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HUMANS AS A FORCE FOR GLOBAL ENVIRONMENTAL CHANGE

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Abstract

The paper describes historical events that led to the emergence of humans as a force for contemporary global environmental change. It highlights particularly the influence of humans on the global climate system, tracing the roots of this influence to our ever-increasing reliance on fossil fuels, coal, oil and natural gas, the energy source that drives the modern industrial economy. It points out that a relatively small fraction of the global population, the richest countries, are largely responsible for the environmental impact triggered by emissions to the atmosphere of the greenhouse gas carbon dioxide released as a by-product of the combustion of fossil fuels, highlighting the fact that those least equipped to cope - the poorest of our fellow global citizens – are most vulnerable to the consequences of global environmental change. Current efforts by the international community to moderate, or at least mitigate, the effects of global climate change will be described with specific attention to the response of the United States. It will be argued that global environmental change poses a challenge that is not merely scientific and technical but that there are important underlying ethical issues that must be acknowledged in the formulation of appropriate policy responses.

1. Introduction.

The Earth is approximately 4.6 billion years old. Together with the other planets and the sun, it formed by condensation from a spinning mass of gas and dust that composed the original solar nebula. As matter accumulated in the proto Earth, the planet began to heat up, responding in part to heat released as a result of gravitational accretion (conversion of potential to kinetic energy), in part to energy released by decay of radioactive elements such as uranium, thorium and potassium. Heating of the interior resulted in an instability, with warmer, and consequently lighter, material at depth rising in some regions to be replaced by colder, and thus heavier, material sinking elsewhere. Weightier elements such as iron settled to the core while more volatile species such as hydrogen, carbon and nitrogen accumulated at the surface forming the primitive atmosphere, ocean and crust.

Chemical differentiation driven by the changes in pressure and temperature associated with vertical motion led to the formation of the distinct zones we associate with the Earth today – the core, inner and outer mantle, crust, ocean and atmosphere. In particular, it resulted in the formation of discrete elements of crustal material geologists refer to as plates. As fresh material was added to crustal plates by upward motion, old material was removed by downward motion elsewhere. Segregation of light from heavy material led to the formation of the continents. The crustal plates floated like rafts on the heavier material that composed the underlying mantle. The pattern of vertical motion and related horizontal motions prompted the plates to move around. The configuration of the continents was altered accordingly. At times, the continental plates found themselves close together forming super continents. On other occasions, they were more geographically dispersed. Mountains appeared where continental plates converged (came together) and were eroded subsequently by weathering (chemical changes induced by contact with water and corrosive atmospheric gases). The Himalayas and the Tibetan Plateau, for example, arose as a consequence of a relatively recent (15 million years ago) collision of India with Asia. The juncture of North and South America was even more recent – it took place only a few million years ago. Previously, North and South America were separated by open water and the Pacific and Atlantic Oceans were connected through what we identify now as the Isthmus of Panama.

The vertical overturning of the Earth – we refer to it as mantle convection – and the associated movement of the crustal plates – we refer to this as plate tectonics – have had a significant influence on global and regional climate. Weathering of continental rocks provides a sink for carbon dioxide in the atmosphere. Conversely, carbon dioxide is returned to the atmosphere as a component of volcanic eruptions when carbon rich sedimentary material is drawn down into the mantle as a consequence of the convergence (collision) of crustal plates. As we shall discuss later, carbon dioxide is an important greenhouse gas – it is effective in limiting transmission of Earth heat, infrared radiation, to space. Concentrations of CO_2 have varied significantly over geologic time and climate has responded accordingly. There were times in the past when climate was unusually warm – temperatures were moderate even at high latitude in winter. And there were times when the Earth was freezing cold even at the equator (Hoffman et al., 1998). Changes in CO_2 are thought to have been at least partially responsible for these large-scale fluctuations in climate.

