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LETTER

Should Ethics Limit Scientific Research?

The article by Liebe F. Cavalieri (April 1989) confuses the natures of science, technology, and humanity. Sciences are bodies of knowledge that have value both as ends in themselves and as bases for technologies. Technologies are techniques and tools by which scientific knowledge can be applied to the production of goods and services. The resulting goods and services are produced to satisfy human needs and desires; Cavalieri's claim that they aren't is invalid, because if they didn't satisfy some need there would be no market for them.

Scientific knowledge is good insofar as it is accurate, complete,, and significant to the whole complex structure of human knowledge. Not all conclusions will be equally valuable, but their value is generally not predictable before the research is initiated. Technological tools and techniques are good insofar as they provide goods and services and not evils and disservices. The goodness of a technology may be inherent, or it may depend on the manner in which the technology is used. Whether the utilization of a technology results in good or evil depends upon the completeness of the scientific knowledge on which it is based; i.e. "a little knowledge is a dangerous thing."

Scientists behave ethically as scientists insofar as they do not unduly harm living beings or the environment, and as their reporting of research results is complete and non-biased. Technologists behave ethically as technologists insofar as they take into account not only the goods but also the evils their technologies can produce. They must understand the possibilities for evil as well as good reasonably well before offering a technology for application, and make those possibilities for evil as well as good clear to the entrepreneurs to whom the technology is offered.

Both scientists and technologists behave ethically as humans and citizens insofar as they give guidance and support for the appropriate regulation of technologies, for the development of new knowledge, and for the production of consumer goods and services. The "ivory-tower" notion that scientists and technologists have no responsibilities as citizens is wrong, and always has been.

To hinder science and technology is to limit the ability of our species to be truly human. Nevertheless, the powers given to human entrepreneurs by science and technology must be used for the good of the planet as a whole, and not merely for ourselves as individuals or larger social groups, or even as a species.

Thus the notion that science and technology should be limited because its results may produce evils and disservices, in addition to goods and services, is wrong. It is also archaic, as indicated by the early appearance of the stories of the forbidden fruit and of Pandora's box. Our need is for more complete knowledge, and for greater wisdom in the use of that knowledge, not for less knowledge.

The related notion that the process of increasing the quantity, quality, and variety of goods and services that can be provided by a given amount of labor should be reversed is equally wrong. It is also an archaic notion, espoused by the Luddites over 150 years ago and by others long before that. We need more efficient technologies, not less efficient ones. We must remain progressive, to ensure that the next generation inherits at least as good a world as we did.

In other words, we need a more careful analysis of our overall social situation and problems, a more integrated "systems approach," if we are to solve our problems. Semirational slogans such as "production for use, not for profit," "satisfy human needs, not those of the industrial structure," "emphasize natural processes," "use labor-intensive rather than energy-intensive technologies," slogans that "make a lot of sense if you don't think about them" as Dagwood Bumstead once said, will provide little help to the planet as a whole.

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ARTICLES

Symposium: The Status and Future of Energy Research and Use

Physics and Society continues its policy of publishing sets of papers based on recent Forum-organized sessions at national meetings. The first four of the five papers printed below are based on invited talks given at a session held on the evening of 15 January 1989 at the San Francisco APS/AAPT/AAAS meeting. The session was organized and presided over by Ruth Howes of the Department of Physics and Astronomy, Ball State University, Muncie, IN 47306. These four papers address four of the most-discussed energy choices: fossil, nuclear, efficiency, and photovoltaics. Although it wasn't possible to obtain a manuscript based on the second talk, the speaker's lecture outline plus the abstract seemed sufficiently complete to warrant printing them here (with the author's permission), especially in view of the importance of nuclear power in the energy debate. The fifth paper, by Albert A. Bartlett, continues the session's theme by inquiring into one fundamental implication of unlimited energy growth. *Physics and Society* welcomes further discussion of our energy future in these pages!

Energy Problems: Oil and Carbon Dioxide

David Bodansky

Energy policy is not a matter of widespread concern in the United States today. With oil cheap and plentiful, the visible manifestations of our past "energy crises" are gone. Nonetheless, we face future difficulties of too little oil and too much carbon dioxide.

For perspective, we first consider the gross trends in the US energy economy from 1973 to 1988. As seen in Table 1 (1), total energy consumption rose by only 8%, while the population increased by 16% and the gross national product (GNP) by about 46%. This marked the end of the close coupling between energy use and GNP which had existed since 1950. During this period there was a large drop in the use of natural gas, and a moderate drop in the use of oil, along with sizable increases in energy from coal and nuclear power. (Table 2). Overall, there was a decrease in direct use of fossil fuels, along with a substantial increase in the use of electricity. In fact a new, perhaps temporary, linkage has appeared, with electricity sales tracking the GNP closely since 1973, rising by 50% while the GNP rose 46%. Unfortunately, from the standpoint of CO_2, most of the additional electric generation came from coal.

Table 1. Energy consumption trends, normalized to population and GNP.

Year	Energy (quads)	E/Pop (1975=100)	E/GNP(1975=100)
1950	33.1	67	105
1955	38.8	72	99
1960	43.8	75	100
1965	52.7	83	96
1970	66.4	100	105
1973	74.3	107	103
1975	70.5	100	100
1980	76.0	102	91
1985	73.9	95	78
1986	74.2	95	76
1987	76.8	96	76
1988	79.9	100	76

Table 2. US commercial fuel consumption 1988 vs. 1973[a]

	1973(quad)	1988	increase	1988 share, %
FUEL:				
petroleum	34.8	34.0	-0.9	42
coal	13.0	18.8	5.8	24
natural gas	22.5	18.6	-3.9	23
hydro	3.0	2.6	-0.4	3
nuclear	0.9	5.7	4.8	7
other	0.04	0.3	0.2	0.3
TOTAL	74.3	79.9	5.7	100
FOSSIL FUEL USE:				
direct	54.4	51.3	-3.1	64
for electricity	15.9	20.1	4.2	25
TOTAL	70.3	71.4	1.1	89
ELECTRICITY:	19.9	28.7	8.8	36

[a]Non-commercial biomass, not included above: 2.9 quad (1984 data), of which 2.6 quad was from wood.

