

CHAPTER 8

TECHNOLOGICAL SOLUTIONS TO ECOLOGICAL PROBLEMS

8.1 Strategies for alleviating ecological damage

The primary result of chapter 7 is stated in principle (P), which affirms a quantitative link between present-day economic activity and degradation of humankind's ecological support system. Given a biosphere already unable to get rid of all the entropy discharged within it, the production of a given quantity of goods and services introduces a corresponding quantity of degradation into the biosphere. A consequence of (P), under these conditions, is that growth in economic production results in increasing amounts of ecological degradation. For the welfare of the human race, it is imperative that this damaging effect be curtailed if not eliminated.

There are several strategies for curtailing environmental damage brought about by economic activity. One is by curtailing economic activity itself. In the analogous case of trying to cut back on lung damage caused by smoking, this is like a curtailment in use of tobacco products. Curtailing economic activity, of course, runs counter to the orthodox view that a healthy economy requires continuing growth. As a result, this strategy finds little support among mainstream economists.

Another strategy is to address the various damaging effects of economic production on a case-by-case basis. Thus we might try to alleviate global warming, for example, by cutting back on CO₂ emissions, try to reduce damage to the ozone layer by eliminating use of CFCs (recall the Montreal Protocol), and try to deal with other problems likewise on a piecemeal basis. This approach is analogous to isolating various forms of lung disease induced by smoking (emphysema, pulmonary fibrosis, cancer) and devising treatments dealing with each one separately. Despite the maxim that an ounce

of prevention is worth a pound of cure, this approach has proved congenial with current economic thinking.

A third strategy is to break the link between economic production and ecological degradation. This would be analogous to breaking the connection between lung disease and smoking by eliminating harmful ingredients from cigarettes. In the present case, one way of breaking the link would be an extensive substitution of “clean energy” for fossil fuels. This also is an approach many economists find attractive.

These strategies, it should be noted, are not mutually exclusive. Any two could be pursued simultaneously. For example, fossil energy sources could be replaced by wind and solar, along with a general decrease in economic production. It should even be possible to pursue all three together, say by scaling back economic activity, by gradually phasing out fossil fuel, and by relying on abatement technology (like catalytic converters) to counter damage from fossil fuels still in use.

To assess the strengths and weaknesses of these approaches, however, it is better to examine them individually. We begin in the present chapter with the approach advocating management of ecological damage on a piecemeal basis. This is the strategy most readily endorsed by mainstream economists, as well as by most sectors of the business community.

Chapter 9 then takes up the approach featuring replacement of fossil fuels by “clean energy,” which most orthodox economists also find congenial. The distinctly heterodox approach of economic retrenchment is set aside for the remaining chapters of Part II. Anathema to mainstream economists, this approach gains plausibility once the shortcomings of the alternatives have been exposed.

8.2 Specific fixes for specific problems

Most of the ecological problems discussed in Chapter 5 are technological in origin. Global warming stems largely from the emission of greenhouse gases from factories, power plants, and automobiles. Holes in the ozone layer are caused in large part by synthetic gases known as CFCs. Agricultural destruction of habitats is due primarily to use of petroleum-based pesticides; and so forth. Given their technological origin, it is not unreasonable to think that such problems admit technological solutions in turn. Inasmuch as human ingenuity is responsible for these problems in the first place, that is to say, it seems natural to expect that human ingenuity can come up with effective remedies.

This optimism is encouraged by the success of technological remedies in the past. A frequently cited success story is the replacement of CFCs (chlorofluorocarbons) with environmentally less damaging substitutes. For decades after their invention in the 1930s, as noted in Chapter 5, CFCs were used widely as refrigerants, solvents, aerosol propellants, fire retardants, and foam-extrusion agents. In the mid-1980s it was discovered that escaped CFCs were causing ruptures in the earth's stratospheric ozone layer, which shields the biosphere from potentially damaging ultraviolet radiation. By this time, ozone depletion was progressing detectably year by year, with corresponding increases in damage to plant life (notably marine phytoplankton) and to human beings (in the forms of skin cancer and ophthalmic disease).

