DISRUPTION: Climatic and Political

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The Disruption of Climate

The global climatic disruption now underway as a result of the accumulation of heat-trapping gases in the atmosphere is the most threatening and serious environmental and political disruption that the industrialized world has ever faced. It will bring major changes to our civilization no matter what we do. The changes may be constructive if we plan and act appropriately to correct disruptive trends in time. Or they may be highly destructive if we fail to act now. The chronic, cumulative changes of climate will produce progressive erosion of environmental function, moving the world downward on the scale of biotic and economic impoverishment toward the nadir represented currently in the western hemisphere by Haiti. Haiti has a dysfunctional landscape, no forests, no potable water supply, no irrigation. Agriculture has been driven to continuously eroding slopes, rivers find new channels as the old channel is clogged with new debris in every rain. While the cause of Haiti's environmental collapse is over population and persistent governmental failures, the environmental collapse puts an almost impossible burden on government because there is so little to work with, nothing on which to build an effective government, no place to stand, not even a water supply…and no money and no internal way to support the reestablishment of a governmental system capable of restoring essential resources and the public services it should offer. The environmental chaos assures, and is intensified by, the continuing political chaos

The choice remains open for other nations in correcting the erosion of the environmental envelope of civilization from rapid, continuous, global climatic disruption, but the longer the delay in making major corrections, the greater the descent toward the self-sustaining Haitian nadir, and the more difficult a return toward a stable human environment becomes.

The problem is straightforward, but consequences and cures are not.

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The problem is the accumulation of heat-trapping gases in the atmosphere as the result of human activities. The total fraction of the atmosphere that is made up of heat trapping gases is very small, far less than 1% by volume. About 80% of the atmosphere is nitrogen and about 20% is oxygen. Neither of these gases traps radiant heat. But water vapor, carbon dioxide, methane and several other gases that occur as mere traces in the atmosphere do trap heat and have a large role in determining the temperature of the earth. Carbon dioxide alone is responsible for about 50% of the additional radiant energy retained in the atmosphere as a result of human activities and, because its concentrations are rising abruptly, the earth is warming. Because its concentration is low, less than 0.04% by volume, its concentration in the atmosphere can be changed, even doubled, by the addition of quantities that are in fact small, well within the range of human activities. Human activities have in fact warmed the earth by an average of about 0.6 degree C over the past century (IPCC 2001) through the addition of heat-trapping gases, especially carbon dioxide, to the atmosphere.

Such a change sounds benign when averaged for the earth as a whole and spread over a century. The change is far from benign. It is in fact a change that varies greatly over the earth. There is, for example, very little change in the tropics but an increase of 0.2-0.5 degree C per decade currently in some sections of the high latitudes of the continents of the northern hemisphere (Environment Canada 2000). I return to the implications of such changes below.

A complicated series of factors influences the carbon dioxide content of the atmosphere. Carbon exists globally in several large reservoirs connected by flows that run in two directions (Fig. 1).