The configuration of the continents also has an impact on climate. It affects the albedo of the Earth (the color of the planet that determines the fraction of incident sunlight absorbed or reflected by the Earth) and has an influence also on the circulation and consequently the redistribution of heat by the ocean. Climate has been generally cold for the past several million years with large quantities of water withdrawn from the ocean, sequestered in thick sheets of ice on continental landmasses at higher latitudes. Twenty thousand years ago, the Earth was in the depths of an ice age with ice covering large regions of North America and Northwestern Europe. Sea level was 110 meters lower than today and it was possible for humans then to make their way from Asia to

North America taking advantage of a land bridge that linked the two continents over what are now the open waters of the Bering Straits. The relatively cold climate of the past several million years (interrupted by brief periods of comparative warmth) has been attributed to a change in ocean circulation linked to the closure of the sea gap between North and South America, in combination with regular, astronomically related, changes in the seasonal distribution of sunlight incident at different latitudes (for a more detailed discussion, see McElroy, 2002).

2. History of Life

It is clear that life has been present from an early stage of Earth history, for at least 3.5 billion years and arguably longer. Precisely how it came about is unclear. Some believe that Earth was seeded at the outset from space by primitive forms of life delivered in a rain of comets - manna from the primordial heavens. Others contend that the molecules that constituted the building blocks of early living organisms were formed in the primitive atmosphere as a consequence of chemical reactions triggered by either lightening or solar ultraviolet radiation. More likely, in our opinion, it developed in the ocean, in the vicinity of hot springs emanating from regions where fresh mantle material entered the ocean. Deep-sea vents distributed along regions of sea floor spreading (regions where the ocean plates are moving apart) support a remarkable ecological system in the ocean today. Bacteria feeding on energy supplied by the oxidation of sulfur contained in the hot (300 C) spring water represent the bottom of a contemporary food chain supporting a dense population of worms and clams in the immediate vicinity of these present-day vents. Oxygen would have been a minor constituent of the early atmosphere. Nitrite or nitrate formed in the primitive atmosphere, however, could have accounted for the oxidant needed to oxidize sulfur emitted in the primitive vents and thus, as a consequence, could have been the source of the energy required for synthesis of the organic molecules essential for early life.

The earliest forms of life consisted of organisms known as prokaryotes. Bacteria and blue green algae are examples of these simple life forms, known to have developed over the first few billion years of Earth history. They have been remarkably resilient and continue to play an important role in the complex web that characterizes life on our planet today. Bacteria function as nature's garbage disposers transforming all kinds of organic wastes to more useful compounds. There are bacteria that rely on chemical energy for their metabolism and bacteria that have evolved the capacity to utilize sunlight. The blue green algae, for example, have the ability, using sunlight, to convert chemically inert diatomic nitrogen (the dominant component of the atmosphere) to forms of nitrogen such as ammonia that can be readily incorporated in the structural material of plants and animals. To transform inert molecular nitrogen to biologically useful nitrogen today we rely on chemical factories consuming large quantities of fossil fuels to produce the high temperatures (thousands of degrees) required to fracture the tight triple bond linking the nitrogen atoms in molecular nitrogen. As another example of the diverse function of bacteria, consider the role they play in allowing animals such as cattle, sheep and goats (so-called ruminants) to feed on plant material (grass for example) that we would find totally indigestible. The bacteria in this case play an essential intermediary role in the ruminant food chain. They convert low-grade organic matter in the second stomach of these animals to higher-grade materials that can be ingested directly by the animals. In the process they evolve waste products such as methane that are released to the atmosphere with implications, as we shall see later, for global climate. Bacteria are ubiquitous, multifunctional and essential for life. And all of this remarkable diversity arose over the first few billion years of Earth history.

The next stage of evolution involved the appearance of eukaryotes, unicellular organisms significantly more complex than their prokaryotic antecedents. Lynn Margulis (1981) suggested that the eukaryotes evolved as a result of the fusion of cells of preexisting prokaryotes. Think of one species of prokaryote eating another. The ingested cell is incorporated by the scavenging cell to form what is known as a mitochondrion, one or more of which are present in all eukaryotes. The new organism combines, and in many cases extends, the functionality of its progenitors. The evolution of the eukaryotic cell paved the way for the development of more complex multicellular organisms, eventually plants and animals and ultimately humans. This monumental evolutionary step – the evolution of the eukaryotic cell - took place roughly 1.5 billion years ago. Along the way, eukaryotes developed a capacity to survive in the presence of free oxygen, the inevitable by-product of photosynthesis. Until organisms evolved this facility, the influence of photosynthetic organisms was limited by the need to dispose of their oxygen waste. They did so by attaching the oxygen to conveniently available, chemically reduced, elements such as iron. The development of an oxygen-mediating enzyme eliminated the need for reduced iron allowing oxygen to be released to the external environment. This resulted in a build up of oxygen in the atmosphere and ocean triggering, roughly 2 billion years ago, the first known consequential change in the global environment. Organisms without the capacity to tolerate free oxygen were banished to anoxic microenvironments or refugia. The appearance of free oxygen in the atmosphere led also to the production of ozone in the atmosphere in sufficient concentration to shield the surface of the Earth from biologically lethal doses of ultraviolet solar radiation that prevailed previously, paving the way later, about 440 million years ago, for the migration of life from the ocean to land.

