GREENHOUSE WARMING:
EFFICIENT SOLUTION OR NUCLEAR NEMESIS?

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The threat of global climatic warming due to the atmospheric greenhouse effect is becoming increasingly urgent.[1] While carbon dioxide (CO_2) has long been known to be a major culprit, recent research has uncovered a number of other "greenhouse" gases in the earth's atmosphere whose concentrations are rising. These additional gases (principally methane, chlorofluorocarbons, nitrous oxide, and ozone) interact in a complex coupling of physical, chemical, and radiative processes, and their combined warming effects could be as great as those expected from CO_2 alone.[2] Moreover, recent studies of the global temperature record over the past 120 years indicate that long term irreversible climate warming has already begun, with an average temperature increase of one degree Fahrenheit since 1860.[3] Indeed, four of the warmest years have occurred since 1980, with 1987 being the warmest year on record, and the first half 1988 even warmer still.[4] Last week Dr. James E. Hansen of the National Aeronautics and Space Administration told the Senate Energy and Natural Resources Committee that it is 99 percent certain that this warming trend is caused by CO_2 and other greenhouse gases. “It is time to stop waffling so much and say that the evidence is pretty strong that the greenhouse effect is here,” he said.[5] I concur with this assessment. Consequences of a warmer climate include a likely sea level rise of a few feet (which could inundate coastal cities and plains), and a northward shift in the rainbelt, reducing yields in vital agricultural regions of the world. Indeed, Dr. Syukuro Manabe of Princeton University testified at the same hearing that the current drought gripping the farm belt is a foretaste of what the United States will face in the years ahead.

In view of these problems, the urgency of reducing future CO_2 emissions by curtailing fossil fuel combustion is more widely recognized than ever before. As a result, many people assume that nuclear power will inevitably be required on a large scale as the only viable means to displace CO_2 emissions on a large scale. Indeed, leading nuclear proponents argue that the greenhouse warming problem is the most compelling reason to revitalize nuclear power.[6]

Abatement of Greenhouse Warming via Nuclear Power

My colleague Gregory Kats and I have analyzed the viability of a nuclear response to the greenhouse problem.[7] We began by reviewing the state-of-the-art research on global energy futures, selecting three representative scenarios that span the range of possible futures -- high, medium, and low energy futures (see schematic in Figure 1).[8] These roughly correspond to high, medium, and low carbon dioxide emissions futures.

In the context of these scenarios, we made assumptions highly favorable to a nuclear response to the greenhouse problem. Specifically, we assumed that

- Nuclear power plants could be built in just six years' time (for 1000 MW), rather than the 10 to 12 year construction periods experienced recently in the U.S.

- Construction costs would be only $1000 per installed kW, with an electricity generation cost of just 5 cents per kilowatt hour (¢/kWh). (For comparison, capital costs in the U.S. are currently around $3000/kW, and the cost of generating electricity from new nuclear plants is around 13 ¢/kWh).

- Nuclear power could displace all coal use worldwide by the year 205. This is an extreme assumption would be very difficult to actually implement. Nevertheless, because coal is the most carbon-intensive fossil fuel, this assumption yields the greatest reduction in CO_2 emissions for each added nuclear plant.

- The host of political, social, and scientific objections to nuclear power will essentially disappear. Although this assumption seems unlikely, in order to assume the best of all possible worlds for nuclear power we omitted any consideration of (i) nuclear waste treatment and storage, (ii) decommissioning costs, (iii) the safety of nuclear plants, (iv) any environmental or health consequences that might result from massive nuclear investment, (v) the possible impact on proliferation of nuclear weapons, (vi) vulnerability to terrorism, sabotage, or acts of war, and (vii) any additional possible adverse impacts.

Under these highly optimistic assumptions, we found the following:

- In the high and medium energy growth. scenarios, massive investment in nuclear power cannot prevent CO_2 emissions from growing. Indeed, to displace the coal in the high scenario, global nuclear capacity would have to be increased at the staggering rate of one large nuclear plant (1000 MW) *every 1.6 days* for the next 38 years. In the medium scenario, a new nuclear plant would have to be built every 2.4 days. Such massive investments would be infeasible in the Third World, and would have severe economic impacts in developed countries. Moreover, despite these huge nuclear programs, global CO_2 emissions would continue to *grow* in both scenarios (due to emissions from oil and natural gas), and greenhouse warming would continue.