An international conference was convened in 1987 to address this problem, resulting in a treaty known as the Montreal Protocol. Among its main provisions, the Protocol called for a phasing-out of the most damaging forms of CFC by 1996, and for an elimination of all ozone-depleting chemicals by 2030. As a result, worldwide production of CFCs dropped by a factor of five between 1989 and 1996, most of the remainder being due to continued use by developing countries. The plight of developing countries in this regard was acknowledged with the establishment of an international fund (the

Multilateral Fund) to help them phase out ozone-depleting substances without compromising their economic growth.¹

By 2005 the vast majority of the world's industrial nations had become parties to the treaty. This joint effort was enabled in large part by the availability of other chemical products to replace the most damaging CFCs. Transitional replacements included HCFCs (hydrochlorofluorocarbons) which, although still containing chlorine, have less effect on the ozone layer. More promising substitutes in the long run are HFCs (hydrofluorocarbons) which are relatively inactive and have little ozone-depleting effect. While efforts to find other replacements continue, the replacement of CFCs with HFCs provides a striking illustration of technologically induced problems alleviated by technological remediation.

Another instructive illustration of this approach is the use of desalination technology when adequate supplies of fresh water are unavailable. The first large-scale desalination plant was built by Kuwait in the 1960s, providing water for agriculture as well as for human consumption.² By the turn of the century, more than 7,500 desalination plants were in operation worldwide, a majority of which are located in the Middle East. As of 2005, the largest plant in operation (in Ashkelon, Israel) was capable of producing 100 million cubic meters of salt-free water per year. Desalination of seawater is a proven technology for augmenting the world's diminishing supplies of potable water (section 5.7).

Consider also the use of smokestack scrubbers and similar devices to reduce emission of sulfur compounds from the burning of fossil fuels. Sulfur dioxide, for instance, combines with water in the atmosphere to form sulfuric acid, which returns to earth as acid rain. Although its effects have been recognized for well over a century, acid rain became notorious in the late 1960s for its destructive effects on lakes and forests. Particularly affected were large areas in the northeastern U.S. and Canada, along with

parts of Germany, Russia, and China. An abatement technique now common in various countries, including the U.S., is to mix hot gases in smokestacks with a limestone slurry that reacts with sulfur dioxide to form calcium sulfate. The latter then can be recovered and used in the manufacture of gypsum products. Here as in previous cases, technology has proved effective in the mitigation of environmental problems stemming from the use of technology originally.

Yet another illustration that might be suggested is the use of genetic engineering to reduce the need for chemical pesticides. As noted in Chapter 5, the application of commercial insecticides and herbicides to control agricultural pests can have effects beyond those on the targeted species (section 5.8). Not only can pesticides cause harm to workers applying them, but they pose dangers to ecologically beneficial life forms as well. Agricultural poisons kill off honeybees needed to pollinate crops, reduce populations of birds that eat noxious insects like mosquitoes, and destroy earthworms and other decomposers essential to healthy soil. Viewed from a perspective not dominated by profitability, use of pesticides is a serious environmental problem.

One anticipated benefit of genetically engineered crops is that they would require less pesticide than their naturally occurring counterparts. Prominent instances are Bt crops whose seeds contain genes of *Bacillus thuringiensis*, a soil bacterium which attacks insects that prey on naturally occurring strains. Bt corn that is resistant to common corn borers has become commercially available in recent years. Bt cotton also has found widespread use because of its ability to control several varieties of budworm and bollworm. At least in theory, genetic engineering appears to provide access to farming methods less dependent than now upon ecologically harmful pesticides.

Apparent successes like these lead to optimism about technological solutions to other ecological problems of our industrial age. Many such problems have their origin in commercially successful technology. Against this background, it seems natural to assume

that technological ingenuity will be able to provide workable solutions for these other problems as well. We have next to consider whether this assumption is justified.

8.3 Problems unresolved by piecemeal fixes

Initial confidence in the piecemeal approach is likely to be dampened by the realization that the remedial technologies described in the previous section have proven less successful than those brief descriptions indicate. In some instances, use of technological remedies has actually aggravated the problems they were intended to remedy. A case in point is the use of genetically modified seed to reduce the need for agricultural pesticides.

According to a report by agronomists from Cornell University⁴, Chinese cotton growers were among the first to plant Bt cotton, which reduced pesticide use during the first three or four years by more than 70%. Within less than a decade, however, Bt farmers had to apply just as much pesticides as conventional farmers, due to a proliferation of other insect pests that replaced the bollworms killed by the toxins. Inasmuch as Bt seed is much more expensive than unmodified varieties, farmers who continued to use it generated appreciably less income than their neighbors using conventional farming techniques.