The pace of evolution has been distinctively sporadic. There were periods when large numbers of new species developed over relatively brief episodes of geologic time. And times characterized by massive extinctions. Progenitors of all of the modern phyla are present, for example, in the Burgess Shale, a remarkable assemblage of fossils, dated at about 440 million years before present (BP), discovered by C. D. Walcott high in the Canadian Rockies in 1909. The explosion of new life forms that arose during the Cambrian Period (543 million to 510 million yr BP), recorded in the Burgess Shale, was followed a few hundred million years later, at about 225 million yr BP, by what Steven Gould (1989) termed the "granddaddy of all extinctions", responsible for elimination of as much as 95% of all marine species alive at that time. A second major extinction, triggered 65 million years ago by the impact of a giant meteorite, led to the demise of the dinosaurs paving the way for the later ascendancy of large mammals and eventually our human ancestors. As Gould points out, mammals spent their first 100 million years (they appeared first about 160 million years BP) as "small creatures living in the nooks and crannies of a dinosaur's world". The demise of the dinosaurs was a happy event for the mammalian world and indeed for us humans. As Gould drolly remarked: "in an entirely literal sense, we owe our existence, as large and reasoning animals, to our lucky stars."

3. Emergence of Humans

Our closest relatives in the animal kingdom are the giant apes (including the gorilla and the chimpanzee). Much of the development that led to the appearance of modern humans is thought to have taken place in Africa. The details of the evolutionary sequence are unclear. It is believed, however, to have proceeded along a trajectory that involved sequentially the appearance of Australopithecus africanus, Homo habilis, and Homo erectus. Homo erectus arrived on the scene about 1.7 million years ago and evolved later into Homo sapiens. Interpretations of human mitochondrial DNA suggest that we share a common maternal ancestor, a primitive Eve, and that she may have lived in Africa about 150 thousand years ago. As Diamond (1997) tells the story, our early ancestors were nomadic, hunter-gatherers, constantly on the move on the search for new sources of plant and animal species for food. Changes in climate may have had an important influence on their migration. The Earth was relatively warm 120 thousand years ago and we might expect that food and fiber would have been relatively available at that time in tropical and sub-tropical Africa. Climate then deteriorated as the world entered what developed as the last great ice age, which persisted with intermittent warm periods for close to a hundred thousand years ending only about 20,000 years BP (before present). It is reasonable to expect that our ancestors in search of food would have made their way first to the Middle East and to southern Africa (perhaps at the time when climate began first to deteriorate) populating subsequently much of the more temperate regions of Europe and Asia. They had arrived in New Guinea and in Australia by 40,000 years BP and had made their way north to Siberia and eventually to the Americas by the time the ice age had reached its peak 20,000 years BP. As noted earlier, sea level at that time was about 120 m lower than it is today. Asia was connected to the Americas by way of a land bridge across the Bering Straights. Within a few thousand years, the human presence had expanded to encompass most of the habitable portions of both North and South America (the exception the region occupied by the receding ice sheet that covered most of Canada for a further six or seven thousand years). By 20,000 years BP, humans had extended their range to encompass all of the world's continental landmasses with the exception of Antarctica.

The total worldwide population of humans in the hunter/gatherer age was small, a few million or less. To put this in context, there were probably more bison (buffalo) roaming the plains and grasslands of the Americas a few tens of thousands of years ago than there were humans at the same time on the Earth as a whole: the population of bison when the Europeans first arrived in the Americas has been estimated at between 20 and 30 million (Lott, 2002). Despite their small population, however, early humans had an impressive, and generally negative, impact on the environment. A short time after their arrival in Australia, most of the native large mammals disappeared. A similar fate befell the bulk of the mega fauna in the Americas.   Diamond (1997) suggests that 15,000 years ago, the American west would have looked much like the Serengeti Plain in Africa today with "herds of elephants and horses pursued by lions and cheetahs, and joined by members of such exotic species as camels and giant ground sloths." In a blink of geologic time this spectacular diversity was no more.

