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Anthropogenic Climate Change: Assessing the Responsibility
of Developed and Developing Countries

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If world fossil fuel use continues to increase the carbon dioxide loading of the atmosphere, and the apparent consensus of the international climatological community is correct, mankind is very likely to cause a significant average warming of the Earth's surface within the next 50 years. Inevitably, questions will arise concerning responsibility for the costs of the adverse impacts that might be suffered by regions or nations as a consequence of increased atmospheric carbon dioxide. In practice this means that a measure would need to be established to determine the proportional contribution of each region or nation to the problem.

One measure which has been used to quantify the relative contribution of carbon dioxide emissions from regions and countries,^{1,2} including developed³ and developing⁴ nations, has emphasized emissions in single, specific years. In our view, consideration should be given to calculating a measure of responsibility in terms of total past and future emissions of carbon dioxide. This is a function not only of annual emission rates but also a measure of the cumulative emissions over time.

In order to compute the future atmospheric burden of carbon dioxide, based on scenarios of future fossil fuel use and past emissions, one must use a model of the carbon cycle that accurately reflects the transient response of the earth-atmosphere-ocean system to annual carbon dioxide inputs. The model of Siegenthaler and Oeschger⁵ provides a calculation of the response of the system to a "pulse" input of carbon dioxide. Those authors make clear the limitations of their model in dealing with

large inputs of carbon dioxide to the atmosphere, since the transient response is a function of changes induced in the chemistry or dynamics of the ocean. However, their model offers results that can be used to approximate the date at which the atmospheric burden of carbon dioxide will have reached a specific level (chosen here to be a doubling relative to the assumed "preindustrial" value of 290 ppm). This model can also be used to calculate the relative contribution of developed and developing countries.

The first step in the application of Siegenthaler and Oeschger's model is the determination of the fraction of each year's emission of carbon that remains airborne after being released. The complete calculation requires a sum of the following kind:

$$\sum_{t=1860}^T f(T-t) E(t)$$

which gives the cumulative carbon burden, at time T , that results from annual emissions characterized by a rate $E(t)$ if a fraction, f , remains of each year's emissions after $T-t$ years. Siegenthaler and Oeschger's decay factor, $f(t)$, can be parameterized as $x/(x+t)$, with $x = 40$ which takes account of the slow takeup of the additional carbon dioxide by the deep ocean water and the biosphere. For example, the remaining fraction of the 1970 emissions will be 50 percent in 2010; but only 40 percent of the 1950 emissions will remain airborne in 2010.

The doubling date and the relative fraction of the added carbon dioxide contributed by developed and developing countries were computed by using the historical record of emissions for the period 1860-1976^{6,7}

and various scenarios of future carbon dioxide release that assume an exponential growth of $E(t)$ after 1976. By evaluating the sum above estimates are obtained of the growth in the atmospheric burden of carbon dioxide as well as the date at which the doubling will occur.

Figure 1 illustrates the fraction of the doubled airborne carbon dioxide contributed by developed and developing nations, as well as the date when the doubling will occur. The growth rates range from 0.01 to 0.04 per year for developed nations and 0.01 to 0.08 per year for developing nations.

It is clear from the diagram that for the developing nations to exceed 50% of the contribution to doubled airborne carbon dioxide in the first half of the next century they must have an average growth rate in fossil fuel use that exceeds 0.06 if the developed nations have only a 0.02 growth rate, or 0.04 if the latter can hold growth rates down to 0.01. Although developing nations have surpassed these levels in the past, such growth rates will become increasingly difficult to maintain, given the Third World's economic prospects for 1980 and beyond. Nor is it certain that the developed nations can limit their growth rates of fossil fuel use to less than 0.02.

Indeed, a growth rate well below previous estimates^{1,2} would seem more likely in the case of the Third World. Direct and indirect financial assistance from OPEC has enabled the 39 oil-importing developing countries to better cope with world inflation, sharp increases in the price of oil, and the heavy burden of meeting external debts owed to developed countries.⁸ The oil-importing developing countries face substantial energy problems even with their economic ties with OPEC countries. Further,

given the continued depletion of OPEC's oil supply, no one can be certain how much longer this aid will be available. There is also no guarantee that as petroleum resources are depleted and coal becomes the major fossil fuel resource, the developing nations will have the wherewithal to buy it from the coal rich nations of China, the U.S.S.R., and the U.S. At the same time, very large investments in either oil or coal imports will diminish developing countries' ability to make needed capital investments in agricultural modernization and industrial development.

A low-growth scenario, as described above, might result in fossil fuel growth rates of 0.01 and 0.02 for developed and developing countries respectively. In this case, the doubling would occur in 2080 and 70 percent of the carbon dioxide airborne at that date will have been contributed by developed nations. Hence Third World contributions to global carbon dioxide emissions may be considerably less than expected. A less likely continued high-growth scenario in which the growth rates of the 1970s persist, shows fossil fuel growth rates of 0.03 and 0.07 in developed and developing countries, respectively. In this case, the carbon dioxide doubling will occur before 2025 and 58% of it will be contributed by developed nations.

In sum, if the international community of nations is ever to assess responsibility for carbon dioxide production and changed distributions of climate, calculations must be extended backward and forward to encompass a range of reasonable scenarios of fossil fuel use and carbon dioxide emissions. The preliminary calculations of this paper indicate that developed countries might have to bear the brunt of responsibility for new climatic regimes, as suppliers of fuel to the world, as major

consumers, and as the major overall cumulative contributors of carbon dioxide to the atmosphere through the next century.

Figure 1. Percent of the doubled airborne carbon dioxide contributed by developed and developing nations. Note: Growth rates are used in an exponential carbon dioxide release model for dates after 1976.

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