The same tendency has been observed in crops grown from seeds genetically modified for herbicide tolerance (HT crops). Most HT crops are engineered to tolerate glyphosate, a herbicide marketed under the trade name "Roundup." Whereas HT crops generally required less pesticide during the first few years after the technology became widespread, however, in recent years (since about 2000) emergence of HT-tolerant weeds has resulted in use of over one million pounds more herbicides on genetically engineered than on conventionally grown crops.⁵ According to a recent report released by a prominent agricultural economist,⁶ farmers in the U.S. now use more pesticides per acre

on the top three genetically engineered crops (corn, soybeans, and cotton) than on conventional varieties.

As far as smokestack scrubbers are concerned, one should not dispute the view that preventing large amounts of sulfur dioxide from being emitted into the atmosphere is all in all a good thing. But we have a tendency to think that once scrubbers have been installed in a coal-burning plant's smokestacks, further emissions from the plant are environmentally benign. Thinking this way overlooks the fact that a typical 500 megawatt power plant (enough to power a city of about 140,000 people) also produces yearly over 10,000 tons of nitrogen oxide, almost 4 million tons of carbon dioxide, about 700 tons of carbon monoxide, over 300 pounds of arsenic and toxic heavy metals, and more than 190,000 tons of commercially worthless sludge from its scrubbers that ends up in local landfills.⁷ The typical plant also uses some 2 billion gallons of water, which is raised about 16°F in temperature before being discharged into a nearby lake or river (for the effects of which see section 5.2).

Environmental drawbacks of desalination processes, in turn, include the generation of waste brine with a salinity about 1.8 times that of seawater, in amounts greater than those of the potable water produced.⁸ Whether discharged on land or in water, this brine has devastating effects on local ecosystems. The desalination process is also very energy intensive, requiring several times more electricity per gallon produced than water pumped directly from lakes and rivers.⁹

Even in that much celebrated case of new technology coming to the rescue, the substitution of HCFCs for ozone-depleting CFCs, the full story is not one of unqualified success. On the positive side are the facts that replacement technology was readily available, that most countries were able to embrace it without economic disadvantage, and that amounts of ozone-depleting gases escaping into the atmosphere at first declined

dramatically as a result. Experts now predict that the ozone layer might actually heal itself by 2050.¹⁰

Nonetheless, although HCFCs are only 5 percent as effective in depleting ozone as CFCs, their use in rapidly increasing quantities has resulted in continued damage to the ozone layer.¹¹ Another problem is that HCFCs are greenhouse gases. While their contribution to global warming is substantially less than that of CO₂, it is far from negligible. No solution to one problem is fully successful if it exacerbates another that is equally serious.

A further negative aspect of this case is that replacement of CFCs by other coolants, however expeditiously accomplished, is a remedy whose curative effects will be delayed for several decades. Ruptures in the ozone layer continue to expand as a result of chlorine already in the stratosphere; and time is required for accumulation of additional ozone to replenish areas where ruptures have already developed. It may indeed turn out that the ozone layer regains its integrity sometime later in this century. But in the meanwhile, increasingly large numbers of people will develop skin cancers and cataracts, and the ocean's supply of phytoplankton will be progressively depleted.

The Montreal Protocol stands as a model of international cooperation in the face of an environmental problem by which all nations are in some way affected. But the shift from CFCs to HFCs by way of response should not be held up as an exemplary instance of environmental problems being solved by technological means. It is instead a case of engineers being able to replace an ecologically damaging technology with another that is less damaging but no less profitable economically. The main lesson to be learned here is that abatement often has unintended effects which can cause additional damage in their own right.

8.4 Ecological problems have multiple causes

A common feature of the ecological problems to which these abatement strategies are addressed, conversely, is that each is influenced by a variety of causes. Chlorine in the upper atmosphere is not the only factor of human origin contributing to ozone depletion. Another chemical agent with this effect is bromine, stemming from halons commonly used in fire extinguishers and from agricultural fumigants containing methyl bromide. Although less bromine than chlorine reaches the stratosphere overall, bromine is 60 percent more destructive of ozone on an atom-by-atom basis.¹²

Desalination technology provides local solutions to widespread shortages of water for drinking and agriculture. These shortages are attributable to a multitude of causes. Some have to do with human consumption. In addition to increasing numbers of people requiring increasing amounts of water, there is a growing demand for water in industry (mining, electricity generation), recreation (golf courses, swimming pools), and lifestyle preference (green lawns, frequent bathing). Others have to do with pollution from human sources. Inland bodies of water are subject to eutrophication by agricultural run-off, and water from springs and rivers is rendered undrinkable by bacteria from animal farming and urban sewage. Natural causes include shifting weather patterns and ocean currents, often associated in some fashion with global warming (section 5.4).