It should be noted that although there was no rise in US energy consumption from 1973 to 1986, there was an increase of 8% from 1986 to 1988. The moderation in energy use until 1986 and the increases since them match the trends in energy prices. This highlights the need for mechanisms to foster energy efficiency, independent of the vagaries of world oil prices.

The at least temporary collapse of OPEC's hold on prices can be understood in terms of competition from other fuels and other oil producers. Worldwide use of coal, natural gas, and nuclear power all rose substantially from 1973 to 1987, but use of oil rose only 2% (Table 3). At the same time, within a crude oil production total of about 56 million barrels per day (mb/d), Mexico and the United Kingdom together added over 4 mb/d, China and Soviet Union together added about 5 mb/d, and other countries added over 4 mb/d. OPEC's share thus dropped from 56% in 1973 to 33% in 1987.

TABLE 3. World commercial fuel production 1987 vs 1973.[a]

	1973(quads)	1987	increase	1987 share, %
Petroleum	124	127	3	39
Coal	63	90	28	28
Natural Gas	43	66	23	21
Hydro	14	21	7	7
Nuclear	2	17	15	5
TOTAL	246	321	76	100

[a]Non-commercial biomass is not included; there is a large, but incompletely documented, use of wood and wastes.

However, it is very likely that OPEC, in particular the major Persian Gulf producers, will regain a dominant position. The Persian Gulf countries hold about 45% of the world's remaining oil resources. Their internal consumption is small and almost all their oil is available for export. It can be expected that in a few decades the "surplus" oil elsewhere will be depleted, and the oil-rich countries of the Middle East will again dominate the market.

This dominance can be forestalled either by reducing the demand for oil or by developing alternatives to conventional crude oil such as Canadian tar sands or Venezuelan heavy oil However, until oil prices rise, investors are not prepared to make the large scale commitments necessary to develop such relatively expensive resources. Thus, unless conservation and substitution are unexpectedly successful in reducing the demand for oil, there is likely to be a substantial gap between the time unconventional oil is needed and the time when large amounts could become available.

It seems probable that the struggle to maintain the availability of oil will be a growing source of economic, political, and possibly military difficulties. DOE projects large increases in the next decade both in US dependence on imported oil and in its costs to us. There have been numerous warnings of the dangers of conflict over oil. Even in a period of apparent plenty we dispatched our fleet to the Persian Gulf to protect oil shipments, and oil is thought by many to have been a factor in our decision to invade Grenada, an island just off the coast of oil-rich Venezuela.

The greenhouse effect is caused by carbon dioxide and other gases in the atmosphere which transmit solar radiation and absorb outgoing infrared radiation, raising the temperature at the surface of the Earth. CO_2 is the most important greenhouse

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gas. Its effect is expected to be roughly equal to the combined effect of the remaining gases, which include ozone, methane, nitrous oxide, and a variety of chlorofluorcarbons. Manmade CO_2 comes almost entirely from fossil fuels, and energy policy can have a decisive effect on CO_2 emissions. In addition, a significant fraction of the manmade component of other greenhouse gases is related to fossil fuel use.

Largely due to fossil fuels, the CO_2 level in the atmosphere has risen from a pre-industrial level of about 280 parts per million by volume (ppm) to a present level of 350 ppm. The level is now rising by about 1.5 ppm per year, of which about 1.3 ppm is attributed to fossil fuels and the remainder to interchanges with the biosphere. A concentration of 600 ppm is commonly taken as a nominal "doubling" of the CO_2 concentration. It is expected that this level will be reached sometime in the middle of the next century, with the actual date dependent upon the rate of increase in fossil fuel use. Taking into account the other greenhouse gases, an "effective doubling" will be reached before the CO_2 doubling itself.

Fossil fuels differ in the amount of CO_2 released for a given energy output. Natural gas is best, in terms of low CO_2 emission, coal is worse by a factor of almost two, oil is intermediate, and synthetic fuels from coal and shale oil are even worse than coal itself. This dooms, or should doom, earlier thoughts of obtaining copious supplies of liquid fuels from coal.

The calculated consequences of CO_2 doubling include an average global temperature rise in the neighborhood of 4°C (with a large uncertainty as to the actual figure), changed rainfall patterns, including possible drought in the US middle west, and an increase in sea level. There already have been some hints of such effects, as during the summer of 1988, although this may have been more a result of normal fluctuations than of the greenhouse effect. However, there seems little doubt that the mean global temperature will rise as the concentrations rise, with only the timing and magnitude at issue.

The temperature rise cited above for CO_2 doubling is an equilibrium increase. The actual surface temperature rise will lag by several decades, due to the thermal inertial of the oceans. Thus, the bad news will be postponed. By the time a clear signal of a temperature rise has been detected, we will be committed to a further increase from the CO_2 already in the atmosphere as well as from the continued use of fossil fuels.

The predicted temperature increases span a wide range and the top of the commonly cited range, about 5.5°C, would represent a change far in excess of anything we have experienced. It could come quite rapidly and the ability of man, other animals, and plants to adjust is questionable. The consequences of the climate changes will not be evenly distributed. For some other countries, greatly complicating the question of international cooperation, the effects might on balance appear beneficial.

Responses to prediction of a greenhouse effect have fallen into three broad categories:

•It is too soon to panic. We do not yet know enough to make rational, temperate plans.