- Only if future growth in energy consumption is relatively small could nuclear power make a substantial reduction in CO_2 emissions, and then only because the overall magnitude of the problem has been greatly reduced. Nuclear advocates have called for a six-fold expansion of global nuclear capacity to abate greenhouse warming, but this would have only a negligible effect unless growth in future fossil fuel consumption is nil. Thus nuclear's slice of the "greenhouse warming pie" is inherently small, and is significant only if the pie itself is shrunk in the first place.

- The major energy factor affecting future greenhouse warming is not the traditional supply question of nuclear versus coal, but rather the question of future levels of energy demand. **The single most important factor affecting future CO_2 emissions is the degree of investment in improved energy efficiency**. Highly efficient energy futures entail reduced CO_2 emissions - *without* a reduction in economic growth. Substantial rates of economic growth can be sustained worldwide for decades with no increase in energy consumption.[9]

Comparison of Nuclear and Efficiency Scenarios

In view of the above findings, it is of interest to compare equal investments in nuclear power and energy efficiency to determine their relative impacts on global CO_2 emissions. For this purpose, we again make the optimistic assumptions outlined above for nuclear power, and we shall make comparatively pessimistic assumptions for electrical efficiency. Specifically, we assume the cost of nuclear electricity will remain fixed at 5¢/kWh up through 2025, while the cost of saving electricity will rise over this time period from an average of 2¢/kWh to 4¢/kWh by 2025. Figure 2 illustrates the resulting carbon abatement for the two scenarios: (i) a sixfold expansion of global nuclear power by 2025, and (ii) the same investment applied toward improved electrical efficiency. As shown in the Figure, the efficiency scenario displaces 17.3 Gt more carbon than does the nuclear scenario. This is a substantial difference, amounting to more than three years worth of today's global CO_2 emissions.

Comparison of Nuclear and Efficiency Investments in the U.S.

While the foregoing analyses focus on the world as a whole, it is important to examine current data in the United States. U.S. policy is especially relevant to the greenhouse problem, because the United States is the single largest source of carbon dioxide emissions in the world (23 percent).

Figure 3 illustrates the relative cost-effectiveness (at the margin) of investments in new nuclear electricity and electrical efficiency for purposes of abating CO_2 emissions from U.S. coal-fired power plants.[10] The left column shows the carbon displaced per dollar invested in nuclear power, and the right column shows the carbon displaced per dollar invested in electrical efficiency. It is evident from the figure that

- Each dollar invested in electric efficiency displaces nearly seven times more carbon than a dollar invested in nuclear power.

- For every $100 invested in new nuclear power, approximately one tonne of additional carbon is released into the earth's atmosphere that *could* have been avoided, had that money been invested in improved efficiency. This provides a measure of the environmental opportunity cost of nuclear power.

Some experts argue that electrical efficiency can be provided at a considerably lower cost than is assumed in Figure 3,[11] while others claim that the cost of nuclear electricity can be greatly reduced in the future. For example, the Atomic Industrial Forum (AIF), which recently merged with the U.S. Council for Energy Awareness, hopes for future regulatory and technological streamlining of all phases of nuclear power, which could reduce the cost of new nuclear electricity to as low as 5¢/kWh. To give fair representation to these differing views, Figure 4 illustrates the relative cost-effectiveness of carbon abatement investments for a wide range of cost estimates. Note that even if the "AIF dream" of 5¢/kWh could be achieved for nuclear power, efficiency is still much more cost-effective in abating carbon emissions.

Other Efficiency Opportunities

Up to this point, we have focused primarily on the electricity sector, in which nuclear power and efficiency can be directly compared. However, improved energy efficiency offers numerous additional opportunities for reducing CO_2 emissions in the commercial, industrial, and transportation sectors. Many of these opportunities lie well outside the electricity sector, and could therefore not be tapped by increasing nuclear power. While a detailed accounting of these opportunities is beyond the scope of this testimony, a few aggregate numbers will serve to give an idea of the huge and environmentally benign "oilfields" that remain to be exploited. As just one example, a recent *Scientific American* article reports that in the United States it costs no more to build an energy-efficient office building than to build an inefficient one, and yet, if these commercial building improvements are adopted, then in fifty years time, 85 power plants *and* the equivalent of two Alaskan pipelines will have been avoided.[12] All told, the article concludes that the U.S. can cut its energy consumption in half (sparing the environment accordingly) *and* save an average $110 billion a year, for an annual investment of just $50 billion.[13] It's as if we were offered $60 billion a year to live in a cleaner environment.