There can be little doubt that humans were responsible for this collapse. Diamond (1997) suggests that the large animals that populated Africa and Eurasia survived because that had coevolved for a long time with humans before humans had refined their hunting skills. As a consequence they had learned to take appropriate evasive action. The large mammals that populated Australia and the Americas had no such experience and had little chance to survive their first encounter with our environmentally insensitive, voracious, ancestors. We have only recently begun to appreciate the extent to which our future depends on a harmonious coexistence with nature. E. O. Wilson (1999) has argued that we are in the midst today of an extinction event that rivals any the world has witnessed over at least the past 500 million years, greater even than the momentous event that terminated the era of the dinosaurs. The weapons we employ now are not the spears or bows and arrows of our hunter/gatherer ancestors but the fire and bulldozers we use to transform landscapes and to eliminate whole ecosystems in our quest for what we perceive as more productive uses of land. Nowhere is this problem more serious than in the tropics where the diversity of life is greatest and where community structures are most complex. A recent study by the United Nations suggests that 25% of the species living in tropical forests today may be doomed to extinction over the next few decades if current trends in deforestation are not reversed. Deforestation in the tropics is responsible today also for significant emissions of CO_2 contributing to the problem of global climate change (the source is estimated to amount to as much as 30% of the source from global combustion of fossil fuels),

4. Current Challenges

Global population has risen now to an unprecedented level of 6.4 billion and is projected to climb to close to 9 billion over the next 40 years. The good news is that an increasing fraction of the world population is enjoying a measure of unprecedented economic progress, the fruits of technological developments that ensued over the past several centuries. According to some estimates, three hundred million people have been lifted from extreme poverty in China since 1990 with an additional two hundred million in India, a monumental achievement by any development measure. Globally, people are living longer. Rates of infant mortality are on the decline. More people have access to adequate facilities for health care and education. And, in many parts of the world, but surely not all, women are assuming their rightful role as coequal partners in society. The bad news is this progress is confined to less than half of the world's population.

More than a billion of our fellow citizens are trapped today in unspeakable poverty, forced to survive on less than a dollar a day (Sachs, 2005). In parts of our modern world, notably in sub-Saharan Africa, deadly diseases such as AIDS, tuberculosis, and malaria are on the rise. The quality of physical environments is in many instances on a path to ruin reflecting unsustainable demands on soils, waters, and the biota imposed by peoples driven to survive in the present without the luxury of planning for the future. It is a sad fact that aspirations for poverty alleviation and environmental protection are often antithetical. Added to this, the toll from disasters, natural and man-made, is in many cases catastrophic and the situation is getting worse not better. Unanticipated variability in climate—droughts, floods and violent storms—pose challenges for those least equipped to cope, a problem experienced increasingly in many different parts of the world, notably most recently in New Orleans and the Gulf States of the U.S. Those of us who live in the so-called developed world owe much of our affluence to access to relatively inexpensive sources of energy - coal, oil and gas - to drive our economic engine. But we are mining this resource at a rate 20 times faster than nature can replace it. Increases in the concentration of CO_2 in the atmosphere – levels higher than at any time over the past half million years and arguably much longer - attest to the significance of this influence. We are concerned today that changes in regional and global climate may ensue with consequences beyond our ability to predict with confidence. And in an interconnected world, we cannot assume that regional problems will be regionally confined.

Can we continue to rely on fossil sources of energy or do we have alternatives that might be environmentally more benign? Can we use what we have more efficiently? Are the resources of the Earth up to the challenge of supporting the aspirations and demands of a future population of close to 10 billion? Can we survive in a world where the gap between rich and poor continues to widen? Are there strategies we can employ to ensure a more equitable distribution of resources? These are the challenges we must confront and knowledge of whence we have come and a sense of moral responsibility are essential if we are to develop strategies that can be successful in the future.