•It is too late to panic. The world is irrevocably committed to a rise in the levels of greenhouse gases and we should learn to adjust.

•We should promptly begin steps to minimize the production of greenhouse gases. While scientists do not customarily call for panic, there are widespread calls to Pursue Actions Now Inhibiting CO_2.

The third of these responses appears to be the appropriate one. The problem is not binary, with well-defined success or failure. We cannot predict either the rate of increase in fossil fuel use or the precise environmental consequences of any given greenhouse gas buildup. Thus, it is not possible to specify an appropriate target. Instead, the goal should be to minimize the buildup.

There is a parallel with exposures to ionizing radiation, where the accepted principle is to keep exposures "...as low as reasonably achievable, economic and social factors being taken into account" (2). The principle is manifestly imprecise, but is useful in setting forth the direction in which to move. In the same spirit, all strategies should be exploited which can reduce the magnitude of CO_2 production unless they have counterbalancing disadvantages.

The greenhouse problem is complicated by its global character. The United States is responsible for about one-fourth of the CO_2 produced. The industrialized world is responsible for about 75%. Achieving agreement among these countries may be simpler than achieving a still broader international agreement. Further, the bulk of the coal resources are in the USSR, US, and China, and it is the vast coal reservoirs that represent the greatest danger. Again, with few players agreement might be achievable.

However, there is another side of the coin. Less industrialized countries represent the large majority of world population. They are small producers of CO_2 because they are poor. If their living standards are to improve, an increase in energy use is essential. Fossil fuels remain the most quickly available source. To prevent worldwide production of CO_2 from rising in the face of this need, it will be necessary for industrial countries to reduce drastically their consumption of fossil fuels.

The issue of reducing CO_2 emissions can be considered concretely in terms of the present US energy budget. CO_2 comes is roughly equal parts from three sources: (1) electricity generation, mostly using coal (33%); (2) the residential/commercial and industrial sectors, mostly from the use of oil and gas (36%); and (3) the transportation sector, using oil almost exclusively (31%). These three categories represent successive levels of difficulty in CO_2 elimination. It would be possible to obtain almost all of our electricity from nuclear and solar sources, including hydroelectric power, eliminating about 30% or the CO_2. In the residential/commercial sector, electricity already accounts for 65% of primary energy and could account for most of the remainder with further substitution in heating. Together with more efficient energy use, this could almost eliminate the use of oil and decrease the use of natural gas. Further gains are possible in industry. In transportation, current designs would allow the fleet mileage of passenger cars to rise from an average of about 19 mpg to over 40 mpg, and beyond. There are longer-term possibilities for reducing oil use by installation of electrified mass transit and electrified vans and cars.

Looking at these possibilities together, one need invoke no novel steps to outline a US energy economy in which CO_2 production is halved. A relatively modest reduction of 2% per year would give this halving in 35 years, with no particular reason to stop there.

Steps to reduce CO_2 production include: (1) More efficient use of energy; (2) greater use of nuclear power; (3) greater use of solar power; (4) replacement of coal by natural gas; and (5) slower deforestation and increased planting of trees. Each of these steps has advantages and limitations. Rather than choose among them, each should be exploited. There is little chance that we will be too successful in restraining global CO_2 omissions.

Overall, the two problems of oil and carbon dioxide have common solutions: greater energy efficiency and greater exploitation of nuclear power, solar power, and natural gas. To speed the pace of implementing these steps, it would be desirable to have massive infusion of funds into research, development, pilot plant construction, and incentives. Raising the funds need not be difficult. A carbon emission tax of $10 per tonne of carbon (in the form of CO_2) would generate $14 billion per year. This would correspond to 0.26 cents per kilowatt-hour for electricity from coal and 2.5 cents per gallon for gasoline. Imposing such a tax and periodically escalating it could provide strong fiscal sticks and carrots for a changed energy policy. Action of this sort might seem premature, with oil plentiful and the greenhouse effect not clearly seen. However, if we wait until the need is apparent to all, we will have waited too long.

Reference and notes

1. The data for this paper are based primarily on Energy Information Administration reports (Department of Energy, Washington DC); *Annual Energy Review 1987* (May, 1988); *Monthly Energy Review, November 1988* (February, 1989); and *International Energy Annual 1987* (October, 1988). Other data are from H.A. Bethe and D. Bodansky, "Energy Supply," in *Physics Vade Mecum*, second edition, H. L Anderson, ed. (American Institute of Physics, 1989) and references therein.
2. "Recommendations of the International Commission on Radiological Protection," ICRP Publ. 26, *Annals of the ICRP 1*, No. 3 (1977).

Is There a Future for Fission Electric Power?

Robert J. Budnitz

Abstract of talk (see introduction to the articles, above):

At present, nuclear fission reactors produce a sizeable fraction of the electricity in the developed world: nearly 20% in the US, and substantially greater fractions in many western European countries and in the most developed Asian countries. However, the construction of new nuclear power plants has stopped almost everywhere, with very few orders having been placed almost anywhere in the world in the last few years. This paper addresses the reasons for this near cessation in new construction; which reasons differ from country to country; the conditions that could in the future generate interest in further expansion of fission-electric power; and activities now underway in various countries in this arena.

The paper discusses both technical and institutional factors. Technical factors include (1) how safe the existing generation of plants are, based on recent analyses; (2) how safety improvements have embedded in several recent advanced designs, based on lessons learned from experience with current designs; and (3) how recent progress has improved the likelihood for a sound technical resolution of the high-level waste issue. Institutional factors include (1) how, and how well, nuclear safety is regulated in various countries; (2) how well the operating electric utilities mange the enterprise; and (3) the way the financial benefits (and costs) of nuclear fission power are treated, and the effect of this treatment on the future of nuclear power. While the paper will emphasize US experience, its perspective will attempt to be world-wide in scope.