Indeed, such synergistic benefits of energy efficiency improvements are perhaps the best reason for investing in them. A single 18-watt compact fluorescent light bulb produces just as much light as a 75-watt incandescent bulb, and yet over its lifetime, the fluorescent bulb prevents the burning of 400 pounds of coal, prevents the release of 12 pounds of sulphur dioxide into the atmosphere (which produces acid rain), and it saves the American economy $15. Thus a simple light bulb simultaneously contributes to a cleaner environment, reduced climate warming, and American competitiveness in the international marketplace.

Conclusion

Our principal conclusion is that while nuclear power offers a small contribution to the abatement of carbon dioxide emissions, the pursuit of nuclear power as a response to greenhouse warming is not a viable strategy because it is slow, expensive, and relatively ineffective. Meanwhile, improved energy efficiency is the opposite: quick, inexpensive, and highly effective. We share a sense of urgency about the greenhouse problem with many nuclear advocates. Precisely because of this urgency, the nations of the world should pursue those energy policies that *will* ameliorate the greenhouse problem as quickly and effectively as possible. For the foreseeable future, the fastest, cheapest, and above all, most effective response to CO_2-induced warming is to curtail the emission of CO_2 by improving the energy efficiency of &e global economy.

Ultimately it will of course be necessary to seek clean alternative sources of energy, and hydrogen is certainly among the most attractive candidates. At present, however, the real energy question in the United States is not which energy supply technology to invest in. The current American energy system resembles a leaky bathtub. As the hot water leaks out, we desperately pursue ever larger and fancier technologies for heating more water, rather than simply plugging the leaks. Until we recognize that our energy consumption is far higher than it need be, due to massive unnecessary waste, we will continue to pay far more than we should -- in both economic and environmental terms -- to provide our energy services. To continue on this path could ultimately spell economic and environmental disaster.

As the old Chinese proverb says, unless we change the way we are going, we *will* end up where we are headed.

Notes

[1]For a review of the scientific theory, see “The Greenhouse Theory of Climate Change: A Test by an Inadvertent Global Experiment," Science 240:293-99 (15 April 1988).

[2]B. Bolin et al., The Greenhouse Effect, Climate Change, and Ecosystems. John Wiley, 1986.

[3]P.D. Jones, T. Wigley, and P. Wright, "Global Temperature Variations Between 1861 and 1984," Nature 322:430 (31 July 1986). See also R.A. Kerr, "Is the Greenhouse Here?" Science 239:569-61 (5 February 1988).

[4]Shabecoff, P. "Global Warming has Begun, Expert Tells Senate," New York Times, 24 June 1988, p. l.

[5]Id.

[6]A. M. Weinberg, colloquium at Los Alamos National Laboratory, 7 December 1987 (quoted in S. Doughton-Evans, "Safe Reactors Power of Future?" Los Alamos Monitor, 8 December 1987).

[7]For full details, see B. Keepin and G. Kate, "Greenhouse Warming- Comparative Analysis of Two Abatement Strategies* forthcoming report, Rocky Mountain Institute, Snowmass, CO 81654.

[8]The high scenario is taken from W.D. Nordhaus and G.W.Yohe, "Future Paths of Energy and Carbon Dioxide Emissions" in Changing Climate, National Academy of Sciences, 1983; the medium scenario is taken from J. Edmonds et al., An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO2, U.S. Department of Energy, 1984, and the low scenario is taken from J. Goldemberg et al., “An End-Use Oriented Global Energy Strategy,” Annual Review of Energy10:613-98 (1985). See reference 7 for details.

[9]See J. Goldernberg et al., “An End-Use Oriented Global Energy Strategy,”Annual Review of Energy 10:613-88 (1985), D.J. Rose, M. M. Miller, and C. Agnew, “Reducing the Problem of Global Warming,” Technology Review 83 (7):49-58, and 1. Mintzer, A Matter of Degrees: The Potential for Controlling the Greenhouse Effect, Research Report No. 5, World Resources Institute, Washington, D.C., April 1987.