Environmental problems in the past were experienced mainly on a local level, associated usually with effluents, both domestic and industrial, responsible for a combination of dirty air and polluted water (both surface and sub-surface) with complex consequences for both human and ecosystem health. It was relatively easy to associate cause with effect. Burning coal adds large concentrations of sooty materials to the atmosphere in addition to gaseous compounds of nitrogen and sulfur oxides and a variety of toxic elements including (for example) mercury. The effluents from coal burning have a demonstrably negative effect on human health. It took a series of air pollution disasters, however, in Donora, Pennsylvania, and in London in the late 1940's and early

1950's before public opinion was raised to a level requiring action. We learned later about the problems of acid rain and photochemical smog.

Solutions for the most part involved technological fixes - reducing the emissions of pollutants either by pre-treating fuels prior to combustion or by installing devices in the smoke stacks of power plants and factories and in the tail pipes of cars to accomplish a similar objective. Alternatively, we opted to switch to less polluting fuels such as natural gas. In either case the solutions involved increased expense. We have been modestly successful in addressing the issue of air pollution in more affluent societies. It remains serious, however, in large developing countries such as China and India where coal is the primary fuel and where priorities for economic development take precedence often over demands for environmental protection. We in the developed world chose to get rich first before taking action. Can we really blame developing countries if they opt to follow our lead?

Environmental problems, unfortunately, are no longer local. They have expanded now to global scale. The end product of combustion of fossil fuels is CO_2 with potential to alter global climate with uncertain implications for temperature, rainfall and even sea level. Warmer temperatures and uncertain supplies of precipitation (sometimes too much, sometimes too little) can exacerbate problems for those least equipped to cope. We have a moral imperative, I believe, to anticipate these problems and to do what we can to mitigate their potential adverse consequences.

The climate of the Earth depends on a complex interaction of the atmosphere with the ocean, biosphere, hydrosphere and cryosphere (the ice world). Coupling between the atmosphere and ocean is relatively direct. Since the thermal inertia of the ocean is greater than that of either the land or atmosphere, an ability to predict the future state of the ocean offers a an opportunity to forecast, at least to a limited extent, the future state of the climate. An important development in recent years is our ability to forecast on a probabilistic basis the state of the tropical Pacific Ocean as much as a year or so in advance: to predict probabilistically the development of an incipient El Nino or La Nina or indeed the multiplicity of possible intermediate states that can arise within these extremes. Knowledge of the future state of the tropical Pacific Ocean allows us to make meaningful predictions concerning the future state of climate with greater or lesser skill for different regions of the world. For example, in the presence of an El Nino we can be reasonably confident that climate conditions in Northeast Brazil will be characterized by drought while conditions in Peru and Indonesia will be distinguished by the opposite - an excess of precipitation. With advance knowledge of climate, we must expect that local authorities could plan better to conserve water resources when this is appropriate, to select optimal crops for planting and to mobilize in advance resources to deal with potential, future, climate-related, diseases such as malaria, for example. Predicting climate on longer time scales is a more demanding, and surely more uncertain, exercise. There can be little doubt though that by adding vast quantities of greenhouse gases in the atmosphere we are on the way to triggering a change in global climate for which we must assume specific responsibility and for which especially the poorest of our global fellow citizens may be least equipped to cope.

The United States is the world’s largest emitter of the critical greenhouse gas carbon dioxide: China is number 2 but sure to catch up in the not too distant future. With 5% of the world’s population, the US accounts for 22% of emissions. Electricity generation, associated mainly with combustion of coal, is responsible for 40% of US emissions. Transportation, fueled primarily by oil, contributes an additional 32%, with the balance attributable to a combination of home/office heating and cooling (11%)and various industrial processes (18%). China, with more than a fifth of the world's population, accounts for about 14% of global CO_2 emissions, reflecting again intensive use of carbon-based fossil fuels. Coal burned chiefly for electric power generation, by industry, and for domestic heating accounts for more than 60% of total commercial energy consumption in China. Oil, supplied increasingly by imports, makes an additional contribution of more than 25%, and, given the ongoing expansion of the Chinese transportation sector, is likely to account for a much larger share in the future. Car ownership is still relatively small in China but growing rapidly. Should car ownership in China approach even a fraction of ownership in Japan or Korea (not to mention the US where there are more cars than registered drivers), the national and regional consequences are likely to be extremely serious: deterioration of air quality with implications for public health, a decline in agricultural productivity (provoked by a likely increase in the abundance of atmospheric ozone), and a need for diversion of scarce economic resources to fund the necessary infrastructure of roads, bridges and gasoline stations. It goes without saying: Los Angeles is not the best model for the future Chinese mega city, nor should it provide a model for India or other populous developing economies. We need to learn from the mistakes of the past to ensure a more sustainable future without compromising legitimate aspirations for development.