Outline of talk:

Current situation

Large capacities in many countries
Worldwide:
- about 400 nuclear units operating
- about 300 gigawatts installed
- about 100 gigawatts under construction

Almost no growth:
- almost no new construction
- moratoria in a few key countries

Chernobyl accident:
- frightened large segments of population
- unlike TMI, it was a truly large accident

Percent electricity from nuclear power, 1987

Rank	Country	% Nuclear
1	France	70
2	Belgium	66
3	South Korea	53
4	Taiwan	49
5	Sweden	45
6	Hungary	39
7	Switzerland	38
8	Finland	37
9	West Germany	31
10	Spain	31
11	Japan	29
12	Bulgaria	29
13	Czechoslovakia	26
14	USA	18
15	U.K.	17
16	Canada	15
17	Argentina	13
18	USSR	11

(none others above 10%)

What happened (it's very complicated)!!

Slow-down in electricity growth
Dramatic increases in costs:
- construction costs
- construction schedules out to 10-12 years
- operating problems/poor capacity factors
- operating cost escalation
- PUCs disallowed passing overruns on to ratepayers
- no standardization

Burdensome safety regulation
Public opposition:
- usually on safety
- sometimes on radioactive waste issues:
  - "NIMBY" (not in my backyard)

Most recent non-cancelled plant order: 1975

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Why try to revive nuclear power?

Electricity use will surely grow
Global climate effects of fossil fuels
Regional/local environmental impacts:
- acid rain
- mining, land abuse
- air pollution
- etc.

Costs may be "favorable" (lesser of two evils on cost!)

Underlying factors

Managerial, operational incompetence:
- complacency
- non-standardization
- not enough self-policing

Safety:
- need for many new regulations
- regulatory overkill--how safe is safe enough?

Reactors perceived as not "safe enough":
- actual safety record is excellent

Cost overruns
My analysis: A vicious circle with positive feedback

What must be fixed to get back on track?

Primarily:
Utilities must believe nuclear power is a prudent investment
Need predictability in the following:
- construction budgets
- construction schedules
- operating costs
- financial regulation
- safety regulation

Also:
Safer designs:
- more passive designs
- simplicity
- attention to human factors
- smaller-sized plants

"Solution" to the radioactive waste issue (NIMBY)

Specific needs

Industry:
- self-policing--managerial competence
- eliminating weaker utility owners
- simpler designs
- standardization
- overcome "paranoia"
- improve operations, availability

Safety regulation:
- improved administration
- rationalize the regulations
- stronger regulation of weak utilities

PUC reforms:
- reform the prudence-review process
- leave safety regulation to the NRC

Federal government:
- support advanced-reactor development
- high-level radioactive waste
- congress: support standardization
- congress: reform NRC:
  - complex regulations
  - procedures

"Public interest" groups
- eliminate demagoguery
- do more careful and supported analysis

The future

It will be awhile before the next plant is ordered in the US. The present generation of US reactors will run their course. Then, in a decade or two, there will be another generation.

Energy Efficiency: The Best Way to Save Money and Slow Global Warming

Arthur H. Rosenfeld and Robert J. Mowris, P.E.

Introduction

Improving energy efficiency in buildings, industry, and transportation can cap world fossil fuel use, delay global warming for 20 to 40 years, and provide time to develop renewable energy options such as nuclear, solar, ocean, and wind, all of which are expensive now but should be cheap in 20-40 years. Figure 1 shows that during 1973-86 conservation and efficiency fueled a 35% growth in US GNP, with no increase in total energy use (1), and a slight decrease in fossil fuel use. Oil and gas use actually dropped an average 1.2%/yr during 1973-86 (Fig. 1). Compared with efficiencies frozen at 1973 levels the US has avoided $150 billion/yr in energy bills--$100 billion due to efficiency, and $50 billion due to structural change. US energy conservation is currently saving about 14 million barrels of oil plus gas per day (Mb/d), about half the capacity of OPEC. Compared to 1973 projections we are saving 50% on our electricity bill, worth almost $100 billion and equivalent to the annual output of 250 baseload power plants (2). Improved world efficiency is currently saving 28 Mb/d, one whole OPEC. This is the reason oil prices are low, and they can continue to stay low as long as OPEC production is kept below 80% of its capacity (Fig. 2).

The environmental benefits from improved efficiency are even more than 35% because we have avoided doubling coal use. If the US were still operating at 1973 efficiencies we would have pumped 50% more carbon dioxide, sulfur dioxide, and nitrogen dioxide into the atmosphere during 1986. But we can do much better. Our target is to reduce total US energy consumption per unit of GNP by 3.5% per year. This would permit 2.5% annual growth, and still cut US energy use and fossil fuel emissions by one-half over the next 70 years. The technology to do this, such as more energy-efficient lights, windows, appliances, motors, and cars, is already available for the first 10-20 years of this path, but we need economic incentives to turn the technical solutions into reality. In addition, if we are to reduce dependence on fossil fuels well into the next century, we must invest now in energy-efficiency R&D.

