CLIMATE CHANGE

CO_2 Arithmetic

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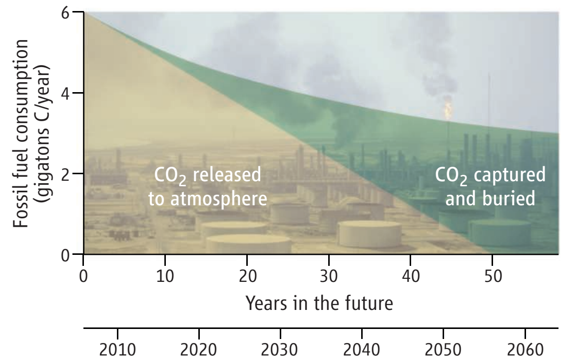
Strict emission limits will be necessary if the rise in atmospheric carbon dioxide is to be stemmed.

If we are ever to succeed in capping the buildup of the atmosphere's CO_2 content, we must make a first-order change in the way we view the problem. Most policies that have been discussed, including cap-and-trade systems and the Kyoto treaty, have treated the problem exclusively in terms of incremental reductions in CO_2 emissions. These, however, will not stabilize atmospheric CO_2 levels; they only slow the rate of increase. Instead, to actually stop the increase, we must develop the concept of what might be called a "carbon pie." Currently, for each 4 gigatons (Gt) of fossil carbon burned, the atmosphere's CO_2 content rises about 1 ppm; including deforestation, we now emit about 8 Gt of carbon per year. Further, this four-to-one ratio will only change slowly in the coming decades. Hence, if we set a desirable upper limit on the extent to which we allow the CO_2 content of the atmosphere to increase, then this fixes the size of the carbon pie. If, for example, this limit were to be double the preindustrial CO_2 amount (i.e., 560 ppm), then the size of the pie would be 720 Gt of carbon [i.e., 4 × (560 – 380)]. Were the limit to be set at 450 ppm, the size of the pie would be only 280 Gt.

Once the size of pie has been established, each of the world's nations would be allocated a slice. In an ideal world, the size of these slices would be based on population. In this case, the world's rich countries would get only about 20% of the pie. If the limit agreed upon were 560 ppm, then the rich nations' share would be about 150 Gt. As these countries together currently consume about 6 Gt of fossil carbon per year, if they continued at this pace, their allotment would be consumed in just 25 years. Faced with this limit, each of these rich nations would be forced to rapidly reduce its emissions (see figure, above). Poor nations would be able to sell portions of their pie slice to the rich countries and still have enough left to permit them to industrialize.

If this scenario were to be implemented, I find it highly unlikely that any combination of increased efficiency in energy use, implementation of non–fossil fuel energy sources, and capture of CO_2 produced in coal gasification plants would be capable of meeting the required reduction schedule: An additional element would be necessary. The gap (see figure, right) between actual and allowed emissions would have to be made up either by purchase of CO_2 allocated to poorer nations or by burial of CO_2 captured from the atmosphere. Stemming the rise in CO_2 would require participation of rapidly industrializing nations such as China and India. Under the pie concept, there would be an incentive for them to join for they would have a considerably longer period of time to adjust their CO_2 emissions than rich nations. The sooner such an agreement was put into force, the better the situation would be for these nations. Until this is done, the size of the carbon pie will continue to shrink at a rate of 70 to 80 Gt per decade.



Hypothetical scenario for use by rich nations of their 150-Gt wedge of the carbon pie. As time passes, the excess of fossil-fuel burning over the diminishing permissible emission limit will likely grow, requiring an increase in the amount of CO_2 to be captured and buried.

Because CO_2 sales would serve only as a temporary stopgap, capture of CO_2 from the atmosphere would be necessary. CO_2 capture from the atmosphere is feasible, but has yet to be implemented, and faces several technological challenges. If the CO_2 carried by the air streams used to drive wind turbines were to be captured, then on an energy-equivalent basis, the physical dimensions of the CO_2 capture devices would be only 1% of the sweep of the turbines (*1*). In other words, in a sense, air streams carry 100 times more CO_2 than kinetic energy.

In addition to allowing the gap between actual and permissible emissions to be filled, air extraction has other attractive features. (i) It could be done at sites far from population centers and close to the sites of CO_2 storage. (ii) Once the rise in CO_2 had been stemmed, the CO_2 content of the atmosphere could be drawn back down to a level at which the earth's ice caps were stabilized. (iii) It would provide a mechanism by which the thorny issue of compensation for past CO_2 emissions by richer nations could be negotiated.

While there is no question that CO_2 capture from the atmosphere is doable, the cost is still unknown. Capture would be affordable if it caused the price of fossil fuel energy to increase by 10 to 30%. However, a large fraction of the operating cost would be for the purchase of the energy required to accomplish the capture and burial. If the cost of sufficient fossil fuel to generate this energy is too high, then this strategy would be impractical.

The largest of the costs associated with air-capture will be those associated with the release of the CO_2 from the capture material and with the recycling of any chemicals used. As sodium hydroxide, an obvious choice, holds onto CO_2 too tenaciously, a better option would be a material that would be able to pick up CO_2 but would release it more readily. Regardless of what material is to be used, it is absolutely essential that research on capture and sequestration be carried out to determine whether the energy costs can be brought down to an acceptable level. Capture from coal gasification plants should also be implemented.

In the present political climate, any attempt to achieve an agreement on either the size of a carbon pie or its allocation among the world's nations would be difficult. However, unless we advance beyond thinking only in terms of conservation and alternate sources and begin to think in terms of a carbon pie, we will have no chance to stop the rise in atmospheric CO_2.

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References and Notes

1. K. S. Lackner, H.-J. Ziock, P. Grimes, in *Proceedings of the 24th International Conference on Coal Utilization & Fuel Systems*, B. Sakkestad, Ed. (Coal Technology Association, Clearwater, FL, 1999), pp. 885–896.
2. I thank K. Conrad, G. Heal, and K. S. Lackner for discussions.

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