5. Potential Responses

There are four obvious strategies to reduce carbon emissions in the US (and other developed countries) while still preserving energy functions we have come to value. We could encourage substitution of energy efficient for energy inefficient electrical devices (replace incandescent lights with fluorescent lights for example). We could institute standards for construction of more energy efficient buildings. We could explore policy instruments to encourage a transition from gas guzzling SUV's to more fuel-efficient alternatives (hybrids for example or improved public transport). And, most ambitious, we could take steps to initiate the transition from carbon intensive energy sources to carbon free alternatives such as wind, solar and/or nuclear. Any and all of these options could provide a better model for development elsewhere.

Independent of concerns for the environment, there is an obvious, security, interest to reduce the world's dependence on oil from potentially unstable, unreliable, sources. Imports account for 62% of current US domestic consumption of oil and their contribution continues to increase. A tax on gasoline could promote a switch to more energy efficient vehicles in the US. Politicians in the US, however, show little inclination to take such a step even if the tax were implemented in a revenue neutral form. It could be offset for example by a reduction in taxes on income and/or capital. We could institute a purchase tax on gas-guzzling vehicles offset by a subsidy for fuel-efficient alternatives. But, political will is lacking. Will it take another oil crisis to prompt action? The solution is clear: we need to reduce consumption of oil - foreign and domestic.

Wind power is economically competitive with fossil sources of electricity today even without subsidies. A recent study by Archer and Jacobson (2005), focusing on regions with mean annual wind speeds in excess of 6.9 m/s at a height of 80 m, concludes that wind power converted to electricity with an efficiency as low as 20% could supply 100% of the world's total current demand for commercial energy or seven times current global use of electricity. To realize the potential of wind power, we need to upgrade and expand national electric grids so that power generated in a farmer's field in North Dakota, or in the Gobi Desert, may be made available to consumers far removed. Excess power could be used to generate hydrogen, or some suitable alternate chemical intermediary, that could substitute at least partially for oil in the transportation sector. And we should think seriously about a new generation of nuclear power plants with appropriate planning to deal with issues of safety and waste.

We need leadership from developed nations to mobilize the intellectual and entrepreneurial skills required to effect the transition from an unsustainable resource-consumptive world to an environmentally friendlier alternative. We should not pretend that global warming is not a problem, that coal can be cleaned to the point where its environmental footprint is negligible, and that we can be isolated from the problems of poverty and environmental destruction in Africa or in Southeast Asia. We live in an interconnected world. It is our responsibility to ensure that its proper order is respected. The world needs leadership not just from developed countries such as the United States, Canada, the European Community and Japan but also from large developing economies such as China and India to mobilize the intellectual and entrepreneurial skills required to effect the transition from an unsustainable resource-consumptive world to an environmentally friendlier alternative. We need time to tide us over the problems associated with the ongoing global demographic transition; at the root of the current crisis is the unprecedented size of the current global human population and the excessive demands it imposes on natural resources. We need to adopt with enthusiasm the goals implicit in the UN Millennium Project (Sachs, 2005) and to invest accordingly to reduce poverty, and improve public health especially for those most vulnerable, the very young and the very old. It is a cruel hoax to allege that air and water pollution and soil depletion and forest destruction and species elimination are acceptable, that global warming is not a problem, that every adult has a right to a private car, that coal can be cleaned to the point where its environmental footprint is negligible, and that we can be isolated from the problems of regionalized poverty and environmental degradation.