The bad news is that since world oil prices fell in late 1985, we have lost our focus on efficiency, and energy use is once

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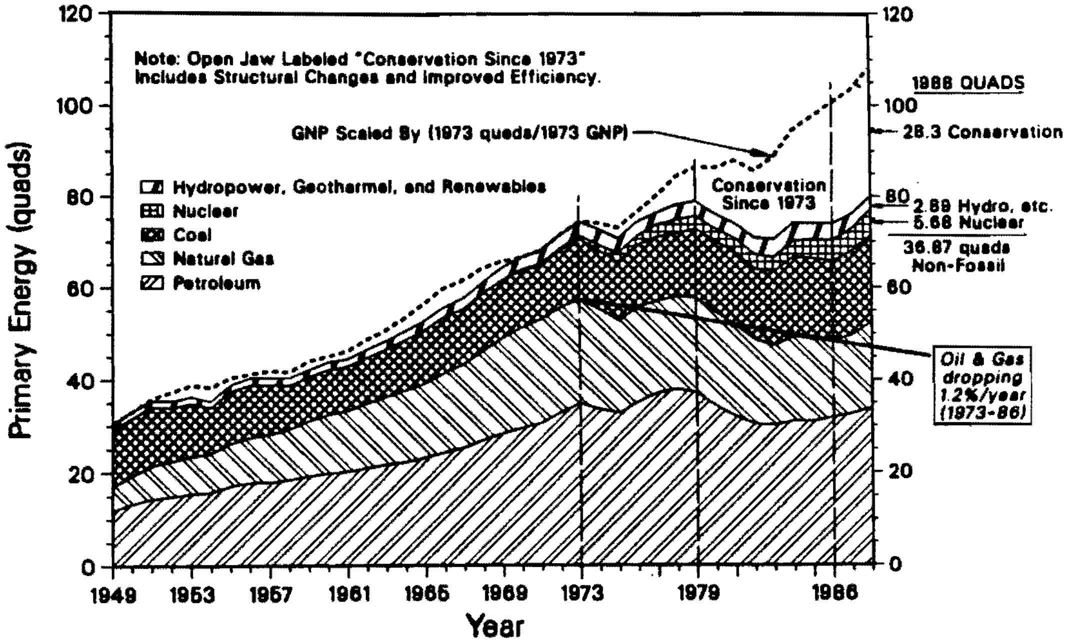

FIGURE 1. US primary energy use: actual vs. predicted by GNP (1949-1988). Energy consumption by source. Conservation and efficiency have made a significant contribution since 1973 and currently provide annual savings of more than 28 quads, worth $150 billion. Note that, shortly after oil prices collapsed in late 1985, pre-OPEC frozen efficiency reappeared and now energy use is once again in lockstep with GNP. Source: US Energy Information Agency.

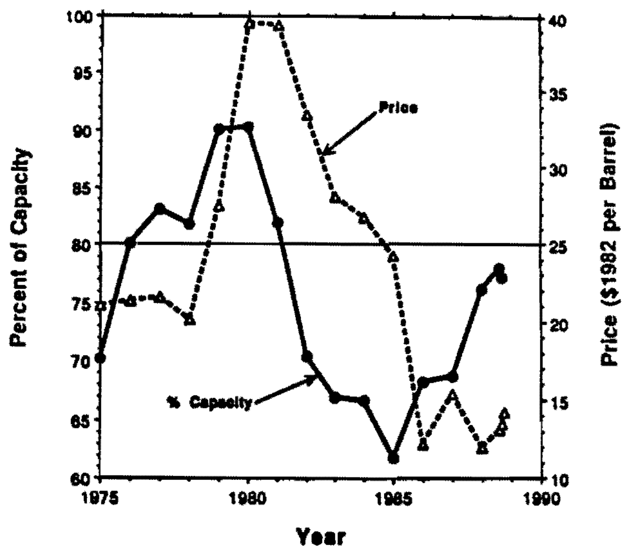

FIGURE 2. OPEC pricing behavior, 1975-1989. The figure suggests that OPEC was able to maintain or increase prices only during those years when 80% or more of its capacity was in use. Source: US Energy Information Agency.

again in lock-step with GNP (Fig 1). Oil imports are growing, and "friendly" reserves are dwindling. We are constructing suboptimal buildings requiring imported energy during most of their lifetimes. We are manufacturing cars and appliances that are suboptimal even at today's low energy prices. This is weakening our economic competitiveness. Behind this bad news is the long-standing tradition that without government and institutional help, consumer's time horizons for efficiency investments are usually three years or less.

Proposals

We must change the rules so as to reduce life-cycle costs for energy services and create rewards for investments in conservation and efficiency. This will require government action tooward policies to promote investments in efficiency. The following least-cost planning proposals could be easily implemented if utilities and governments were convinced to go after the cheapest conservation alternatives.

Gas guzzler fee/rebate program. Motor gasoline use in the US currently accounts for over 7 Mb/d, slightly more than oil imports (3). All of our industrial competitors pay a $2-3 tax per gallon of gasoline, and average new car fuel efficiencies are either the same or only about 10% higher than the current average new car fuel efficiency in the US So our federally mandated efficiency standards provided the same fleet improvement that occured in these countries as a result of high prices. However, concern for global warming, requires further improvements. A recent study (4) showed that we could improve new car efficiency from 27 to 38 mpg without changing the mix of small, medium, and large cars. Unit costs were $250 to go from 27 to 31.9 mpg, $152 to go from 31.9 to 34.8 mpg, and $208 to go from 34.8 to 38 mpg.

To stimulate demand for efficient cars we propose a revenue-neutral "front-end" fee/rebate on new cars. The revenue neutral fee/rebate program would require purchasers of "gas-guzzling" new cars to pay a fee of about $200/mpg for every mpg below a target value. The fees would pay for rebates to purchasers of "gas-sipping" new cars as well as administrative costs. Figure 3 shows an example of fees and rebates calculated for the 1987 model year. In this example cars assembled outside the US were excluded from getting a rebate. We recognize that this proposal will be perceived as a threat to American automakers, so initially we recommend paying out rebates proportional to American-made content and labor. In the short term this will protect American jobs and motivate foreign automakers to move to the US, as many have already done.