[10] Based on the following costs: new nuclear power plants: 13.5 ¢/kWh; electrical efficiency: 2 ¢/kWh. See reference 7.

[11] For example, Amory Lovins of the Rocky Mountain Institute estimates that all told, some 50% of U.S. electricity can be saved at zero net cost, and 75% can be saved at an average cost certainly below 1¢/kWh, and probably near 0.5 ¢/kWh (documented in Competitek SM quarterly update service provided by Rocky Mountain Institute, Snowmass, CO 81654).

[12] Arthur H. Rosenfeld and David Hafemeister, "Energy Efficient Buildings," Scientific American 258 (4): 78-84, April 1988.

[13] The article (reference 12) quotes annual savings of $220 billion (in 20 years' time), which averages to $110 billion per year during the interim. Private communication with Arthur H. Rosenfeld.

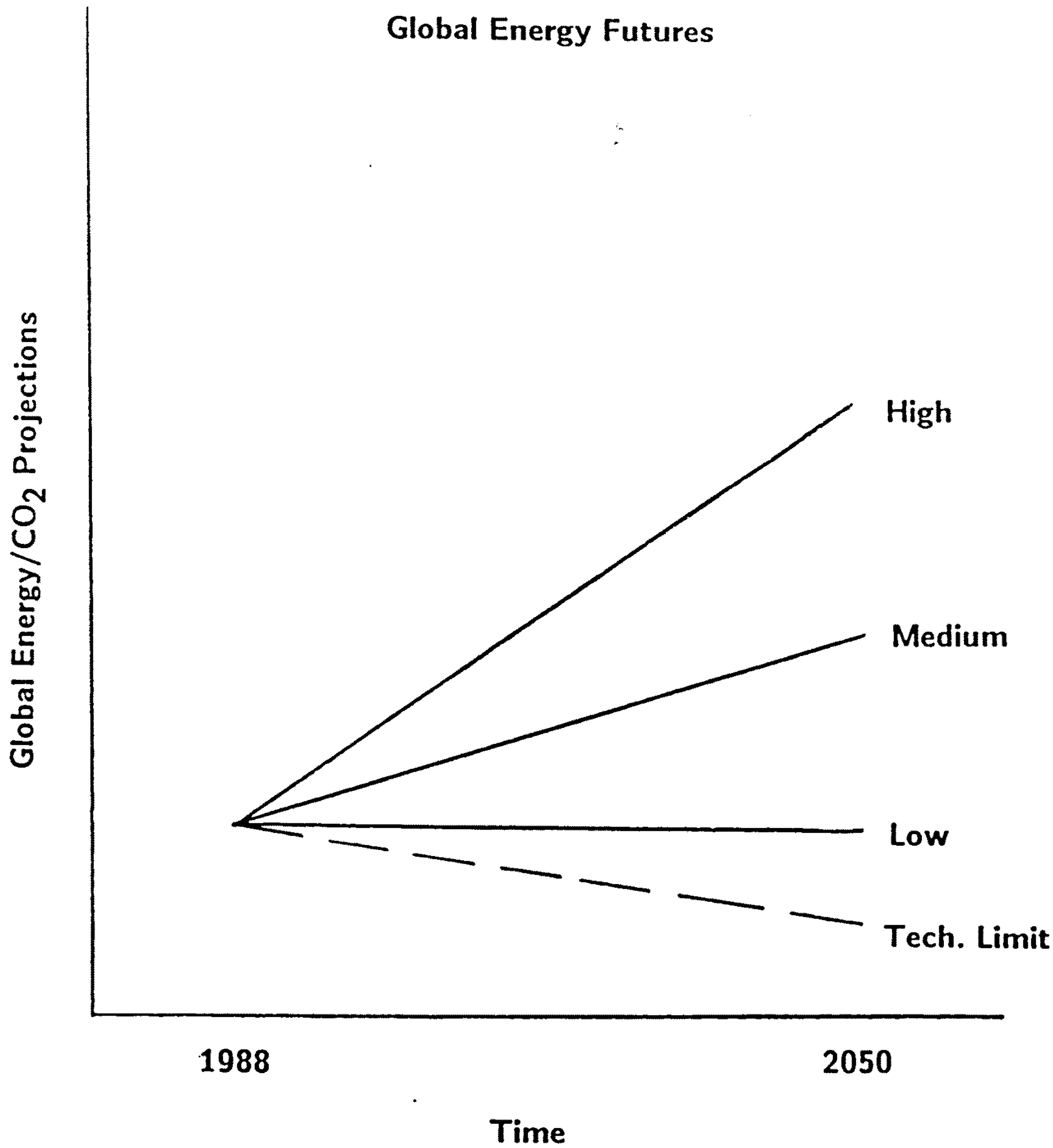
Global Energy Futures
Global Energy/CO2 Projections
High
Medium
Low
Tech. Limit
1988
2050
Time

Figure 1.