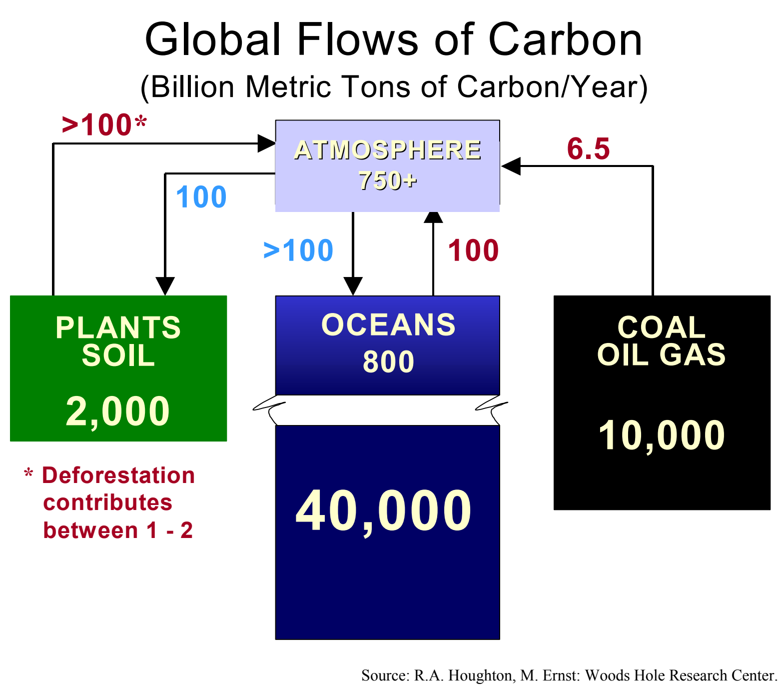
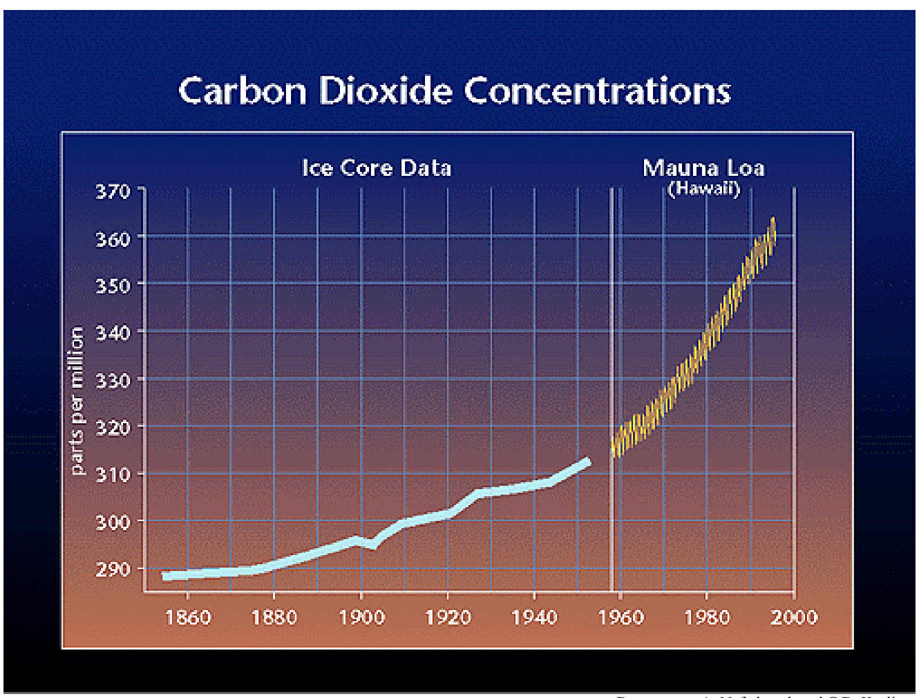


Figure 1

In the normal, pre-industrial world, the atmospheric carbon concentration was in an approximate equilibrium with both the oceans and the land. There were annual exchanges between the atmosphere and the oceans that involved about 100 billion tons. There was, and is now, another equivalent exchange on land with plants, largely forests, absorbing about 100 billions tons through photosynthesis and releasing it through respiration. The oceans are a very large reservoir of carbon held as gas dissolved in water as part of the carbonate-bicarbonate system. The time required for the surface water of the oceans to mix with the very much larger volume of deep water is 500–1000 years. That long mixing time means that in the short time of years to decades the capacity of the oceans for absorbing carbon dioxide from the atmosphere is limited although their total capacity is very large.

The industrial revolution of the past century and a half has brought two changes. First, the exploitation of fossil fuels, coal, oil, and gas, for energy taps a very large reservoir of carbon stored in the earth's crust and releases the carbon as carbon dioxide into the atmosphere. Second, it has brought major changes in the vegetation of the earth, especially the replacement of forests over large areas by agriculture and other uses of land. The carbon once stored in those forests in plants and in the organic matter of soil has also been released into the atmosphere.

The record of these two human activities is written into the biosphere in various forms. One of the best known and most compelling records is that of the carbon dioxide content of the atmosphere as measured on Mauna Loa in the Hawaiian Islands (Fig. 2).



Data source: A. Neftel et al. and C.D. Keeling.