Urban trees and light-colored surfaces. A recently rediscovered efficiency option with less than a one-year payback is planting urban trees and using lighter-colored surfaces. Although greenhouse warming is just starting to be

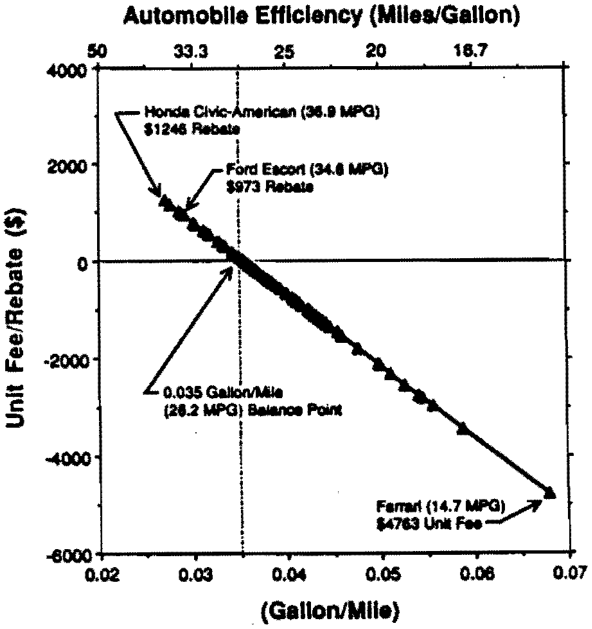

FIGURE 3. Gas guzzler fees and rebates vs. automobile fuel efficiency (7), based on 1987 new car sales. Fees would be collected for cars with efficiencies worse than the neutral point (28.2 mpg) to pay for rebates for those with efficiencies better than the neutral point. In 1987, $3.4 billion would have been paid in fees and $1.7 billion would have been rebated.

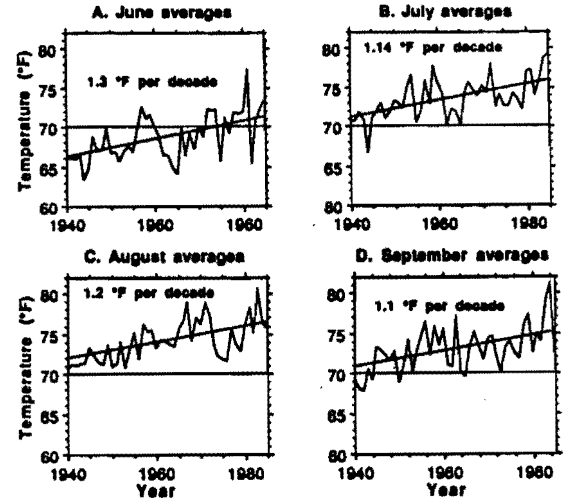

FIGURE 4. Summer Monthly Temperature Averages for Los Angeles (1940-1985). The figures all have slopes of about 1.2 °F/decade. The 45 years of data show a 5°F warming trend, and this will hit 10°F in another 30 years.

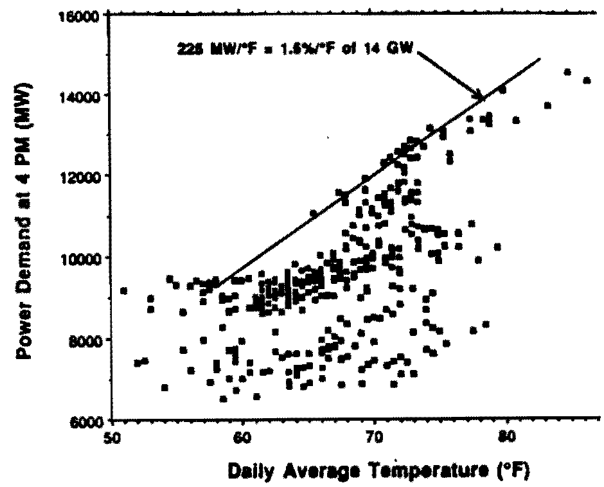

FIGURE 5. Electric power demand for Southern California Edison at 4 PM (i.e. at peak demand) in 1986 (3). The straight line representing the envelope of the data has a slope of 225 MW/°F, corresponding to 1.6% of the peak demand of 14 GW. Adding the LA Dept. of Water and Power, which covers the rest of LA basin, the total is 300 MW/°F. Los Angeles is already 5°F hotter than it was in 1940. If peak electricity is worth 10¢/kWh, then this rise of 5°F increases demand by 1.5 GW or $150,000 per hour.

recognized as a real threat, most residents of large cities can already attest to the occurance of uncomfortable summer heat islands. Our research at LBL shows that planting urban trees and using lighter-colored surfaces for roofs and pavement will reduce the effect of urban heat islands, *and* is also the cheapest way to save kilowatts of air conditioning power. Put simply the recipe is: pay $15-$75 to plant and water 3 trees around a house, wait 10 years for the trees to grow, and then save 1-2 kW of peak power and 750-2000 kWh/yr in air conditioning energy per house, worth $50-$150/yr. Similarly, when asphalt streets or parking lots need resurfacing, they should be finished off with a thin surface of light-colored sand, and any re-roofing jobs should be done in white.

Figure 4 shows the magnitude and rate of temperature rise of the heat island in Los Angeles (5). Since 1940 summer average temperatures are up about 5°F and are continuing to rise about one degree per decade. Combine this with global warming, and the expected temperature rise could be as high as 2°F per decade. Figure 5 shows how peak demand for Southern California Edison rises with temperature in the Los Angeles Basin. We estimate that for every 1 °F rise in temperature, peak demand rises about 225 MW. Our estimate for Los Angeles Department of Water and Power is about 75 MW/°F. The 5°F rise since 1940 thus requires Los Angeles Basin utilities to supply an additional 1500 MW of peak power for air conditioning. On a hot afternoon this additional 1500 MW costs $150,000/hour!

