Chapter 4: Implications for Global Climate

Future Concentrations of CO₂ in the Atmosphere

To prepare for a 1995 international meeting regarding the state of the global environment (led by the United Nations Environment and Development Program), the Intergovernmental Panel on Climate Change (IPCC) requested an in-depth study of the carbon cycle. The participating scientists were given a set of atmospheric CO₂ concentrations ranging from 350 to 1,000 ppm (that is, from today’s level to three times as great as today’s). Their job was to produce schedules of total anthropogenic emissions that would allow atmospheric CO₂ to stabilize at the chosen levels. The schedule selection was relatively arbitrary—many other choices could have been made—but all the schedules involved a smooth transition from 1990 emission levels to the levels that would be required to attain the target concentration. The project was designed to illustrate the relationship between emissions and resulting CO₂ concentrations. This relationship is not straightforward, because as atmospheric CO₂ concentrations increase, the percentage taken up by the ocean and the terrestrial biosphere decreases.

Figure 17 shows the emissions schedules that would lead to stabilization at three levels: 450 ppm, 550 ppm, and 650 ppm. In all cases emissions continue to rise initially and then drop sharply and rapidly. The IPCC participants allowed the initial rise because they considered it unlikely that governments would be able to enforce strict reductions before technology improved and fossil-fuel use became more efficient. The large decreases that follow do not represent predictions about changing policy or technology; they are simply the patterns that would be necessary to stabilize CO₂ at the chosen levels. Stabilization at any of these concentration levels (all of which are higher than today’s level) is only possible if emissions are eventually reduced well below 1990 levels.

For comparison, Figure 18 shows the atmospheric CO₂ concentrations resulting from three scenarios about future increases in human population, economic growth, and energy needs. (These scenarios, labeled...
IS92a, c, and e, were developed in a 1992 IPCC report.) IS92c is considered “optimistic” in terms of emissions because it assumes an eventual decrease in human population. Scenario IS92e is considered “pessimistic” by some because it assumes a phase-out of nuclear power (which most people believe would lead to increased fossil-fuel emissions), high economic growth, and moderate increases in human population. Scenario IS92a is considered by some to be “realistic” in its projection of human population growth, fossil-fuel use, and economic growth.

In fact, the relative “realism” of all the scenarios is hotly debated, since for a variety of reasons they do not take into account all of the factors known to affect emissions. For example, they do not include the effects of changes in land use, changes in the nitrogen cycle, or climate feedbacks. The effects of changing land use alone could add hundreds of Gt C to the atmosphere over the next one to several centuries, or could eventually store similar amounts over many centuries.

Thus these projections serve only as illustrations of the relationship between human disturbance of the carbon cycle and the atmospheric concentration of CO₂, rather than as definite predictions of future atmospheric concentrations. As one group of scientists noted, “An improved understanding of the carbon cycle is essential to predict the future rate of any atmospheric CO₂ increase and to plan eventually for an international CO₂ management strategy” (Tans et al., 1990).

**Options for Mitigating CO₂ Releases**

In an ideal world, mitigation options would not be necessary because people would realize the potential damage caused by perturbation of the natural carbon cycle and would work to curtail emissions from land use and use of fossil fuels. This not being a perfect world, there are several options for mitigating human-induced carbon cycle perturbation. The options center on three basic themes: (1) reduce emissions, (2) switch to a renewable energy source, and (3) increase the amount of carbon stored in the ocean and in the terrestrial biosphere. Obviously, these themes overlap. For example, switching to a renewable energy source, such as solar power, reduces emissions from fossil fuels. Likewise, planting forests to store carbon creates a renewable energy source.

Emissions will be reduced only if new technology becomes available that makes conservation economically sound or if governments force the reduction, through either subsidies, incentives, or taxes (disincentives). Keep in mind that any major transformation of the energy, industry, and transportation sectors of the economy is not likely to happen overnight, so emissions will continue to grow in the immediate future.

We are probably all familiar with some of the options for reducing emissions, such as taking public transportation instead of driving a car and keeping buildings cooler in the winter and warmer in the summer. This section will concentrate on the other types of mitigation options, those involving alternative energy sources and
carbon storage. One issue that must be remembered when assessing any of these options is whether it contributes to or undermines the goal of supporting a growing human population and simultaneously providing the required amounts of food, fodder, fiber, and biomass. An analysis of the socioeconomic costs associated with various mitigation options is presented in IPCC (1997).

