



# THE WOODS HOLE RESEARCH CENTER

149 Woods Hole Road · Falmouth, MA 02540-1644 USA  
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## **Awkward Facts About Climatic Disruption: Laissez-Faire Hell or a Garden of Eden?**

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I explore below paths that might, if followed, lead out of the chaos of an open-ended climatic disruption. Unfortunately the issues are complicated, the time for action is now late, and effective action is growing more difficult daily. Effective action is possible, however.

At the moment we appear to have a growing sense among political and economic interests that various natural laws and biophysical facts are easily compromised and adjusted to accommodate political and economic interests often defined as immutable "political reality". Such discussions have buried the scientific reality and led recently to discussions of the necessity for "adaptation" to "climatic change" as though there is a realistic hope of civilization's accommodating the accelerating erosion of virtually all aspects of the human environment, including its capacity for supporting agriculture and producing food for a still-expanding human population. Worse, well-defined changes in the earth's biophysics, accelerate the disruption as effects accumulate.

The fact is that the human enterprise is performing a massive shift in the distribution of carbon that has been stored over hundreds of millions of years in the crust of the earth, moving that carbon in just a century or so back into the atmosphere as carbon dioxide and methane. The transition is important because these gases are both heat-trapping gases: they both absorb radiant heat, the type of heat received from the sun on earth and the type of heat re-radiated by the earth back into the cold blackness of space. The carbon dioxide is the more important because it is more abundant and stays around in the atmosphere much longer than methane. We have, over the past century and a half, increased the carbon dioxide content of the atmosphere from about 270 ppm by volume to 383ppm, more than 40% . To be sure, not all of that increase is from burning fossil fuels; some of it is from deforestation, which continues at a high rate. But all of that increase is human-caused and its effect is to increase the retention of heat in the atmosphere. It warms the earth, destabilizing climates globally. The destabilization is now affecting the global food supply as the continents warm and become more arid. Effects are becoming clear in Australia, Africa and in our own Southwest. They are also becoming clear as prices of grain rise globally.

The details of this process, the accumulation of carbon as carbon dioxide in the atmosphere, and its causes and effects, are important because they tell us the seriousness of the problem, its causes, and what can be done to correct it.

The atmosphere is, in the normal world, in equilibrium with both the surface water of the oceans and the plant communities on land, the largest and most important (at least in this context) of which are forests. Although the concentration of carbon dioxide in the atmosphere is very low, less than 0.04 %, the total amount of carbon in the atmosphere is about 750 billion tons. That pool of carbon is in continuous exchanges through diffusion with carbon dioxide in the surface water of the ocean, another pool of carbon of about 800 billion tons, only slightly larger than the atmospheric pool. The exchanges through diffusion are large over the course of a year, about 100 billion tons in each direction, diffusing in and out. A small change in that series of exchanges can be important in that it will affect the atmospheric pool.

The atmosphere is also in continuous exchange with plants on land which absorb carbon as carbon dioxide from the atmosphere through photosynthesis and release it through respiration. Photosynthesis depends on light and is little



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affected by temperature, while respiration depends on temperature and is not affected by light. The magnitude of these exchanges is also about 100 billion tons in each direction annually. Again, a small shift in either process has the potential for affecting the composition of the atmosphere significantly.

Forests are by far the largest influence on land because they cover a large area, contain in their plants and soil about three times as much carbon as the atmosphere, and have the potential for absorbing and storing, or releasing, carbon in large quantities. They are also important because they are being destroyed over large areas and their stored carbon is being released, through decay, into the atmosphere, adding to the atmospheric accumulation.

Into this system of interacting carbon pools, atmosphere, oceanic surface water, and forests, humans have introduced massive additional quantities of carbon by mining and burning fossil carbon stored in the crust as coal, oil, and gas. This flow is one way: it is released as the product of combustion, carbon dioxide, heat and water, into the atmosphere. That flow, augmented by a flow from deforestation, has resulted in the accumulation of carbon as carbon dioxide in the atmosphere to a concentration that is now higher than at any time in the last 650,000 years for which direct measurements are available and probably higher than at any time in the last 20 million years.