6. Ethical Dimensions

Do we have the right to change the composition of the atmosphere globally when we are unsure as to the ultimate consequences and when the best scientific studies suggest that they could be serious and persistent? The God of the Old Testament as recorded in the message of Genesis gave man "dominion over the fish of the sea and over the birds of the air and over every living thing that lives on the earth." Nowhere, though, did He give man the right to destroy for no good reason. Dominion, for most biblical scholars, implies stewardship, not domination. No less an authority than Pope John Paul II is on record with a statement of the underlying principals. In a message delivered on January 1, 1990, referring specifically to the "depletion of the ozone layer and the related greenhouse effect [that] has now reached crisis proportions as a consequence of industrial growth, massive urban concentrations and vastly increased energy needs" he stated that:

> Theology, philosophy and science all speak of a harmonious universe, of a cosmos endowed with its own integrity, its own internal, dynamic nature. This order must be respected. The human race is called to explore this order, to examine it with due care and to make use of it while safeguarding its integrity.

How can this message be reconciled ethically with a decision to do nothing in response to the range of human-induced threats to the global life support system discussed here? There is only one possible justification: a conviction that the problem is not real. But even the most recalcitrant skeptic must accept the possibility – I would say probability – that the threats are serious and conceivably even understated. We do not, I believe, have the right to place the balance of the global life support system at risk when there are sensible actions that can be taken at least to slow the pace of human induced change. The answer to the question posed at the beginning of this paragraph, for me at least, is an unequivocal no!

How should we view the attitude expressed by the United States Senate, endorsed by President Bush, that the United States should not act to reduce its greenhouse gas emissions until such time as the large developing economies such as China and India are prepared to make a similar commitment? Energy consumption, measured on a per capita basis, in the developing world is more than 10 times less than it is in the developed world. With approximately 5% of the world's population, the United States is responsible for more than 20% of global emissions of CO_2. Is there not an ethical imperative for the rich to take the first step? The New Testament extols the responsibility of the rich to help the poor. The Gospel of Mark teaches that "it is easier for a camel to pass through the eye of a needle than for a rich man to enter the kingdom of God" and indicates as the Second Great Commandment that "you shall love our neighbor as yourself." Is it not appropriate, and indeed ethical, for we who have enjoyed for so long the benefits of unsustainable energy consumption to take the first steps? For me at least, the answer again is affirmative. And there is also a practical reason to take the lead. A commitment on the part of the United States to reduce domestic emissions of CO_2 could stimulate development of new energy-efficient technologies that would find applications not only in the developed world but also in countries of the developing world. It is clear that we could accomplish much of what we do today with less energy. Expanded use of hybrid vehicles or improvements in public transportation, for example, could increase the efficiency of energy use in the transportation sector. Advances in fuel-cell technology offer promising opportunities to curtail demand for fossil fuels. Wind power is already competitive with fossil-fuel-generated electric power in some regions. With additional investment, solar energy could make a contribution, and, despite current difficulties, the potential for safe nuclear power in the future should not be ignored. The key is to provide incentives. These are largely lacking in an era when gasoline is (still) cheaper than bottled water and where costs of waste disposal are invisible.

President Bush was correct in his overall conclusion that the Kyoto Protocol is unworkable in its present form. The response, however, is not simply to walk away but to develop an alternate approach and to work with the international community to bring this into effect. A primary difficulty with the existing Protocol relates to the time line. It is unrealistic to expect countries such as the United States to meet their presently defined commitments by 2008–2012. Emissions in the United States are now more than 15 percent higher than they were in 1990. It would be helpful to extend the time horizon, to, say 2030, while at the same time stiffening requirements. This would acknowledge the reality that it will take time to effect an economically efficient transition to a more sustainable industrial order. Large amounts of capital are invested today, especially in developed countries, in systems rooted in the past - in an age of cheap fossil energy. Rather than relegate productive investments of the past to a premature scrap heap, it would seem sensible that they be phased out gradually as they reach the end of their useful life, permitting a more orderly transition to a less carbon-intensive future. We need a long-range plan, and incentives to encourage an effective transition.

The Bush administration has proposed an ambitious plan to address future energy needs of the United States. The plan includes incentives for conservation, for development of more efficient hybrid vehicles, for energy systems based on environmentally friendly fuel cells, for renewable sources of energy and for a new generation of nuclear power plants. It recognizes the need for a strategy for safe disposal of nuclear wastes and proposes important investments in so-called clean coal technology. It would be useful if the plan could be integrated with a strategy to address the climate issue. By emphasizing both the need to ensure the energy security of the United States while at the same time minimizing emission of undesirable pollutants, the administration could take an important step in formulating a comprehensive blue print that could ensure not only the economic future of the United States but also a more sustainable future for the less advantaged citizens of our global community.

