



# THE WOODS HOLE RESEARCH CENTER

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## **Controlling the Climatic Disruption in Our Own Time**

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I am a scientist with an abiding interest in connecting science, especially the knowledge of environmental structure and function, to human affairs. I find it, however, most effective to follow the advice of Alvin Weinberg, who, for many years as Director of Oak Ridge National Laboratory in Tennessee and a highly effective expositor of the benefits and hazards of nuclear energy, argued that it is best to separate the clear knowledge of science--the facts--from social, political, and economic causes, consequences, and interests. 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 scientific reality.

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.

In the normal world, the carbon dioxide of the atmosphere is in equilibrium with both the surface water of the oceans and the plant communities on land, the largest and most important of which are forests. The total amount of carbon in the atmosphere is about 750 billion tons. That pool of carbon in the form of carbon dioxide is in continuous exchanges through diffusion with the surface water of the ocean, another pool of carbon of about 800 billion tons. The exchanges are large over the course of a year, about 100 billion tons of carbon diffusing in and out. The atmosphere is also in continuous exchange with plants on land which absorb carbon from the atmosphere through photosynthesis and release it through respiration. The magnitude of these exchanges is also about 100 billion tons in each direction annually. A small shift in either process has the potential for affecting the composition of the atmosphere significantly.

Into this system of interacting carbon pools in the atmosphere, oceanic surface water, and forests, humans have introduced massive additional quantities of carbon by mining and burning fossil fuels stored in the crust as coal, oil, and gas. This flow is one-way: It's released as one of the products of combustion (carbon dioxide, heat, and water) into the atmosphere. That flow, augmented by a flow from deforestation, which releases as carbon dioxide the carbon stored in plants and in soil, has resulted in the accumulation of 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.

The transition is important because carbon dioxide is a heat-trapping gas--it absorbs radiant heat, the heat received from the sun. That heat either accumulates in the atmosphere or is re-radiated by Earth into the blackness of space.

Over the past century and a half, we've increased the carbon dioxide content of the atmosphere from about 270 parts per million (ppm) to about 387 ppm--more than 40 percent. 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.



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There is a worrisome suggestion that a rise in global mean temperature of two degrees Celsius would be acceptable. The suggestion is that the warming might be limited to two degrees by an 80-percent reduction in emissions from fossil fuels by 2040 or 2050. But average values for a global warming are misleading. The warming in the tropics is slight, while at higher latitudes the effect is magnified. A 2-degree Celsius change in the average temperature of Earth means 4-6 degrees or more in higher latitudes, a catastrophic warming that would assure mobilization of massive stores of carbon in the boreal forest and tundra as the heat speeds respiration of all plants, decay of organic matter is accelerated. And, of course, warmer forests dry and burn with greater frequency. As permafrost thaws and coastal waters warm large quantities of methane, also a heat trapping gas, are mobilized as well. Despite its popularity, the assumption about two degrees of warming is the ultimate in fallacy because these positive feedbacks—warming leading to more releases of heat trapping gases and greater warming —will almost certainly take disruption beyond human control. Stopping after two degrees of warming will not be possible.

The fact is that the warming already entrained, the warming assured from the carbon dioxide already in the atmosphere, will ultimately produce two degrees of warming without further buildup from burning fossil fuels and continued deforestation. An 80-percent reduction in emissions must be a much earlier objective--if it were set for 2012, it might be effective in avoiding serious feedbacks.

A quick review of the numbers involved in the climatic disruption show what will work as a solution and what will not. 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, there was a release from deforestation of about 1.5 billion tons per year for a total approaching 10 billion tons of carbon for that year. In that year 5 billion tons accumulated in the atmosphere. That sum, 5 billion tons of carbon, is the immediate target. It was in that year well above the highest projection of any model used previously to anticipate rates of accumulation under business-as-usual. It stands as a serious warning that the disruption of climate is proceeding at a rate exceeding commonly accepted predictions.

Worse, reactions to the urgency of the global climate crisis are themselves disturbing: massive efforts to substitute alcohol for gasoline, a transition that not only puts fuel for automobiles in competition with food, raising prices for all, but also probably produces a net increase in carbon emissions globally; suggestions that we put dust into the atmosphere to reflect sunlight and cool the earth; equally poorly based assertions that fertilizing the oceans with iron will trigger algal blooms that will store massive quantities of carbon as sediment; and the ever-hopeful assertions that we can capture carbon dioxide produced by coal plants 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 long delays on the part of U.S. governmental leaders--the time for those experiments has run out.

The immediate challenge for the first year of a responsible U.S. administration is clear leadership in stabilizing the atmospheric burden of heat trapping gases in preparation for a major global program of reduction toward 350 ppm of atmospheric carbon dioxide or less. Solutions must involve billions of tons of carbon per year. There are two methods only for controlling billions of tons of carbon. But there are two methods: reductions in use of fossil fuels and managing land to



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favor forests. The removal of five billion tons of carbon from annual emissions is clearly possible in a very few years, given the political will.

Start with forests. Current emissions of carbon include about 1.5 billion tons from deforestation, changes in land-use from primary forest (intact, ancient forests) to non-forest uses, primarily agriculture, including pasture. There are many reasons for stopping this further destruction of the vegetation of the earth, all documented abundantly by the World Commission on Forests of several years ago and subsequently by The Millennium Assessment and others. Needs for land and fiber and timber can be met from secondary forests. Preserving the remain primary forests globally would reduced carbon emissions by about 1.5 billion tons annually.

In addition reforestation of 1-2 million square kilometers of deforested and impoverished land in the normally naturally forested regions globally would store annually in the developing plants and soils 1-2 billion tons of carbon for a total reduction in the 5 billion ton target of 2.5 billion tons.

The remaining 2.5 billion tons must come from a global reduction in use of fossil fuels of the order of 25-30 percent. This transition might involve placing a moratorium on any further development of coal power, and displacing such energy systems with solar-based electricity supplemented by new system for storage of energy. A massive program of producing and using hydrogen from hydrolyzing water with solar electricity may be the most promising major program. Progressive taxes on carbon emissions will encourage and subsidize the development and use of renewables and the various transformations in society that the transition demands.

This transition is, of course, only the first step in the inevitable transition to renewable energy. The stabilization of the atmospheric burden of heat –trapping gases starting with carbon dioxide does not stabilize global climates. Further reductions in emissions will be required to return the atmosphere toward the approximately 280 ppm carbon dioxide of 1900, a concentration not previously exceeded in 800,000 years. But the fact is that an emergency exists that requires the immediate stabilization of the atmosphere, and that stabilization is possible. While such steps seem heroic at this late date, they are small relative to the chaos assured if we fail to take them.

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. We have already watched the continental warming long predicted, with its resultant aridity, affecting Africa, Australia, the Southwest United States, and Mexico. We anticipate crises of water availability, sea level rise, agricultural displacement with declining yields, forest fires, human and biotic disease epidemics, and the displacement of millions as environment erodes around them, depriving them of place, food, and livelihood.

Waiting longer only makes the challenge larger. But by taking these steps, we'll not only avoid environmental chaos, we can lead ourselves into a new world, potentially a Garden of Eden. The fact is that the transition is available to us and not beyond reach, even at this late date.