Figure 2

Those data show that the carbon dioxide content of the atmosphere has risen from about 315 ppm in 1958 when the direct measurements were started to more than 379 ppm now. The data have been supplemented by data taken from gas bubbles trapped in glacial ice that provide a record of the last 460,000 years. We now know that the current carbon dioxide content of the atmosphere exceeds by more than 30% the highest atmospheric concentration in the most recent 460,000 years. The total amount in the atmosphere is more than 750 billion tons (Fig. 1). This sum has been rising annually by 2-4 billion tons as the two major processes releasing carbon have accelerated over recent decades (Fig. 2). The difference between this number, the 2-4 billion tons accumulating and the 8 billion tons released, is clearly being absorbed either into the oceans or onto land (IPCC 2001; Woodwell 1995; Woodwell et al.1995).

The terrestrial vegetation and soils also contain a large amount of carbon. The best estimates are that the total is more than 2,000 billion tons, approximately three times what is currently in the atmosphere. This large pool of carbon on land is maintained by an annual input through photosynthesis of about 100 billion tons that is approximately balanced by an annual loss through respiration, including microbial decay. Any change in either the rate of fixation of carbon (photosynthesis) or its release back into the atmosphere (respiration) has the potential for affecting the amount in the atmosphere immediately. The extent of that potential control appears in the data from Mauna Loa where there is a conspicuous seasonal cycle in the atmospheric concentration. That cycle is due to the difference in phasing of the seasonal curves of photosynthesis and respiration (Houghton 1987a,b). These two independent curves are integrated in the atmosphere and produce a seasonal minimum concentration at the end of the northern hemisphere summer and a maximum at the end of the winter. Any factor that affects either photosynthesis or respiration will affect the net accumulation in the atmosphere. In a flow of 100 billion tons of carbon in each direction, the potential for a significant effect is clear.

While the human-caused release currently is at least 8 billion tons of carbon, the accumulation in the atmosphere has been substantially less. Over the last decade it has been 3-4 billion tons annually. The remainder has been divided between the oceans and the land. About 2 billion tons appear to be absorbed into the mixed, surface layer of the oceans and the remainder is probably absorbed into forests, although defining just how and where has proven difficult (IPCC 2000).

The climatic disruption problem arises from the annual accumulation of those 3-4 billion tons of carbon as carbon dioxide in the atmosphere. Stabilizing the atmospheric composition would require immediately the removal of that amount of carbon from current releases. As the atmosphere becomes stabilized and the difference in partial pressure between the atmosphere and the surface water of the oceans drops, additional steps would have to be taken in reducing releases to accommodate for the reduced diffusion into the oceans and, possibly, for reduced uptake by plants as those pools, too, diminish in capacity (IPCC 2000). Stabilizing the composition of the atmosphere will ultimately require substantial abandonment of fossil fuels.

And Then What Happens?

The earth warms as radiant heat is trapped in the atmosphere. The warming, however, is not uniform. At low latitudes where the angle of the sun is high throughout the year and there is a greater inflow of radiant energy there is also abundant water available. The water, warmed, absorbs the heat in the energy of vaporization. The vapor enters the global atmospheric circulation to be released at higher latitudes where the vapor is cooled, condenses releasing its energy, and falls as precipitation. The higher latitudes are warmed by two to three or more times the average for the earth as a whole. While the average temperature of the earth has risen over the past century by about 0.6 degree C, northwestern Canada in the boreal zone has seen increases in temperature approaching 2.0 degrees C.

There are many other effects. One of the most important is the warming and drying of the continental centers leading to significant changes in the viability of forests, vulnerability to fire, and changes in agricultural potential across Europe, Asia and North America. At the same time glaciers are melting globally and sea-level is rising in response to the additional water and in response to the warming itself which causes the seawater to expand and fill the oceanic basins to new levels (Vellinga and Leatherman 1989).

But the fact is that the consequences are complicated, especially in the face of an open-ended warming that will proceed at rates of 0.1-0.3 or more degree C per decade in many parts of the earth. If the atmospheric concentration of heat trapping gases were stabilized immediately, there is sufficient warming already entrained to take the world into unknown and unpredictable territory.