The data showing this accumulation define year-by-year an upward march in the atmospheric burden. But they also show a seasonal cycle in the concentration that follows the metabolism of forests in each hemisphere with the high concentration at the end of the winter and the low concentration at the end of the summer. The cycle is more pronounced in the higher latitudes of the northern hemisphere where there is more land and more forest. It is important because it confirms the importance of biotic processes in affecting the composition of the atmosphere over a period of weeks.

The effect of the accumulation of carbon dioxide is a warming of the earth of, so far, averaged for the earth as a whole, something less than one degree Celsius since about 1850. Such an average is very misleading, however, for the warming is not uniform. The warming in the tropics is slight. There, water is abundantly available and the energy is absorbed through the evaporation of water and transferred as water vapor carried in the normal atmospheric circulation to the higher latitudes where, as the vapor cools the energy is released, warming those regions differentially. So a one degree change in the average temperature of the earth as a whole appears as very little change in the tropics and as three or more degrees of warming in the middle or higher latitudes.

And that, of course, is what we are seeing with the glaciers of Greenland melting with unexpected speed, the circumpolar boreal forest warming and drying out and burning with greater frequency and with larger fires than ever in history, the Arctic Ocean turning from an ocean of reflective white ice to an open sea in summer, dark and absorptive of energy. The process puts new energy into the atmosphere as water vapor and further disrupts climates around the world.

The changes in climate are far more serious than they may appear. The control that the metabolism of forests exerts over the composition of the atmosphere is but one sign of the extent to which the human habitat is a biotic system, maintained suitable for life by living systems themselves. Every organism exists in its place as a product of an array of genes selected to support that organism in that place. If the genetic complement were not appropriate, the organism would not be there. As the environment changes the organism becomes quickly maladapted and, maladapted progressively, it becomes vulnerable to diseases and pests. There is no surprise in the massive mortality of trees due to insect damage in the forests of southern Alaska, or the plague of bark beetles in the forests of Arizona. Chronic disruption of environment contributes to progressive biotic impoverishment of land and water. The culmination of the process of



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biotic impoverishment, whatever the cause, is conspicuous around the world on sites such as Easter Island at the time of rediscovery in the 18th century when resources had been depleted to the point where society had disintegrated to warring bands and cannibalism. Or we might look at contemporary nations such as the island nation of Haiti where over-population and mismanagement have led to a dysfunctional landscape that cannot support an economy or a government and, as a consequence, has had no functional government for decades. As in New Orleans, recovery in Haiti will depend on massive aid from outside. That aid must be aimed at restoring, first, a functional landscape with drainage basins stabilized by forests and with a re-established agriculture moved from 30 degree slopes that erode away in a year or two to stable land in the valleys now ravished repeatedly by floods of successive storms.

These changes, the warming of the higher latitudes, the destruction of forests, the accelerated decay of organic matter in forests and tundra soils, the melting of permafrost, the change from a reflective frozen white to black open water in the Arctic Ocean, and the warming of the surface water of the oceans all point to an acceleration of the warming trend. These are "positive feedbacks" which dominate as the earth warms and accelerate the disruption. Despite their importance, they have not been included in appraisals that suggest that a 2 degree average change in the temperature of the earth might be acceptable. The fact is that the feedbacks will almost certainly take the disruption beyond human control well before the temperature rise is 2 degrees C. Stopping at 2 degrees will not be possible.

A quick review of the numbers involved in the climatic disruption show what will work as a solution and what will not.