**Developing Renewable Energy Sources**

Development of renewable energy sources would reduce emissions of traditional fuels. However, this transformation would have to be economically feasible, either through technological developments or via incentives. For example, vegetable oil crops are already used to produce biodiesel, and this fuel can be used in current diesel engines. The cost of biodiesel, however, is slightly higher than the cost of petroleum diesel, and so its use is not common.

Planting biofuel crops not only promotes alternative energy use, it also reduces emissions of traditional fuels and temporarily increases carbon storage. It is estimated that dedicated energy plants could be grown sustainably on 8–11% of marginal to good cropland in the temperate zone. One drawback is that biofuel crops compete with food crops for limited resources (e.g., water and nutrients).

Use of recycled wood and paper products and industrial timber and paper industry wastes as biofuels is an interesting option, but one that is not yet feasible.

**Increasing Carbon Storage**

Where sufficient land is available, planting forests can result in a fairly long-term (50 to hundreds of years) storage of carbon. Forestry currently offsets 90% of carbon released in Sweden through fossil-fuel burning. Table 6 shows the percentage of fossil-fuel emissions that is offset by forestry in eight other countries. In addition to serving as a storehouse for carbon, forests, like agricultural crops, can be used as an alternative source of energy. Wood grown in plantations can be used to generate electricity instead of using coal; this substitution can dramatically reduce CO₂ emissions to the atmosphere. Figure 19 depicts the amount of carbon that can be either stored or saved (not released to the atmosphere) by forests in several latitudinal bands. Note that the forests of the tropics have the greatest potential to affect future atmospheric CO₂ levels.

In some parts of the ocean, lack of iron (rather than lack of nutrients) appears to limit marine plant growth. It has been suggested that

Figure 19. Average annual rate of carbon uptake and storage per decade through forest management practices by latitudinal region. Note that the forests of the tropics have the greatest potential to reduce future atmospheric CO₂ concentrations. From Brown et al. (1996), p. 786.

<table>
<thead>
<tr>
<th>Country</th>
<th>Carbon Stored in Trees and Litter (Mt)*</th>
<th>Fossil-Fuel Carbon Emissions (Mt/yr)</th>
<th>Percentage of Fossil-Fuel Emissions Removed by Forests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain</td>
<td>&gt;87</td>
<td>164</td>
<td>1.5</td>
</tr>
<tr>
<td>New Zealand</td>
<td>113</td>
<td>8</td>
<td>44</td>
</tr>
<tr>
<td>Finland</td>
<td>978</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Germany</td>
<td>1,500–2,000</td>
<td>268</td>
<td>2</td>
</tr>
<tr>
<td>Canada</td>
<td>12,000</td>
<td>136</td>
<td>37.5</td>
</tr>
<tr>
<td>India</td>
<td>10,000</td>
<td>137</td>
<td>3.6</td>
</tr>
<tr>
<td>Poland</td>
<td>1,113</td>
<td>131</td>
<td>6</td>
</tr>
<tr>
<td>USA</td>
<td>18,585</td>
<td>1,300</td>
<td>6</td>
</tr>
</tbody>
</table>

*Mt is millions of tons.
increasing oceanic iron concentrations in these areas could speed up the biological pump and thus reduce atmospheric CO₂ levels. However, experiments in adding iron to ocean waters (called iron fertilization) have shown that although productivity was greatly increased at first, the final effect was negligible because the additional plant material simply joined the food chain. In other words, iron fertilization led to more sharks rather than to less atmospheric CO₂. Most scientists now believe that even excessive iron fertilization of selected areas of the ocean would have a relatively small impact on atmospheric CO₂ levels.

Several carbon storage options also not only reduce climate change but increase or restore ecosystem health. One such option is to convert marginal or surplus cropland and pasture to forest or natural (ungrazed) grassland. Another is to improve land-management practices, such as returning crop residues to fields, decreasing periods of fallow (when erosion danger is high), and reducing tillage. These changes would both increase carbon storage and reduce its loss in agricultural fields.

Because soils and vegetation have a finite capacity to store carbon, mitigation options that increase carbon storage are not sustainable over many centuries. To stabilize atmospheric CO₂ concentrations, eventually we will have to cut emissions, preferably via a combination of alternative fuel sources and increased efficiency.