicle owner can, at night, connect electricity and water to his car, and thereby generate his hydrogen fuel for the next day.

Safety of the fuel hydrogen in the prototypes to be manufactured in Pennsylvania is assured by storage in tanks in "powdered" metal hydride form. Thus stored, it is a safer fuel than gasoline.

Piped hydrogen, derived from electricity generated by windpowered turbines, could be distributed and provide us with continued economical transportation.

Unquestionably we are now getting down to the business of solving the inevitable problem of ultimate fossil fuel depletion. As the years pass and we are driven by price and necessity in a free and profit-seeking society, some of the now primitive approaches will become economically feasible, and it does not now appear that profligate man is doomed to a cold, dark and bitter future. The chart provided you on cost projections for alternate "sustainable" power sources is encouraging and pleasant to read.

Looking back over our rapacious record, we can comfort ourselves by observing an important truth: without the use of the fossil fuel which we have bled and torn from the earth, there would certainly be no advanced industrial and scientific community to grapple with this frightening and inevitable problem of fuel depletion.

It is too soon to begin massive applications. Misdirected, inefficient approaches which would later be scrapped would be both wasteful and unwise. We must first exhaust the creativeness of our research community, engineer and get the optimum technology off the drawing board, then build prototypes and test the new approaches exhaustively. Some work is already underway by us, and by others. There is still time, and indeed our best hope may lie in benign neglect by the government, allowing the free enterprise system, driven by the profit motive, to create solutions. Some of the most effective solutions may only remotely resemble the methods outlined in this paper.

One final observation (which relates to our priorities in the future, for the time is not yet) is this: four million 500 kilowatt wind turbines are needed to replace all U S electrical energy from all sources being used today. At the same time forty billion dollars is required to maintain our military presence in more normal times in the Indian Ocean and Persian Gulf. Simple division reveals that his represents $10,000.00 per wind turbine. Somehow, expressed in this way, the idea no longer appears altogether absurd. Perhaps, then, we should begin to think about this and other promising projects. Perhaps, even, as citizens we should insist that our nation should begin, in earnest, to try and do something about it.