Figure 6 shows that even more significant than the multi-million dollar air-conditioning costs may be the increase in smog caused by the 5°F rise in temperature rise. We see that LA never experiences smog episodes below 74°F, but by 94°F smog has become more or less unbearable. Of this 20°F window between onset of smog and unacceptability the heat island seems already responsible for 5°F and is headed for 10°F. Fortunately we now understand enough about the causes of this heat island to undo it, and return American cities to pre-1940 summer temperatures.

"All-sources" bidding. The Public Utility Regulatory Policies Act of 1978 required utilities to purchase power from small and independent power producers at the "avoided cost" a given utility would have to pay to provide the same power on its own. Several public utility commissions have adopted a similar competitive process called "all-sources bidding" to provide future electricity capacity by improving the efficiency of existing buildings and industry. Seven states have approved all-sources bidding systems, and some of these have awarded contracts to small independent companies to install retrofits. Regulations are being developed in three other states. Typically, small companies contract to retrofit lighting systems, heating, ventilating, and air conditioning systems, improve the energy efficiency of an industrial process, and/or improve the building shell.

Sliding-scale hookup fees and rebates. Yet another way to build energy efficiency into new residential and commercial buildings is through sliding-scale hook-up fees and rebates. This proposal involves setting target energy consumption and

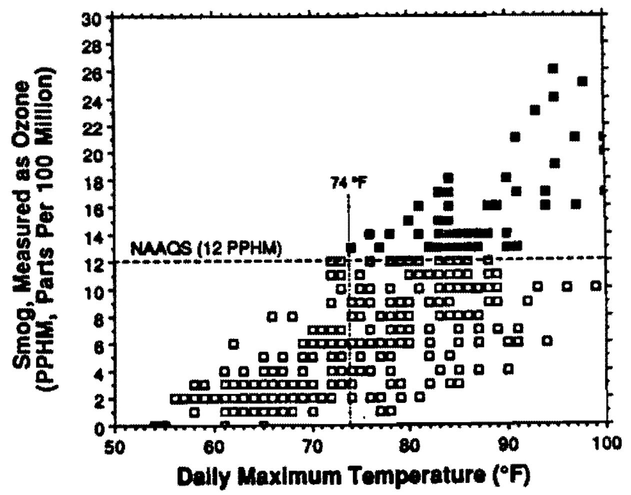

FIGURE 6. Los Angeles smog concentration at North Main Street (1985 Data). The horizontal line marks the national standard for ozone of 12 PPHM, and shows that Los Angeles never experiences smog episodes when the daily maximum temperature is below 74 °F. Source: Laura Wilson, University of California, Berkeley, based on California Air Resources Board, *California Quality Data*, Volume 17, No. 1-4, 1985, and US Dept. of Commerce, *Climatological Data, California*, 1985.

peak demands for new buildings. Buildings using more watts/ft^2 than the target values would be charged a \$1000/kW fee, and buildings using less would receive a rebate. The target would be adjusted annually to keep the account revenue neutral. A portion of the fees would cover administration costs, and some portion could be shared with the utility as a reward for conservation.

A revenue-neutral carbon dioxide pollution fee/rebate program. To help prevent global warming we propose a fee/rebate based on CO_2 emissions corresponding to about 2¢/kWh for a coal-fired plant and 1¢/kWh for a gas-fired plant. This proposal calls for all 50 states to participate, but with no interstate income transfers. The idea is to reduce carbon dioxide generated by utilities within a given state by getting them to shift from fossil fuels to improved efficiency and renewables. In order to get the program accepted by states heavily dependent upon coal, the federal government could provide funds to retrain coal miners, and provide other financial incentives for energy conservation or renewable energy demonstration programs.

Premium profits for utilities who offer lowest cost energy services. Regulators should rewrite profit rules so as to motivate utilities to sell energy services rather than raw energy. This could be accomplished by creating a base period and establishing an index comprised of the average bills of all utilities in a given region. Premium profits could be earned by a utility depending on the relative performance of the average customer bills compared to the index.

Conclusion

The goal of these policy proposals is to reduce energy intensity in the US by 3.5% per year over the next 20 years. Studies (6) show that if policies like these are vigorously pursued the US could keep total energy use at or below current levels, and save \$1.3-2.2 trillion more over the next 20 years. The total investment in conservation measures would be four times less than this \$1.5 trillion saving, or about \$300-500 billion. The US could cut oil imports by 2-3.5 mb/d, cutting the trade deficit by \$20-40 billion/yr, and delay the time when OPEC regains control of the world oil market. Investments in improved efficiency would provide industry with a better competitive position in world markets, and free up more than \$100 billion annually for capital investment in other industries. The poor would benefit from lower energy costs and additional jobs. Reduced emissions of carbon dioxide and other pollutants would lessen environmental damage and reduce the impact of global warming.

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Photovoltaics In Our Energy Future

H.M. Hubbard and Gary Cook

Introduction

As populations grow and economies expand, the world will continue to increase its energy consumption. Some projections suggest that world primary energy consumption will more than double by 2030. If the world continues to rely primarily on conventional energy sources, then problems of supply and related concerns of trade balance, environmental degradation, and waste disposal will increase dramatically.

To allay such concerns, the world should increase its reliance on conservation and new supply technologies. The incorporation of both types of technologies is appropriate for industrial nations who, although they will consume more total energy, should continue to cut their consumption per GNP. The developing nations, on the other hand, will expand their energy consumption per GNP, and so should rely on new supply technologies as the most appropriate way to decrease dependence on conventional supplies. The most important types of the new

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technologies may be those for generating electricity, for at least two reasons. First, all nations continue to expand their consumption faster than any other energy sector. The United States, for example, increased electrical use by 17% during 1982-87, although total energy consumption grew by only 5.7%. The electrical growth rate in developing nations is even greater. Second, most nations continue to rely heavily on conventional technologies for electricity, which could prove harmful to the world environment.