Scientists are attempting to define what they think are the most important and compelling threats to the human future from this series of global climatic disruptions. The fact that the answers vary greatly only confirms the seriousness of the transitions. Four responses serve to emphasize the complexity, seriousness, and urgency of rapid collective action to deflect these hazards as rapidly as possible. I can only call attention to these analyses, not offer any of the richness of detail advanced by their authors.

The first and most common and probably most directly useful in government is series of analyses that starts with business as usual. John Holdren has offered the most comprehensive treatment in two comprehensive presentations recently to groups representing financial and political interests.[2] The emphasis is on energy and how the major user of fossil fuels, the United States, might lead the transition away from fossil fuels to stabilize the composition of the atmosphere at either 450 or 550 ppm, or by default, at even higher levels. Delays in taking any action at all make 550 ppm appear almost inevitable. The basic assumptions are that powerful forces are at work to support business as usual in the hope of a painless transition. Such a course could easily lead to a

[2] J. Holdren spoke on one occasion to the Institutional Investors Summit on Climate Risk, United Nations Building, November 2003, and again to the Carnegie Institution of Washington, Capital Science Seminar, March 2004.

substantially uninhabitable earth. He keeps all options open including nuclear power and hydro as well as the various forms of solar. Adaptation to the changes that have already occurred and further changes already entrained is essential and to be planned. Surprises, while real enough, cannot, of course, be planned into such elaborate systems. Nor can adjustments that seem superhuman or beyond reality at the moment. He pulls no punches in offering a diagnosis of what must be done and describes the consequences of failure by showing a slide of an earth warmed by 4x the pre-industrial burden of atmospheric carbon dioxide. There is little doubt as to the consequences for civilization of such a heat-blistered earth.

James Hansen (2004) has taken a slightly more mechanistic approach in which he lands heavily on the importance of the rise in sea level that is already entrained and likely to accelerate. The increase in sea level is due primarily to the melting of glacial ice that is now supported on land. As that ice melts or slips from the land to the oceans it adds to the volume of the oceanic water and raises seal level globally. So far those increases have been small, restricted to modest increments of new floating ice and new melt-water and to the expansion of the oceanic water as it warms. But the potential for increases in sea level are significant. After all, during the most recent glaciation, 10,000-15,000 years ago, sea level was more than 300 feet lower than it is at the moment. The ice cap on Greenland at the moment contains enough water to raise sea level by more than 20 feet. The melting of that ice cap appears to be accelerating (Fig. 3). The West Antarctic ice cap is also vulnerable and large enough to raise sea level by 20 feet. How soon such changes can occur is in question (Gregory et al 2004), but their reality over decades to a century is not. Nor can one rule out a sudden rise in sea level of a foot or more at almost any time. The implications for the world's billions, concentrated around continental shores and water bodies connected to the sea, are for more than a little inconvenience.