Consider next the matter of acid rain. Although its main cause is airborne sulfur dioxide, acid rain can result from nitrogen and chlorine compounds and to some extent from CO₂ as well. To some extent, all these compounds were present in the environment before the advent of heavy industry. Sulfur dioxide and hydrogen chloride are typically discharged in volcanic eruptions, and dimethyl sulfide is emitted by phytoplankton in the ocean. Forests and lakes were subjected to acidic precipitation from time to time as a matter of course, but usually at levels to which their resident populations could at least partially adapt.

Acid rain became an ecological problem with the additional accumulations of sulfur and nitrogen oxides in the air resulting from the increasing use of fossil fuel (mostly coal) in factories and power plants. By the late 1960s, scientists had begun to associate the collapse of freshwater ecosystems and the decline of northern forests with noxious emissions from up-wind smokestacks. Here was a clear case of other creatures being destroyed by human use of fossil fuel. Moreover, human beings themselves were increasingly at risk from the corrosive effect of these chemicals on their respiratory systems.

The basic problem is not simply that acid rain is falling on our lakes and forests. This has been happening for countless millennia. The problem is that human technology has increased the intensity of this natural phenomenon to a point where many organisms affected can no longer cope with it. Installing scrubbers in factory chimneys curtails one source of the problem. But the problem is not resolved merely by cutting back on one of its multiple sources.

Genetic engineering of crops was cited in section 8.2 with reference to its potentially beneficial effect of reducing the use of chemical pesticides in agriculture. As already noted, Bt corn and cotton contain genes lethal to natural predators, and the built-in resistance of HT crops to commercial herbicides makes it easier to control nearby weeds with less concentrated doses of poison. Although reduction of pesticide use probably was not a motive in their development (companies responsible for genetically modified seeds sell pesticides as well), it seemed theoretically possible that these products might help alleviate the baneful effects of commercial poisons throughout the biosphere.

The problem of a biosphere choking with noxious chemicals, however, is much too general to be relieved by cutbacks in one or another kind of pesticide. From an ecological perspective, reduction in use of any pesticide is unquestionably a good thing.

But the sources of noxious substances in the biosphere are so many and so various that the problem is not likely to be solved on a piecemeal basis.

By and large, the ecological problems we confront today are too pervasive to be attributable to simple causes. A consequence is that they cannot be resolved by technology designed to lessen their impact in specific circumstances. Attempting to solve ecological problems of this dimension with specialized technological fixes is like trying to cure obesity by giving up a particular brand of soda pop: when there are multiple sources of a pernicious condition, focusing on a single source in isolation is a feckless expedient.

8.5 Systemic malfunctions are not fixed by technological remedies

The idea of fixing ecological disorders of technological origin by further technology may strike one initially as an appealing concept. Other things being equal, it is better to take advantage of technological innovations when they prove helpful than to eschew new technology entirely. But new technology often turns out to have adverse effects that were not anticipated. And the ecological disorders in question are often too complex to be alleviated by technology addressed to specific manifestations. These points have been argued in the preceding sections.

Let us take our analysis of this approach another step forward. The basic shortcoming of this piecemeal approach is not merely that technology often has unexpected side-effects, nor that the ecological problems in questions have multiple sources. The underlying shortcoming is that these problems show up as malfunctions on the part of complex adaptive systems and that the proposed remedies do not correct these functional failures.

Return to the case of desertification. Precipitation over a given land mass occurs as a result of complex interactions involving evaporation from neighboring bodies of

water, prevailing winds in the upper atmosphere, temperature gradients set up by convection currents near the surface, and the atmospheric drift of dust particles around which moisture can condense, as well as various other factors (section 5.4). Dry spells typically result when one or more of these factors behaves abnormally, such as prolonged extension of equatorial convection currents due to global warming (section 5.4). And the affected land mass turns arid when dry spells persist.