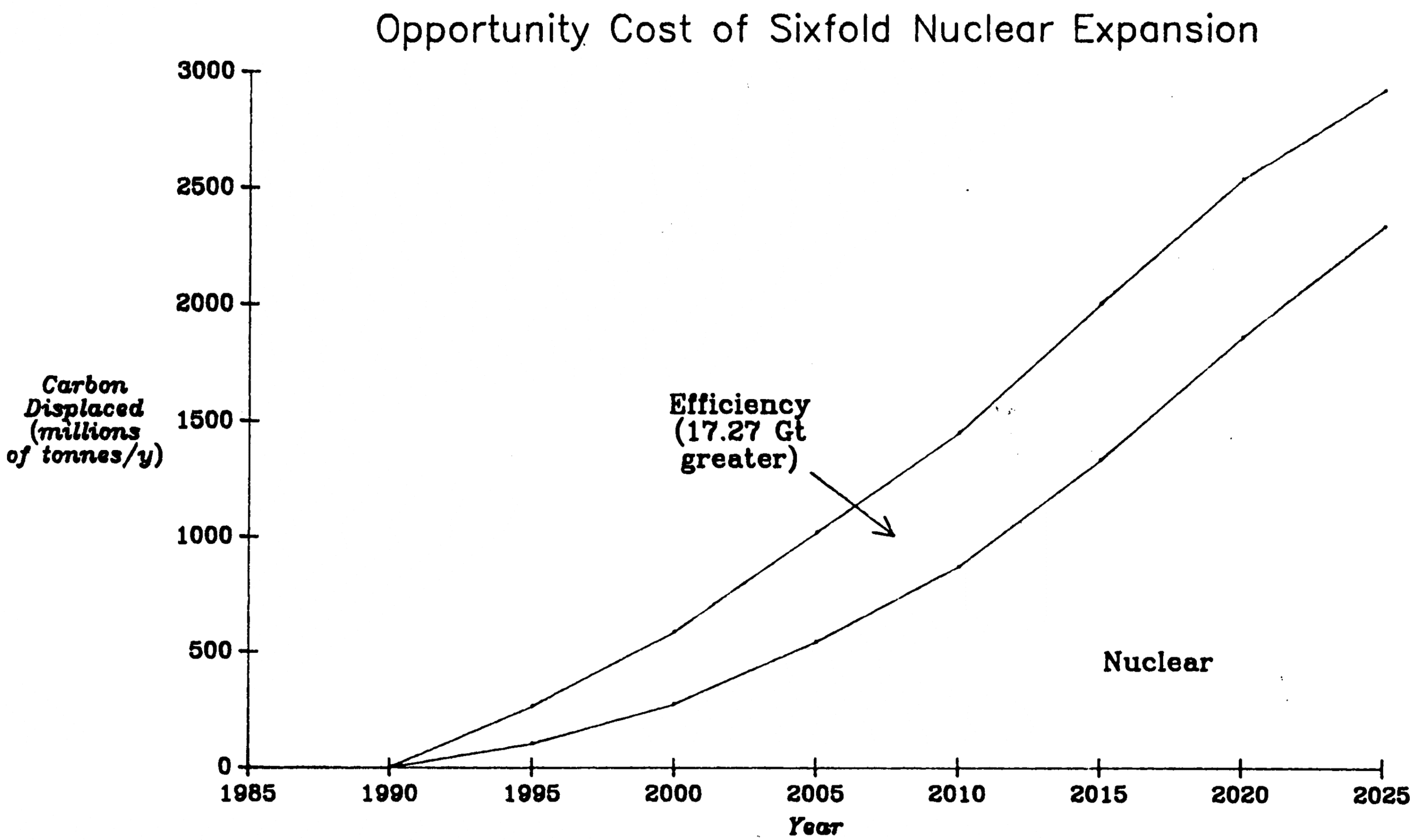
Opportunity Cost of Sixfold Nuclear Expansion
Carbon Displaced (millions of tonnes/y)
3000
2500
2000
1500
1000
500
0
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Efficiency (17.27 Gt greater)
Nuclear