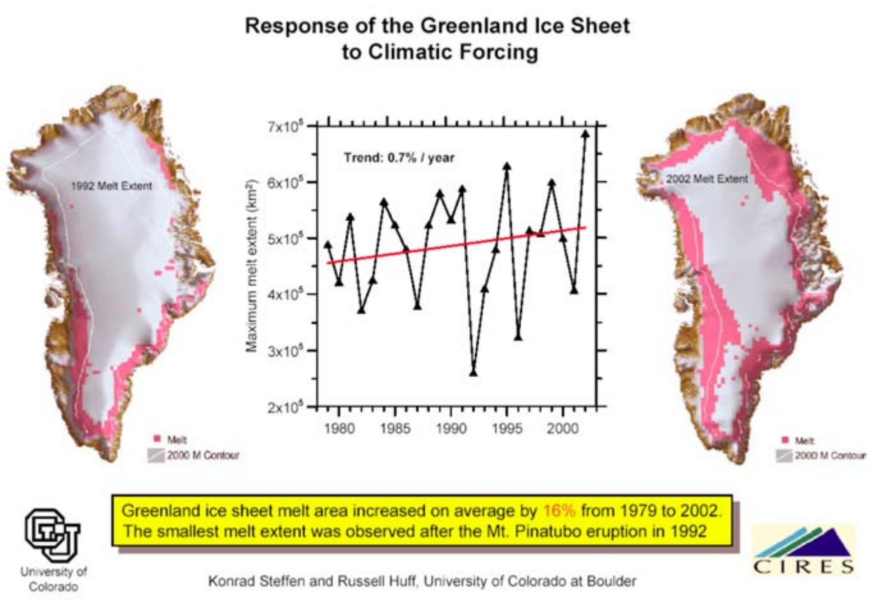


Figure 3

Beyond the certainty of a rise in sea level as the warming accelerates, oceanographers point out that the primary oceanic circulation in the North Atlantic Ocean is the Gulf Stream. The continuity of that massive transfer of water and energy from southern waters to northern Europe, Scandinavia and the coastal Arctic Ocean of Russia is dependent on the production of new deep oceanic water in the Labrador and Norwegian Seas. That flow depends on the density of the surface water, which must be high enough for the water to fall into the depths to flow southward into the Atlantic and replace the water flowing north and eastward in the Atlantic from the Caribbean. The melting of glacial ice in Greenland, Svalbard, and on the Eurasian continent to the eastward is flooding the region with freshwater which reduces the density of the surface water and raises the question of how long the circulation will continue at present rates (Gagosian 2003). Recent data suggest a reduction in the flow over the decade of the '90s (Hakkinen and Rhines 2004). The consequences of a reduction in the flow of the Gulf Stream, which appears to have happened in past time, are almost unimaginable and reach to major changes in the climatic regime of the northern hemisphere.

Complicating the awkwardness of increases in sea level is the further set of questions concerning the climate of the northern hemisphere as the ice that currently covers the Arctic Ocean year around continues to thin and gradually to disappear in summer. The change involves a shift from a white surface in summer to the dark surface of the open ocean with far greater potential for evaporating water into the atmosphere. How that new source of energy for the atmosphere will affect climates is not clear, but the potential is for further disruption.

These changes are not dreams. The fact that they are possibilities in a world hard pressed now to support 6.5 billion people is reason enough for concern.

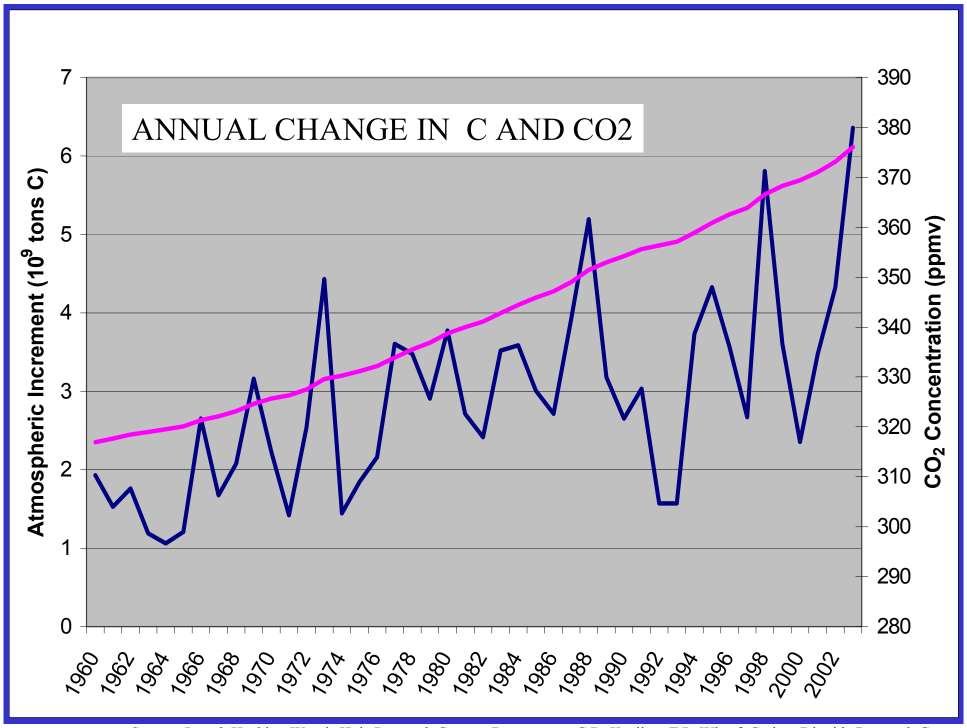
But these changes are not all. There are many other changes in the human circumstance entrained through climatic disruptions only superficially understood. I have been concerned for many years about the potential effects of increases in temperature on the metabolism of terrestrial ecosystems, especially in the boreal forest zone and in the northern hemisphere tundra where large quantities of carbon are stored in soils. The topic has been explored in detail by Woodwell and Mackenzie (1995). The essential facts are, first, that the carbon dioxide content of the atmosphere is affected profoundly in the short term of weeks to months by the metabolism of forests. The evidence for that controlling influence is the seasonal oscillation in the carbon dioxide content of the atmosphere conspicuous around the world and best documented in the record from Mauna Loa (Fig. 2). The oscillation we see in that record is the integration of two curves that are out of phase, the curve describing the annual course of net photosynthesis for the hemisphere as a whole and the curve describing the annual course of gross respiration. Because they are out of phase and may be of different magnitudes, the carbon dioxide content of the atmosphere in the Northern Hemisphere varies between a peak observed in late winter or spring and a minimum in September or early October. A similar pattern occurs in the Southern Hemisphere following the Southern seasons. The oscillation in the Southern Hemisphere is diminished in amplitude because there is much less land and less forest in those latitudes. A mere consideration of these curves is enough to emphasize the magnitude of the influence of the metabolism of forests on the short-term carbon dioxide content of the atmosphere (Houghton 1987a).