It is obvious that climatic abnormalities of this sort are not neutralized by desalination plants installed in Saudi Arabia (or anywhere else) to supply drinking water not available through local rainfall. While this technology can help mitigate the effects of desertification in specific locales, it does nothing to restore regularity to the water cycles on which countless ecosystems depend in other affected areas. These cycles are parts of complex systems of interacting climatic variables that extend over vast areas of the earth's surface. Increasing local supplies of drinking water by technological means does not help bring these complex systems back into equilibrium.

Consider also the case of ozone depletion. When intact, the layer of ozone in the stratosphere blocks ultraviolet radiation that is harmful to many forms of life, including plants that convert lower wavelengths of sunlight into biomass. This ozone layer is held in equilibrium by a set of complex chemical interactions involving high-level winds, changing seasons, oxygen molecules migrating from the troposphere, ultraviolet radiation, and so forth (section 5.6). As long as these interactions remain in balance, the quantity of ozone they produce remains relatively stable and almost all of the incoming ultraviolet energy is absorbed in the process.¹³

This equilibrium was seriously interrupted during the last century when chlorine

compounds used as air-conditioner coolants and spray-can propellants began entering the stratosphere in substantial quantities (sections 5.6, 8.3). As mentioned previously, the industrial world's response to this threat was the Montreal Protocol of 1987. This initial agreement called for a stage-wise reduction in use of CFCs by developed nations (with special provisions for developing countries) which it was hoped would lead to a total cessation by 1996. Subsequent amendments allowed continued production of CFCs at 15% of the 1986 baseline to help developing countries meet their basic needs, and mandated a complete phaseout of HCFCs by 2030. An important proviso currently is that all parties can continue to use the compounds in question when necessary for health or safety, and when there are no technically or economically feasible alternatives.¹⁴

Even if these extended deadlines prove impracticable (which seems likely), the Montreal agreement is admirable both as an example of international cooperation and as a response to a serious environmental problem. But let us look carefully at the nature of the response. Ozone depleting substances (e.g., from volcanoes) have been in the stratosphere for eons, and were part of the balance that remained basically stable until the introduction of CFCs produced by human industry. The basic stability of this balance enabled the development of life as we know it. Introduction of CFCs and related substances early in the 20th century upset this balance, allowing appreciable amounts of harmful radiation to reach the earth's surface in subsequent decades. The proposed solution is just a partial reduction in use of the chemical that caused the problem in the first place.

What we need to realize is that even a *complete* phaseout of ozone-depleting chemicals will not automatically restore the balance. Once the stability of a complex

system of interacting processes is upset, it cannot be reinstated merely by removing the aggravating cause. Ozone-depleting agents now in the stratosphere will remain active for decades, and it will take the ozone layer an unknown period of time (probably longer than currently predicted) to regain its equilibrium even after these disruptive chemicals are dissipated.

To a limited extent, technology can compensate for the unfortunate effects of natural systems that have gone out of kilter. We can build desalination plants on desert seashores; and we can wear sunscreens while waiting for the ozone layer to regain stability. But the fact remains that complex natural systems that have become dysfunctional cannot be set aright by technological means.

For yet another example of massive system malfunction, recall the underlying causes of global warming laid out in Chapter 5. Global warming results from a disturbance of the complex feedback mechanisms by which tropospheric air temperature is maintained within a relatively constant range. These mechanisms are based on the tendency of low-lying cumulus clouds to reflect sunlight, keeping it from reaching the earth's surface, and the tendency of higher cirrus clouds to absorb heat, keeping it from leaving the atmosphere. When some sector of the air mass becomes abnormally hot, moisture evaporates from the earth's surface and the proportion of cumulus to cirrus clouds increases. The net effect is a decrease in temperature of the air mass affected. When a given sector of the troposphere becomes unusually cold, conversely, the proportion of cumulus to cirrus clouds decreases. This amounts to fewer low-lying clouds to block incoming sunlight and more high-level clouds to absorb outgoing heat, causing the affected air mass to undergo a temperature increase.

As noted previously (section 5.3), greenhouse gases cooperate with upper-level water vapor in absorbing heat energy before it can leave the atmosphere, thus leading to global warming. Greenhouse gases (notably CO₂) have been present in the atmosphere since plant life began, and were instrumental in establishing a stable range of ambient temperatures in which current life forms could develop.