Figure 2

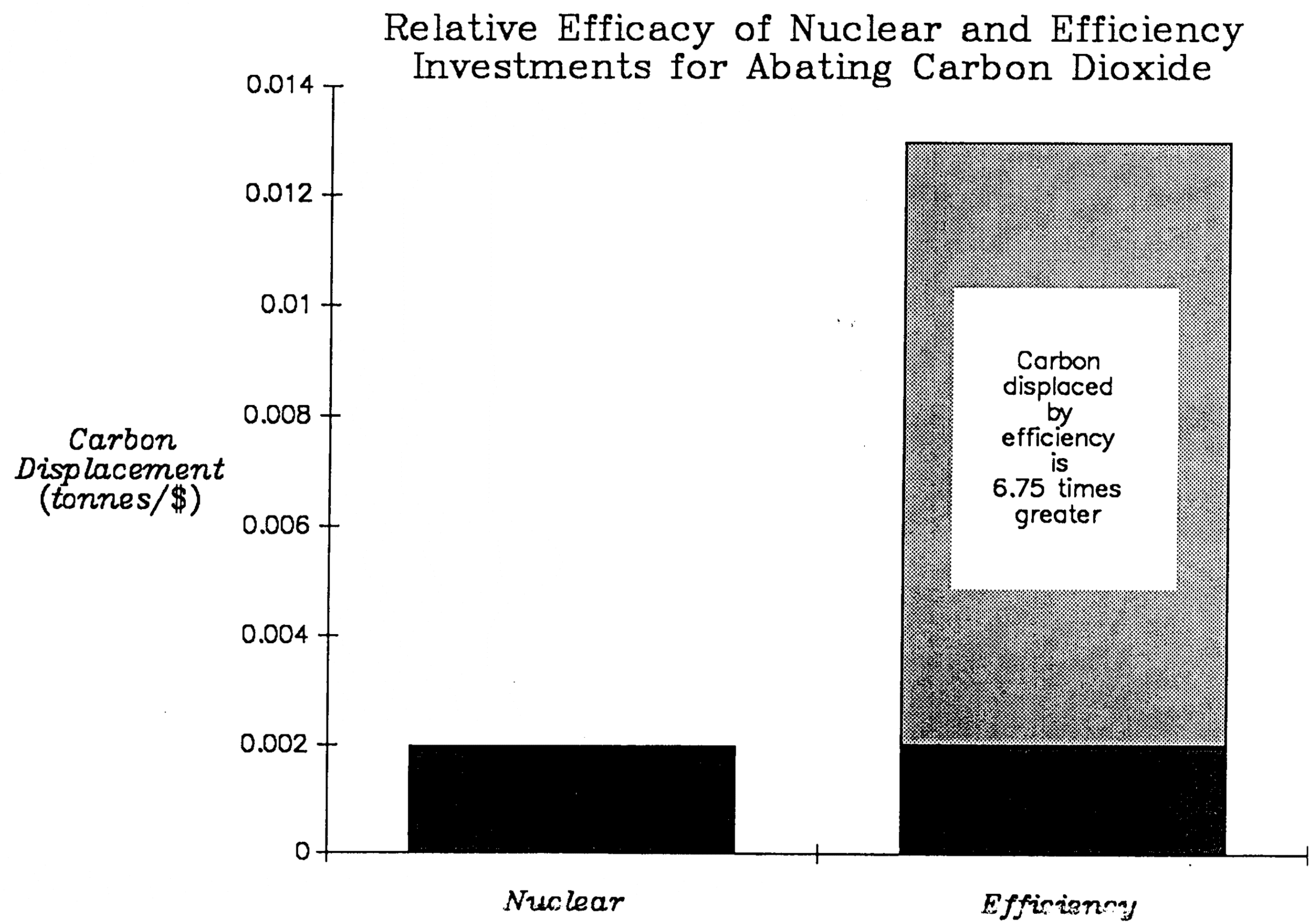
Relative Efficacy of Nuclear and Efficiency
Investments for Abating Carbon Dioxide
Carbon Displacement (tonnes/$)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Carbon displaced by efficiency is 6.75 times greater
Nuclear
Efficiency