The second important but often overlooked fact is that the higher latitudes are warmed more than the rest of the earth. The difference is appreciable. The warming is 2 to 3 times the average for the earth as a whole.

Finally, because there is much land in these higher latitudes, about a third of the total metabolism of the terrestrial vegetation globally occurs in those latitudes. If the total metabolism on land approximates 100 billion tons of carbon annually, the metabolism of these northern forests and soils exceeds 30-billion tons of carbon. A 10% change in the ratio of photosynthesis to respiration due to an environmental change would be large in the global budget outlined in Figure 1.

Over the past twenty years and more the concentration of carbon dioxide has been increasing in the atmosphere by about 1.5 ppm annually. In the most recent decade the annual increment has increased to about 1.8 ppm. The annual increment of 1.5-1.8 ppm represents an increase in carbon in the atmosphere of between 3 and 4 billion tons, 50–60% of the annual release from burning fossil fuels, about 6.5 billion tons. There is a further increment released from the destruction of forests (changes in land use) of about 1.6 billion tons (Achard et al. 2002, DeFries et al. 2002, Houghton 2003b). The practical implication is that a total of about 8 billion tons of carbon appear to be being emitted into the atmosphere annually with 3-4 billion tons accumulating. The remainder is absorbed into the oceans or into plants on land. If we wish to stabilize the atmospheric burden of carbon dioxide, the initial step is to remove 3-4 billion tons of carbon from total global emissions, a difficult but entirely possible step that would require a 50-60% reduction globally in use of fossil fuels. Such an objective might also involve reductions in deforestation, of course. The Kyoto Protocol to the Framework Convention on Climate Change was negotiated to put the greatest burden for reductions on the industrialized nations that have made, and continue to make, the greatest contribution to the build-up.

The problem has become suddenly more serious. While the average annual accumulation of carbon in the atmosphere over more than a decade has been in the range of 3-4 billion tons, the rate of accumulation appears to be increasing (Fig. 4). In the past 6 years there have been two years in which the annual increment has surged above 5.0 billion tons. The most recent year, 2003, saw an accumulation as measured at Mauna Loa of 6.3 billion tons (NOAA), the highest level yet.



Source: Joseph Hackler, Woods Hole Research Center. Data source: C.D. Keeling, T.P. Whorf, Carbon Dioxide Research Group, Scripps Institution of Oceanography (SIO), University of California, La Jolla, CA USA 92093-0444.