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First, the total emissions of carbon from burning fossil fuels reached about 8.4 billion tons per year in 2006, higher than ever previously. In addition to that release there was a release from deforestation, changes in land use from forest to agriculture (or impoverished land), of about 1.5 billion tons per year for a total approaching 10 billion tons of carbon for that year. Some of that carbon, about 2.0 billion tons annually, diffuses into the mixed layer of the oceans as a simple result of the higher concentrations in air. Some accumulates in the forests of the earth and their soils, probably 2.5-2.9 billion tons per year at present. The residue of 5.0 billion tons accumulated in the atmosphere in that year. This accumulation was well above the highest projections of any model used previously to anticipate rates of accumulation under business-as-usual and stands as a serious warning that the disruption of climate is proceeding at a rate exceeding commonly accepted predictions.

In 1992 the United States and virtually all other nations signed the Framework Convention on Climate Change at the Environmental Summit Meeting in Rio. The Treaty was later ratified by the US and the rest of the approximately 190 nations who in ratifying agreed to stabilize the heat-trapping gas content of the atmosphere at a level that would protect human interests and nature. That level has, obviously, been exceeded.

Worse, there is now a common suggestion that a two-degree change – one-degree more than that at present -- in the temperature of the earth would be acceptable and might be achieved by an 80% reduction in emissions of fossil fuels by 2040 or 2050. A two-degree change in the average temperature of the earth would be 4-6 degrees or more in higher latitudes, a catastrophic warming that would risk the mobilization of massive stores of carbon in forests and soils of the north, and a further release of methane as permafrost thaws and coastal waters warm. The positive feedbacks would own the earth and the warming would be beyond human control. Such assertions such as the two-degrees assumption are the



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ultimate in fallacy despite their popularity. The feedbacks open the real possibility that the commitment to warming existing in the atmosphere at the moment will produce a two-degree warming without a further buildup from additional use of fossil fuels and additional deforestation. An 80% reduction in emissions must be a much earlier objective. If it were set for 2012 it might be effective in avoiding run-away feedbacks.

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What might a new administration do if the world is fortunate enough to have wisdom and courage once again allied in the front end of government in the US?

First, it is clear that continuing on the present course of accelerated use of fossil fuels will lead to an open-ended climatic catastrophe whose earliest effects are underway now and accumulating in number and severity. These changes will inevitably produce a new, progressively impoverished world, a chaos that no one wants. We have already watched the continental warming long predicted with its aridity affecting Africa, Australia, our own Southwest and Mexico. We anticipate crises of water availability, of sea level rise, of agricultural displacement with declining yields, of disease, of fire in forests, and epidemic diseases of plants and people of the displacement of millions as environment erodes around them depriving them of place and food and livelihood. The migrations are already underway. The southern European frontier is overwhelmed now with African refugees fleeing the political and economic chaos of impoverished regions. The consequences of these environmental changes for political upheaval in a world of 6.5 billion people are frightening. And they are with us now. Continuing on the present course assures an environmental, and therefore an economic and political, hell over the next decades.

The era of fossil fuels must end abruptly. The immediate challenge for the first years of a responsible US administration is clear leadership, first, in stabilizing the atmospheric burden of heat trapping gases in preparation for a major global program of reduction toward 350 ppm carbon dioxide or less. These steps are necessary and US leadership essential. It can be done, but it must be a new global effort.

There is a mix of innovations that a president can draw on, but scientific insight and advice will be required to be sure that the steps taken are in fact incisive and likely to be effective. Solutions must involve billions of tons of carbon globally.

## **First, displacement of the carbon-based energy systems:**

It seems obvious that there must be a major international program in developing solar-based electricity and solar-powered production of hydrogen (and ways to store it as well as use it) while encouraging every nation to participate through ambitious foreign-aid programs with the wealthy industrial world taking the lead.

## **Second, conservation:**

A US president of courage, good will and wisdom will lead the nation in an immediate reduction in use of fossil fuels by 25 % through conservation alone to reach 50% within five years through structural changes involving improved equipment and conservation.

This transition might well involve a decision to proscribe any further development of coal and a rapid transition away from present uses. There are many obvious advantages in avoiding further mining and further corruption of land and



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water and air through use of coal, whatever its price. We disapprove of murder in general, even for profit, and must disapprove of continued killing with coal.