Figure 3

Relative Efficacy of Nuclear and Efficiency Investments for Abating Carbon Dioxide

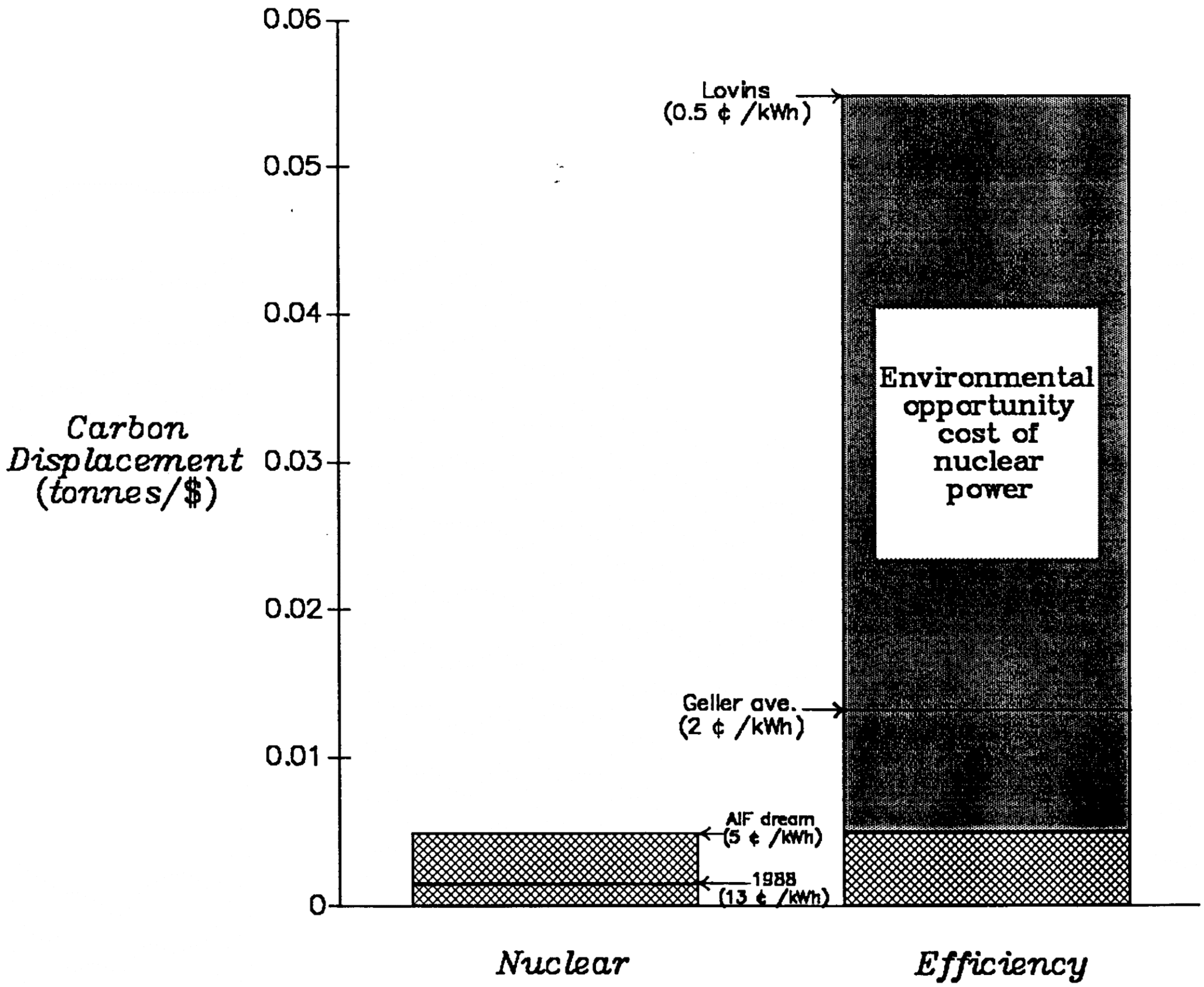

Figure 4