ENERGY, ECONOMICS AND CLIMATE – AN EDITORIAL

If all the climatologists in the world were laid end to end, they might never reach a conclusion about the seriousness of the CO_2 problem. But they have been led to accept one assumption about it: that increases in the rate of burning fossil fuel are inevitable (and essential for global development). Elaborate analyses of the climatic consequences of releasing carbon from fossil fuel have been built on that assumption. But the ingenuity and skill devoted to those analyses have been disproportionate to the quality of their most basic assumption: the future rate of burning fossil fuel. That rate is usually assumed, in a cursory opening paragraph, to increase by several percent per year, continuously and indefinitely. How many is 'several' matters little; all values lead to the same place sometime in the next century, and it is a place where only the webfooted would want to be.

Recent development in the energy marketplace, however, should give us pause. The United States since 1979 has gotten about a hundred times as much new energy from energy savings as from all expansions of energy supply combined. Moreover, of those expansions, more new energy has come from renewable sources than from any or all of the nonrenewables. OPEC is selling a third less oil than it did on the eve of the 1973 Arab oil embargo; there is a glut of coal-mining capacity; oil companies and utilities are being severely discomfited by flat or falling demand in place of the rapid growth that had been forecast; and nuclear power is commercially dead, having achieved in thirty years, after $40 billion in direct Federal subsidies, about half the rate of energy delivery that wood has achieved in five years with no subsidies.

These startling developments are often blamed on the current recession, and indeed changes in economic activity, by sector and in total, must be carefully taken into account. But what emerges from such an accounting is that the energy sector is undergoing a profound and historic structural change – driven largely by price (along with expectation of future price, perceived insecurity of supply, and many other psychological factors).

The enormous increases in real energy prices since 1973, and especially since 1979, make it timely to re-examine how far most climatologists' expectations of rapid growth in the rate of burning fossil fuel are still consistent with either observed or theoretically cost-minimizing behavior. Has OPEC already solved the CO_2 problem (and most of the acid rain, strip-mining, and oil-spill problems) by making it simply uneconomic to burn most of the fossil fuels?

When asked this question in a WMO expert group meeting in January 1977, some of our colleagues considered it academic if not frivolous, because nobody had yet done the analysis. In 1981, however, it was examined in detail in a study commissioned by the German Federal Environmental Agency, just published in updated and illustrated form [1]. We hope that it will help energy analysts, economists, and climatologists to become better acquainted with each others' concepts while changing the way each thinks about the others' disciplines.

An economist might try to estimate likely future responses of energy demand to price by extrapolating from historic responses. Although history offers valuable lessons, how-

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ever, it is likely to understate future price responses. Many of the most important technologies for wringing more work from our energy did not exist a few years ago. Information on such opportunities was (and often still is) poorly distributed, as is the up-front capital people need to buy them. Many people who have the price incentive to use energy more efficiently are prohibited from doing so by various institutional barriers ('market imperfections') which, in general, were even more severe in the past than they are now. For all these reasons, one can discover how much energy efficiency is worth buying in the coming decades only by an engineering-economic analysis of the incremental costs of higher energy productivity vs increased energy supply. Even this comparison provides a lower bound to plausible future savings, because it assumes, among other things, an unchanged composition of economic output (rather than fewer Winnebagoes and more Apples), no changes in societal values, and no technological progress.

The most sophisticated engineering-economic studies of energy efficiency examine hundreds of sectors and thousands of technologies. They are correspondingly opaque to the general reader. Our analysis sought instead a simpler, more transparent calculation emphasizing the most important terms. It applied up-to-date empirical data from a dozen countries to a case-study of the West German economy in 1973 – the world's most heavily industrialized economy, and one of the most energy-efficient. We assumed no changes in lifestyle (except increased personal comfort); unchanged 1973 economic output; presently available technologies; and the purchase of greater energy productivity at a level mostly cost-effective at recent German fuel prices and all much cheaper than marginal supply. Nonetheless, we found that the main efficiency improvements would have reduced by 82% the total energy needed to run the 1973 German economy. To be sure, such a thorough fixing-up of buildings, vehicles, and factories would take decades to implement completely – if done at rates somewhat *slower* than those observed in recent years. But we also weighted the result with many unfavorable assumptions, and assumed far less efficiency than would be worth buying compared with realistic prices for new power plants, synfuel plants, and other proposed replacements for oil and gas.

We then extrapolated this German model, in a consistently conservative fashion, to yield long-term regional (European) and global scenarios. These are not forecasts of what *will* happen, but show what *could* happen if people used energy in a way that saves them money. Such scenarios offer special advantages to developing countries, which have the opportunity to choose the most energy-efficient devices the first time rather than having to fix them up later (which is slower and costlier). Thus a world with doubled population and nearly quintupled global economic activity – a world in which (assuming this to be possible and desirable on other grounds) all developing countries have come to look like West Germany – could use less than half as much total energy in 2080 as it does today.

