Climate Change and the Transformation of World Energy Supply

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In December, world attention turned to Kyoto, Japan, where parties to the Framework Convention on Climate Change negotiated a protocol to reduce the greenhouse-gas emissions of the industrialized countries by 5 percent over the next ten to fifteen years. The agreement was attacked from both sides, with environmental groups claiming that deeper reductions are urgently needed, and opponents claiming that reductions are unnecessary and would curtail economic growth.

Both groups are wrong. Immediate, deep reductions are neither necessary nor politically possible. We must, however, begin today to prepare for the inevitable reductions that lie ahead. Most especially, we must lay the foundation for a global transition, beginning in the next ten to twenty years, away from traditional fossil fuels.

The objective of the Climate Convention is to achieve “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” The level that would prevent “dangerous interference” remains undefined, however. Most analyses have focused on the effects of a doubling of carbon dioxide concentrations from the preindustrial level of about 280 parts per million (ppm). A doubling of carbon dioxide concentrations would increase the average global temperature by 3 to 8 °F over a period of roughly 200 years. For comparison, the average temperature has varied up or down by only about 2 °F over the last 10,000 years, and by about 10 °F over the last 50 million years. More important than global averages, but more difficult to predict, will be regional and seasonal variations in climate, particularly in the frequency of storms and drought.

After examining numerous analyses of the possible effects of climate change on ecosystems, agriculture, sea-level rise, human health, and economic productivity, I believe that the stabilization target should be no higher than an equivalent doubling of carbon-dioxide, to about 550 ppm. At this level, significant changes in climate would be almost certain, and there would be some chance of widespread,

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disastrous consequences. It would be desirable to set the target lower if possible, but a doubling should be a minimum standard that almost everyone can agree with.

Over the last 150 years, deforestation and the burning of fossil fuels have increased the concentration of carbon dioxide by 80 ppm, to about 360 ppm. If we also take into account the increase in other greenhouse gases, such as methane, nitrous oxide, and halocarbons, the total rise is equivalent to a carbon-dioxide concentration of about 420 ppm. Thus, we already are halfway toward an equivalent doubling of carbon dioxide.

Emissions of carbon from fossil-fuel burning have risen steadily over the last half century, from about 1.4 billion metric tons in 1945 to 6.2 billion tons in 1995—an average growth rate of 3 percent per year. In order to stabilize greenhouse gas concentrations at the equivalent of a doubling of carbon dioxide, global emissions should peak at about 8.5 billion tons per year in about 2015, after which they would begin a steady decline to about 6 billion tons per year in 2050 and 3.5 billion tons per year in 2100.

The implications of this scenario for world energy supply are profound. Today, fossil fuels supply 86 percent of the world's commercial energy supply. The demand for energy will grow substantially over the next century, driven by increases in both population and per-capita consumption in developing countries. Even if steady progress is made in improving the efficiency of energy use, overall demand for energy is likely to at least double by 2050. But if greenhouse-gas concentrations are stabilized at levels equivalent to a doubling of carbon dioxide, traditional fossil fuels could not supply more energy in 2050 than they supply today. Thus, in the next 50 years, commercial energy sources which do not emit carbon dioxide will have to go from 14 to over 60 percent of a doubled world energy supply, which will require an average growth rate of 4 to 5 percent per year.

The transition to non-CO_2-emitting sources will be the third transformation in world energy supply. The first major shift, from firewood to coal, took place from 1850 to 1900. The second major shift, from coal to oil and gas, took place from 1925 to 1975. In these first two shifts, it took 50 years for the dominate source to go from 10 to 60 percent of total supply. The third major shift, from fossil fuels to non-CO_2-emitting sources, will occur from 2000 to 2050—if, that is, we decide to take seriously the task of preventing dangerous interference with the climate system.

How will all this energy be supplied? Only four sources are capable of supplying the very large amounts of energy that will be needed in this time frame without emitting significant amounts of carbon dioxide: solar, biomass, fission, and decarbonized coal. Other sources are either too limited (hydro, hot-water geothermal, and wind), too expensive (ocean thermal and wave energy), or too unproven (fusion and hot-rock geothermal) to become a dominant energy source.

Each of the four major alternatives currently has significant economic, technical, and/or environmental handicaps. Solar is environmentally benign, but the current cost of producing electricity with solar photovoltaic cells is at least five times higher than coal-fired electricity, and solar would require massive and inexpensive energy storage if it is to supply a large fraction of energy demand. Biomass has the potential to supply low-cost portable fuels, but generating large quantities of biofuels would require vast areas of land, in competition both with agriculture and the preservation of natural ecosystems. Nuclear fission can produce electricity at prices competitive with coal, but it suffers from public-acceptance problems related to the risks of accidents, waste disposal, and the spread of nuclear weapons. Finally, coal is abundant and can be converted cheaply into either electricity or portable fuels, but the cost and environmental impact of capturing, transporting, and disposing of the carbon dioxide might be very high.

The most pressing need, therefore, is research and development aimed at reducing the liabilities of the major alternatives. Last year, the U.S. government spent a little more than $1 billion on energy R&D, compared with the $500 billion spent on energy in the United States ($60 billion of which went for imported oil). Total energy R&D amounted to less than 1 percent of energy expenditures, compared with an average of 3.5 percent for all U.S. industries.

In the past, it has taken at least 20 years to realize significant commercial benefits from energy research and development. To prepare for—and profit from—the transformation in energy supply that must begin in earnest by 2015, we must do the R&D today. Our options are limited, and we are not smart enough to pick sure winners and losers. We need a balanced R&D program that includes substantial investments in all four of the sources mentioned above, including nuclear fission.