The choice of 1990 as a reference point in the Kyoto protocol against which to gauge targets for greenhouse gas reductions was arbitrary. It works unduly to the advantage of the European Union in that events unrelated to the climate issue were responsible for an unusual decline in European emissions in the immediate post-1990 period (the demise of the coal industry in England and the integration of the energy profligate east into the new Germany). It would be useful to adjust the reference point to provide a more realistic representation of emissions by parties in the recent past. An alternative standard could be based on average levels of emissions for the decade of the 1990s.

In present form, the protocol addresses the emissions of a suite of greenhouse gases. It might be preferable, initially at least, to focus on one, the major culprit, CO_2. Our understanding of the factors responsible for the increase in the concentrations of a number of the other gases, notably CH_4 and N_2O, is deficient. Sources are related to a variety of disparate activities ranging from leaky gas lines to animal husbandry to waste disposal to rice cultivation. It is difficult to quantify emissions from any particular activity. In contrast, it is relatively easy to define the contributions to CO_2.

President Bush is correct that a successful strategy to address the challenge of climate issue will require a commitment not just by developed countries but also by the global community, specifically by the larger developing economies such as China, India, Brazil and Indonesia. Inclusion of the latter two is important in that these countries host the bulk of the world's dwindling reserve of tropical forests and a disproportionate share of the planet's biological diversity. They are responsible also for major sources of CO_2; emission of CO_2 associated with tropical deforestation is estimated (McElroy, 2002) to contribute at present a source of CO_2 equal to as much as 30% of that derived from worldwide combustion of fossil fuels. It is important, though, that developing countries be engaged in a manner consistent with the agreement defined by the Framework Convention, that "developed countries should take the lead." Extension of the time line to 2030, or even later, would allow time for diplomatic initiatives to define an equable basis for participation by the developing world and for developed countries to demonstrate their bona fides.

Decisions should not simply be left to governments. Private foundations, non-governmental organizations, businesses, academic institutions, and religious organizations all have important roles to play in advancing the goal of a sustainable, equable, global society and in protecting the irreplaceable legacy of 4.5 billion years of planetary evolution. Private foundations are increasingly important players on the international stage, responding to priorities defined by socially conscious sponsors. Free of the political constraints limiting actions by governments, they have taken the lead in recent years in addressing a variety of socially important issues in the developing world ranging from immunization of children against infectious disease, to the provision of small loans to encourage empowerment of women and other disadvantaged members of global society. Non-governmental organizations made their presence felt at the Earth Summit in Rio de Janeiro and subsequently at meetings of the World Trade Organization, the International Monetary Fund and the gathering of the so-called G8, the leaders of the world's most developed economies. Answering only to their members, these organizations are emerging as a powerful new force in international affairs. Investments and decisions by multinational corporations regulate flows of capital across borders, affecting the lives of countless millions of people around the world. Academic institutions, offering insights into nature and the human condition, also have an important role to play and can contribute to a more equable global society by fostering a deeper understanding of human problems while at the same time identifying creative strategies for their solution. Religious institutions can help set the ethical agenda. To be effective, though, they must be dynamic and must clearly enunciate their view of the place of humanity in nature. Where necessary, doctrines rooted in the past must be updated to incorporate insights from modern science. We must appreciate that human society, like nature itself, is dynamic. We need a global vision - to recognize that there is a unity to life on Earth, that we are part of nature, not independent, that we have the potential to change our environment but that we must exercise this power with discretion. We need a deeper appreciation for ourselves and for nature drawing on insights not only from science but also from intellectual traditions codified in the world's great philosophical and religious traditions.

Jared Diamond makes the point out that civilizations have risen and fallen repetitively in the past. For the most part collapses have been local or regional. The problems we face now, and prospectively in the future, are unlikely, however, to be geographically confined. For better or worse we live in an interconnected world. We have a responsibility to protect its environmental integrity while promoting better and more sustainable lives for its peoples. Inevitably, this will require hard choices and compromises. We must recognize that we are all members of the same global community. If we fail to act promptly, and in consort, our civilization, - regional and global - is at risk.

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