Figure 4

The variation year-to-year is not a sudden change in the use of oil and coal and gas. If it were, we would have had to change our use by 25-50% in one year. We could not and do not do so. There may have been some change in annual consumption of fossil fuels, but far larger than any such change are changes in the metabolism of plants, especially forests and the deep organic layers of tundra and northern forest soils. The large increases conspicuous in the record (Fig. 4) are almost certainly surges in net emissions from the 100 billion tons per year of biotic exchanges between plants, including their soils, and the atmosphere. There are several components including the forest fires that have swept over the early years of the new millennium across the North American and Eurasian continents. Even larger, however, is the additional release of carbon from the accelerated decay of the large quantities of organic matter in the peat of tundra and boreal forest soils where the warming is 2-3 times the average for the earth as a whole. The process is but one element in the series of feedback systems associated with the warming of the earth. The overwhelming weight of those feedbacks is to accelerate the changes (Woodwell and Mackenzie 1995).

As the average annual growth rate of carbon dioxide in the atmosphere rises it approaches the limits of potential human control represented by the rate of release of carbon from burning fossil fuels, currently about 6.5 billion tons. The feedbacks then become dominant and the possibility of human control declines…or disappears. The problem is even more troubling in that at any moment in this process the temperature of the earth lags the heat-trapping potential of the atmosphere at that time. Once the concentration of heat-trapping gases has been stabilized in the atmosphere there will be still further warming as the earth gradually comes to a new temperature equilibrium over decades. As the temperature of the earth rises, the feedback mechanisms become stronger and raise the goal for stabilization.

What Should be Done?

The four transitions outlined here are underway. They are accelerating as the momentum of an industrialized world powered by fossil fuels continues to accumulate. The first, focussed simply on the requirements of the current civilization for energy without allowing for any biophysical deflection, leads to global increases in temperature that are clearly catastrophic in that they substantially destroy over the next decades the environmental envelope that the entire world depends on. The common assumption of the economic and political world, actively supported by the fossil fuel industry and allies, is that such a disaster is only the worst possibility of many and in any case sufficiently remote in time to allow a comfortable re-adjustment of energy sources to avoid a serious disruption. No real response is entrained beyond discussions under the Kyoto Protocol to the Framework Convention on Climate Change, both of which have been dismissed by the United States' current administration.

The other three possibilities deal with details of the climatic disruption. Each is considered by some as imminent with effects that will be felt in years, possibly decades. Effects, such as a major shift in oceanic currents, or an abrupt rise in sea level, could be severely disruptive. They are, of course, not the only changes entrained, but they are conspicuous major disruptions whose potential is enhanced daily by the array of positive feedbacks discussed above.

The nations of the world have ratified the Framework Convention on Climate Change and in ratification have declared their intent to stabilize the heat-trapping gas content of the atmosphere at levels that will protect both nature and human interests. The nations collectively, but under the leadership of the United States, have squandered the opportunity for a gradual transition away from fossil fuels, a transition started in the Carter administration and abruptly and stupidly abandoned in the Reagan administration and scorned by all subsequent US Houses of Congress.

The need now is for a major national effort in the US, first, to shift away from fossil fuels to renewable sources of energy. It must be a massive effort to be effective. An initial objective of reducing use of fossil fuel energy in the US by 20% is realistic and could be achieved almost immediately if we chose to do so. A 50% reduction is possible with substantial readjustment over a very few years. Greater reductions must come as we turn to renewable sources and massive efforts in conservation of energy. Second, there is no possibility of success without a parallel plan for management of forests that substantially stops further deforestation (changes in land use) and restores currently impoverished land to forest. These are not modest steps. They require governmental leadership including changes in tax structure, subsidies for alternative energy, and broad support from the public at large. Getting to that point will require intensive efforts by science and scientists to clarify the urgency and to define paths that will in fact work. The advantages are many, including personal and institutional independence from reliance on fossil fuel producers, correction of unfavorable balances of payments among nations, and simple solutions to a host of local and global pollution problems all related to use of fossil fuels.

None of these changes will occur without strong and persistent leadership from the scientific community sufficient to generate the political will to displace wars against people to a massive war against the rapid erosion of the human environment.

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