The problem stemming from the introduction of additional greenhouse gases by fossil-fueled industry is that more heat is now building up in the atmosphere than its natural heat-control mechanisms can handle. A dire consequence is that greenhouse gases from human industry have incapacitated these feedback mechanisms to a point where the very ecosystems supporting that industry are severely threatened. Both the problem and its sources have been amply documented.

It goes without saying that every effort should be made to reduce the amount of greenhouse gas produced by human industry to the lowest level possible. What we need to realize, however, is that even radical cutbacks in greenhouse-gas emissions will not restore the temperature-control mechanisms of the atmosphere to their preindustrial effectiveness. As is the case with the water-cycle and the ozone layer, once natural systems of this magnitude are rendered dysfunctional by outside influences, they cannot be restored merely by reducing the presence of the disturbing factors. In particular, they cannot be restored by technological intervention.

8.6 Emissions trading, carbon offsets, and similar matters

Technological remedies are popular within the business community because they provide a new kind of commodity to buy and sell. An example is equipment manufactured to reduce pollution. At the turn of the century,¹⁵ compliance with existing

air pollution standards in the U.S. would have required a 10 million ton reduction in sulfur dioxide emissions. Using smokestack scrubbers to achieve that goal, at over \$300 a ton, would have cost an estimated 3 billion dollars. Purchase of equipment accounts for a major portion of this estimate.

Anticipating a bonanza in pollution-abatement markets, Japan moved into the new century aiming to be the world's leading vendor of abatement technology.¹⁶ This led to the development of equipment for eliminating both sulfur and nitrogen emissions, which it is now selling to other countries. Another emphasis was the development of low-polluting automobile engines, which led to Japan's being recognized a decade later as the world's leading manufacturer of hybrid cars.

Another lucrative commodity was inspired by the Kyoto Protocol of 1997, which authorized the buying and selling of carbon emission credits. This agreement required the countries involved to reduce their emission by a certain amount (averaging 5.2% below their 1990 baseline) over the next decade, which those countries may convert into emission caps assigned to individual factories or industries. Companies with emissions exceeding their caps then are enabled to buy carbon credits from others with emissions below their limits. This scheme allows polluting industries to decide between buying expensive abatement equipment and paying other business entities for permission to continue polluting.

Once carbon credits became established as tradable instruments, financial investors started buying them to sell at a profit. Open trading in SO₂ emission rights, for example, got under way in 1995, and by 2000 rights to emit SO₂ sold for about \$260 a ton.¹⁷ By 2007, markets for trading emission credits had been established in several countries,

including the UK, Canada, and Japan, and non-Kyoto-based markets had been set up in Illinois, California, and Oregon of the U.S.

Closely related to these emission-credit schemes is the business of carbon offsetting. Like carbon credits, carbon offsets involve paying someone else to compensate for your carbon emissions. A typical transaction of this sort involves a conscience-ridden individual paying an enterprising organization to plant trees that will absorb CO₂ in an amount supposedly matching that produced by the individual's air travel.

By some calculations, planting 900 trees is enough to remove as much CO₂ as an average U.S. citizen generates each year. At a typical going-rate of one dollar for each 10 trees planted, this average citizen can continue to drive his or her SUV with an environmentally clear conscience for less than \$100 annually.¹⁸

A major difference between emission credits and carbon offsets is that trading the former is regulated by a strict legal framework, whereas carbon offset transactions are generally unregulated. One source of abuse is to base offsets on emission-abatement operations of dubious effectiveness. Offsetting schemes currently in business include reducing methane seepage from farm manure and throwing iron particles into the ocean to bring phytoplankton to the surface.¹⁹

In contrast with the initial impact of carbon-credit trading,²⁰ the environmental effectiveness of these offsetting schemes remains unclear. While there is no doubt about trees taking up CO₂, for example, the cooling effect of trees planted as carbon sinks in temperate climates may be largely canceled out the heat produced as they absorb winter sunlight that would otherwise be reflected back into space by an open snow cover.

Another source of uncertainty is that many of the tree-planting projects on which carbon offsets are based would probably have been initiated anyway for other reasons, such as producing pulp for paper mills or lumber for construction. When this is the case, money made by selling offsets is merely a bonus for the producer and has little to do with any reduction in CO₂ accomplished by the project.