The new president would as well use all his or her influence to proscribe the exploitation of tar sands and oil shales for oil on the basis that there is just not environmental room for such wasteful enterprises, destroying land and water and atmosphere for momentary profits at public expense.

### **Third, restructuring economic incentives:**

Progressive taxes on fossil fuels will produce money to provide subsidies for the development and use of solar energy and local energy-producing facilities, to speed the development of mass-transit, the relocation of housing close to work places, and other obvious elements in the transition to a new world most of whose details have yet to be imagined.

### **Fourth, managing forests globally:**

Deforestation globally must cease. Globally we can reduce the build up in the atmosphere by 1.5 billion tons annually by declaring all primary forests off limits for further cutting. That step would have no effect on timber or fiber availability according to the Report of the World Commission on Forests. World needs can be met from managed stands of secondary forests and from existing agricultural land. This step puts all the earth's remaining primary forests into reserves, as they should be for many reasons that have nothing to do with global carbon management but much to do with human interests and welfare.

Reforestation of 1-2 million square kilometers (a million square kilometers is about 600 miles by 600 miles) would store annually 1-2 billion tons of carbon in trees and soils.

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The urgency of the global climatic crisis is finally attracting public attention as the predictions of the Stern Report, a recent statement by Achim Steiner, Executive Director of the UN Environment Programme (NYT, p. 10/25/07), Al Gore's persistent representations, and the longstanding entreaties of the scientific community in various forms over decades become the present reality. The reactions are themselves disturbing: massive efforts to substitute alcohol for gasoline, a transition that puts fuel for automobiles in competition with food, raising prices for all; suggestions that we put dust into the atmosphere to cool the earth; equally poorly based assertions that fertilizing the oceans with iron will store massive quantities of carbon as sediments; and the ever- hopeful assertions that we can capture carbon dioxide produced by power plants burning coal and store it indefinitely in deep wells, thereby assuring the future of cheap coal-fired power generation. With a surging world crisis, the product of studied delay by venal interests abetted by ideological stupidity on the part of US governmental leaders time for those experiments has run out and these techniques are rapidly becoming trifling and largely futile. Yes, efforts at developing them must be continued, but they have little to do with the immediate crisis, the product of irresponsible neglect over decades.

Stabilization globally can in fact be achieved through reducing the use of fossil fuels combined with management of land to favor forests. No other action offers short term corrections in the range of billions of tons of carbon. One combination of actions that would meet the need would require:

1. preserving all remaining primary forests globally, worth about 1.5 billion tons of carbon;



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2. reforestation of 1-2 million square kilometers of abandoned or impoverished land, 1.0 -1.5 billion tons per year;
3. an immediate global reduction in the emissions through use of fossil fuels of 25% of the current 8.5 billion tons about 2.1 billion tons per year.

There is no other way to find the new world we want and avoid the disaster we are headed for. In the slightly longer term, of course, the goals must include many other changes, especially a reduction in the human population toward 2 – 3 billion as opposed to the 6.5 billion or more now present or enroute. While Adaptation is often touted as a cure, or partial cure, there is no conceivable way for a world of 6-7 billion people, already desperately short of essential resources, including food, to adapt successfully to progressive, continuous, relentless, further impoverishment of its environment.

The important step at the moment is to realize that the emergency exists, requires immediate stabilization of the atmosphere, and that the stabilization is possible. While such steps seem at this late date heroic, they are small relative to the chaos assured if we continue to fail to take them. Waiting longer only makes the challenge larger. Taking these steps will not only avoid environmental chaos but can, if properly planned and effective, lead to a new world, potentially a Garden of Eden, with an industrial civilization powered, not poisonously by burning hydrocarbons stored in the earth's crust over hundred of millions of years, but by hydrogen obtained by hydrolyzing water using renewable sources of energy far more equitably available to all of the earth's inhabitants than oil and coal and gas, a wasting resource in every sense of that word.