



By Craig M. Pease

How Might We Cool The Earth?

Scientific knowledge about global climate change has now reached the point where there is longer any real debate over its fact or cause. This in turn has engendered an important yet under-appreciated shift in the focus of the technical literature, from studying the problem to finding a solution. We have moved from the realm of science to the practice of engineering.

Before discussing possible future solutions, it is sensible to summarize our "progress" to date. Since the 1997 Kyoto Protocol, atmospheric carbon dioxide has risen from 363 to 386 parts per million. Even more worrisome is the evidence that this increase is accelerating, driven principally by global economic growth, as summarized in two companion articles by Josep Canadell, Michael Raupach, and colleagues in the *Proceedings of the National Academy of Sciences*. Moreover, in a recent and not uncontroversial paper in *The Open Atmospheric Science Journal*, James Hansen and colleagues suggest a goal of 350 ppm or lower to prevent catastrophic loss of the Greenland and Antarctic ice sheets, a target well below the consensus view of even several years ago. Everything is moving, in the wrong direction.

Science is the study of the possible and probable, whereas engineering is the art of the practical. Science tells us loss of the polar ice sheets is pos-

sible, though there remains debate as to exactly what atmospheric carbon dioxide level will make this probable. It is the engineers who must actually supply a cost-effective solution. This brings us to Daniel Sarewitz and Richard Nelson's December 2008 commentary in *Nature*. The article posits "three rules for technological fixes," the apparent premise of which will no doubt dismay many of my readers.

Their contribution deserves a fair hearing. It is important not for its provocative and surprising bottom-line conclusion (about which more later), but rather for its path to that endpoint. They ask us to contemplate a broad array of potential engineering technologies for reducing atmospheric carbon dioxide, and to develop explicit rules to cull out the scientifically workable from the politically, legally, socially, or economically dead on arrival.

Space limitations preclude a full presentation of their rules here. One can, however, illustrate the essence of their argument by comparing the policy options available to reduce carbon dioxide emissions from coal-fired power plants. As Hansen has forcefully argued, reducing the atmospheric carbon dioxide derived from these emissions is key. Evidently, our options are to reduce demand for electricity (increased energy efficiency), replace these plants with energy from non-carbon sources (biofuels or nuclear power), or capture carbon dioxide as the coal is burned (carbon capture and sequestration).

Many in the environmental community favor less esoteric engineering. Fair enough. We do not need a Manhattan Project to advance the engineering of blown cellulose insulation. The engineers have this one figured out. Yet there remain substantial, perhaps huge, opportunities to improve the energy efficiency of residential and commercial buildings. Here the engineering works, but our

existing political and social institutions cannot capture all the opportunities the engineers have provided.

Biofuels present somewhat different obstacles. Though you might quibble over the accounting, a posse of outraged scientists and engineers argue convincingly that we burn as much or more fossil fuel to grow corn than the energy value of the ethanol. Corn ethanol will not reduce atmospheric carbon dioxide. To understand why the incoming secretary of agriculture favors it, look at the electoral map. Obama's margin of victory was less than the electoral votes of the Midwest farm states receiving substantial corn ethanol subsidies. Here we can achieve a political compromise, but only to further a scientifically nonsensical program.

Sometimes it is a real advance to just state the obvious. Sarewitz and Nelson, authors of the *Nature* commentary, suggest we remove carbon dioxide from the atmosphere with machines built specifically for this task. The engineering difficulty appears roughly equivalent to

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capturing and sequestering carbon dioxide from coal-fired power plants. Yet it looks politically superior, as it would not require the cooperation of the

owners of coal-fired power plants.

Their rules thus push the technical literature beyond engineering narrowly defined, to provide an explicit framework for interdisciplinary problem-solving, just as the IRAC template structures legal analysis.

We obviously need interdisciplinary solutions to global climate change. Yet judging by current atmospheric carbon dioxide trends, we have yet to find a single policy option that is at once achievable by politicians, sensible to economists, not in violation of scientific knowledge, and actually buildable by engineers.

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