About the only thing certain about such schemes is that carbon offsetting has developed into a very profitable business. Recent data indicate that over 280 million dollars of offsets were sold in 2006 alone.²¹

The point to bear in mind, by way of summary, is that carbon offsetting, emission credit trading, and abatement technology are all piecemeal responses to a complex crisis. In their emphasis on technology and profit, they are basically extensions of the economic practices that led us into this predicament initially. Attractive as they may be from a business point of view, they offer no additional credibility to the dubious prospect that our environmental crisis can be resolved by technological means.

Notes

1. In the years following the initial agreement, China became the world's largest producer of CFCs. By 2007, it had shut down most of its CFC plants, and joined the U.S. in using HCFCs (hydrochlorofluorocarbons) for air-conditioning instead. See *New York Times*, March 15, 2007. The environmental effects of HCFCs are discussed elsewhere in the text.
2. See <http://desline.com/articoli/8109.pdf> (accessed February 2009).
3. See <http://coastal.ca.gov/desalrpt/dchapl.html> (accessed February 2009).
4. See <http://www.news.cornell.edu/stories/July06/Bt.cotton.China.ssl.html> (accessed

February 2009).

5. See Union of Concerned Scientists website

http://www.ucsusa.org/food_and_agriculture/science_and_impacts/impacts_genetic_engineering/genetically-engineered-crops.html (accessed February 2009).

6. See “Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years,” by C.M. Benbrook, Biotech Infonet, Technical Paper Number 7, October, 2004.

7. See http://www.ucsusa.org/clean_energy/fossil_fuels/offmen-how-coal-works.html (accessed February 2009).

8. See <http://www.coastal.ca.gov/desalrpt/dchap1.html> (accessed February 2009).

9. See <http://www.coastal.ca.gov/desalrpt/dchap1.html> (accessed February 2009).

10. A revision of the previous estimate of 2050 to 2065 as a likely date for recovery of the stratospheric barrier was widely reported in December of 2005.

11. See *New York Times*, February 23, 2007.

12. See http://www.epa.gov/ozone/science/g_a.html (accessed February 2009).

13. The feedback interaction between photosynthesis and the chemistry of ozone production is elusive. An evocative description of this interaction by Professor Ingmar Grenthe is contained in the Presentation Speech for the 1995 Nobel Prize in Chemistry. See http://nobelprize.org/nobel_prizes/chemistry/laureates/1995/presentation-speech.html (accessed February 2009).

14. See http://www.afeas.org/montreal_protocol.html (accessed Feb. 2009).

15. Data in this paragraph come from

http://findarticles.com/p/articles/mi_m1076/is_n6_v40/ai_20979661/pg_4 (accessed Aug.

2007), and <http://equalitystate.org/ESPC%20Website%20Generic%20Pages/Opinion%20articles/06feb2000.html> (accessed Aug. 2007).

16. See <http://www.newint.org/issue231/techno.htm> (accessed Aug. 2006).

17. See http://www.newamerica.net/publications/articles/2001/trading_futures_in_dirty_air (accessed Feb. 2009). Comparison with the \$300 per ton cost (in 2000) of reduction by emission abatement equipment cited above illustrates why companies often find it cheaper to continue polluting. These figures of course are in flux. The price of carbon credits has declined dramatically since 2000.

18. Offsets have also been purchased by large corporations with unfavorable reputations for greenhouse gas emission. A recent example, according to the *Washington Post*, August 16, 2007, is American Electric Power, which reportedly purchased offsets for about 4.6 million tons of carbon dioxide. At a rate presumably close to \$10 per ton, this amounts to an investment of about 50 million dollars for a more positive public image.

19. See <http://www.libertyrichter.com/steaz.pdf> (accessed Feb. 2009), and <http://climatechange.110mb.com/nations-iron-seeding-oceans.htm> (accessed Feb. 2009).

20. During the period from 1995 to 2000, there was an approximately 25% reduction in acid rain falling in the northeast part of the U.S. This reduction has been attributed to the trading in SO₂ emission credits that got underway in 1995. See <http://www.newamerica.net/index.cfm?pg=article&DocID=434> (accessed Aug. 2006).

21. As reported in <http://www.junkscience.com/ByThejunkman/20070719.html>.