Moreover, detailed studies for many of the least favorable cases, checked by a variety of regional and scoping calculations, show that the best present art in renewable sources, already available and already economically competitive at the margin, can meet essentially all world energy needs within a half-century or so. And both efficiency and renewable measures can be – as in many countries they are already being – deployed faster than more complex and less accessible technologies.

Our analysis departs from most others not only in conclusions but in structure. It is customary to try to calculate (even though there is no theoretically valid or practical way to do so) [2] the climatic 'costs' of greater fossil-fuel use to be offset against the economic 'benefits' of the energy derived. Instead, we showed that a steady reduction in the *rate* of burning fossil fuel, to about zero over the next half-century or so, would be feasible and save money even if the climatic costs of burning that fuel were assessed at zero. A 'least-cost energy strategy' – which also happens to be a low-climatic-risk energy strategy – should thus be pursued if for no other reason than because it provides energy services more cheaply.

Adding CO_2 to the atmosphere at a rate which decreases rather than increases also makes the terrible arithmetic of exponential growth work backwards, in one's favor. The bulk of the 'CO_2 release commitment' is then in the short term, which is more foreseeable and controllable, rather than in the long term which runs off the right-hand side of the graphs. Even modest reductions in the rate of burning fossil fuel can buy a disproportionate amount of time to assess and cope with the CO_2 problem, because the total amount of CO_2 released is reduced by the *product* of how much times how soon the rate of burning the fuel is reduced. Within a few decades, a modest rate of reduction can make the 'tail' of fossil-fuel burning so slender that the integral under it becomes small; its length therefore becomes climatically almost immaterial, and one has centuries or millenia of leisure in which to squeeze out the last bits of fossil-fuel use. This is just the opposite of conventional exponential-growth graphs, in which only a few years or decades separate the times at which various disagreeable CO_2 concentrations will inexorably be exceeded.

The 'low' scenario published by the Energy Group of the International Institute for Applied Systems Analysis [3] envisages a world in which, by 2030, global energy use is two and a half times its present rate. The 2030 rate (22 TW) is two to three times lower than was in vogue a few years ago, but it is still so great that despite thousands of reactors and a 3-6x increase in the rate of coal-mining, conventional hydrocarbons would be largely depleted both in and outside the Middle East and at both low and high prices. By 2030, the CO_2 concentration is about 450 ppmv, rising by 50 ppmv every decade or so. In contrast, our 'efficiency scenario', assuming just the same population and economic growth, uses 4-5x less energy. It costs less, stretches oil and gas for centuries, dispenses with reliance on both the Middle East and the atom, and by 2030 has attained a CO_2 level barely 10% above today's and rising by 5 ppmv every three decades or so. The main causal difference between this scenario (which makes the CO_2 problem, and many others, virtually disappear) and IIASA's (which makes them prominent and worsening) is that we take economics seriously. The IIASA study assumes low energy efficiency, derives high energy demand, requires a costly supply system which entails very high energy prices, yet supposes that those prices in turn will elicit only derisory improvements (and some actual worsening) [4] in energy efficiency. Instead, by systematically and symmetrically comparing all investment opportunities to seek those which will deliver incremental energy services at least incremental cost, we guard against underinvestment in climatically benign energy efficiency at the expense of overinvestment in climatically damaging supply.

We do not claim that this is how people *will actually* behave – though in many countries they are already doing so far faster than our analysis contemplates. Behavior depends on many noneconomic factors, including the willingness of the political system to tolerate least-cost solutions which discommode the suppliers of uncompetitive technologies. The range of uncertainty remains great. But people who consider high-energy futures plausible should now explain why they think people will behave in a way so clearly contrary to their own economic interests. [5] The CO_2 problem is probably an artifact of an economically *in*efficient energy policy. It is the high-energy, high-climatic-risk strategies that are *un*economic and cannot survive the test of a free market. [6] The CO_2 problem, unless it is already virtually upon us, therefore will not arise unless major energy-using nations, particularly the U.S., deliberately suppress – far more vigorously than today – those market forces that would tend, unhindered, to eliminate the burning of fossil (and nuclear) fuels.

This does not mean that all the climatologists who were busy worrying about CO_2 can now forget about CO_2 and turn their attention to the host of other threats to climatic balance. We still need to know much more about how climate works. But it does mean that we won't necessarily have to row our boats up to the Capitol steps to testify on what went wrong. Economic rationality, for all its manifest imperfections and limitations, can be our strongest *ally* in curbing the worst assaults on the climate. It is time we all found out what energy economics means and why it matters.

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[6] Lovins, A. B. and Lovins, L. H.: 1982, *Brittle Power. Energy Strategy for National Security*, Brick House, Andover. See especially the economic Appendices.