Hence photovoltaics (PV), an emerging technology that employs semiconductors to produce electricity directly from sunlight, could be one of the world's most important 21st century energy technologies. Photovoltaics offers a fundamentally different approach to energy and meets the requirements that the world will demand of tomorrow's technologies:

•It is versatile. Systems can be designed for remote or centralized uses, dc or ac applications and for one milliwatt to hundreds of megawatt applications.

•The energy supply for photovoltaics, sunlight, is available to everyone, vast, and inexhaustible. More than 55,000 quads of sunlight fall on the continental United States yearly, 700 times greater than US energy consumption.

•Photovoltaics are relatively benign to the environment. Although there are minor concerns over mining, space allocation, and toxic manufacturing materials, these concerns are minor compared to all conventional technologies. And once installed, PV systems do not use fuel, produce exhausts or wastes, or contributed to global warming.

•Photovoltaics have the lowest operation and maintenance costs of all electrical options.

Photovoltaic technology

The underlying idea is simple: starting from a small semiconductor unit (or *cell*) that changes sunlight into electricity, you can add units to build a system of any size and output. A cell has specially prepared semiconductor layers that absorb light to free electrons. A junction between the layers creates a voltage to drive the electrons through a circuit.

The next largest unit is the *module*, which is generally formed by connecting a few or many cells together. This produces more power and provides protective packaging. Cells do not have to be connected to form a module. With some amorphous and polycrystalline devices, modules are made by depositing the material over a large area, which is actually a single cell. For large power needs, modules are grouped together in *arrays* or fields of arrays. Photovoltaic systems produce direct current which can be used as is, or which can be converted to alternating current.

There are generally three avenues to make PV systems cost effective: you can make devices that are efficient, or inexpensive, or both. In any case, modules must operate reliably for 20 to 30 years.

The efficiency of a device is limited by carrier capture and loss mechanisms. The largest factor is the inherent inability of a device to capture and use all of the solar spectrum. Efficiency is also limited by the quality and type of material, carrier recombination, reflection of light from the surface, shading by the grid, and series and contact resistances.

Cost is also determined by several factors: the kind of materials used and the amount required; the choice of substrates; device design; and fabrication technique.

Although many materials are being investigated, most progress is from crystalline silicon, amorphous silicon, polycrystalline thin films, and III-V single-crystal materials.

Crystalline silicon comes in two forms: single-crystal and polycrystalline. Single-crystal silicon has the longest history of any PV material and the largest technology base. Single crystal silicon devices are more efficient than polycrystalline devices, but also more expensive. Polycrystalline silicon devices can be made less expensively because they utilize cheaper, less pure silicon produced by less costly manufacturing methods like ribbon technology, which grows sheets of silicon, and cast silicon, which produces square ingots.

Both single-crystal and polycrystalline silicon technologies have advanced appreciably over the last decade. Methods have evolved for making better materials. Manufacturing processes continue to become more automated. And device and materials physics have resulted in innovative designs that employ such advances as antireflection coatings, pyramid textured top surfaces, back-surface mirrors, and extremely small p- and n-type point contacts on the back surface.

Consequently, devices have become less expensive and more efficient. For example, some single-crystal cells can now convert as much as 22.8% of the incident sunlight into electricity under ordinary sunlight and 28.2% under concentrated sunlight. With further improvements, efficiencies could go as high as 30% and 36%, respectively.. For polycrystalline silicon, the efficiency of research cells is about 17%, nearly double that of a decade ago. And design innovations may help make polycrystalline cells 40 times thinner than current cells while attaining efficiencies greater than 19%.

Amorphous silicon, a thin-film material, presents a less expensive option than even polycrystalline silicon, but cells made with it are less efficient. Amorphous silicon absorbs light extremely well, can be deposited over large areas on a variety of inexpensive substrates, and is amenable to automated production. Since the first cell was made in 1976, single-junction cells have progressed from 0.2% efficiency to 12%. Multijunction cells, in which several cells are stacked on top of each other to capture more of the solar spectrum, have reached 13.3%. And large submodules (over 1000 cm^2) have surpassed 9%. With further advances in materials and device design, efficiencies of three-junction cells may pass 20%.

Polycrystalline thin-film materials, notably copper indium diselenide and cadmium telluride, offer all the advantages of amorphous silicon yet they are more stable. Although they are new PV materials, they are already resulting in relatively efficient devices for thin-film materials. Large cadmium telluride submodules (more than 1000 cm^2), for example, are now greater than 7% efficient, while small-area cells have reached beyond 11%. And square-foot submodules of copper indium diselenide have achieved greater than 11% efficiency, while some new cells are reported to be more than 14% efficient.

Even higher efficiencies are in the offing using multijunction concepts. One organization reports a 15% efficiency for a multijunction device that uses hydrogenated amorphous silicon for the tip cell and copper indium diselenide for the bottom cell. Others are working on two-junction devices that use cadmium telluride and copper indium diselenide, a concept that might reach efficiencies above 20%.

III-V materials, such as gallium arsenide and its alloys, may offer the highest efficiencies. Most of the efficiency records for photovoltaic devices are held by III-V materials: the highest efficiency for any thin-film cell, 22.4%; 24.3% for single-junction cells under ordinary sunlight; 29.2% for a single-junction cell under concentrated sunlight; and 31.0% for a gallium arsenide on silicon, two-junction cell, the all-time record. III-V materials have the ability to reach efficiencies as high as 40% in a 3-junction configuration.

III-V devices still face the obstacle of lowering the cost. But researchers are exploring a concept that could make gallium arsenide devices both efficient and inexpensive: reusable substates, where devices are grown on a low-cost substrate and then peeled off, so the substrate can be used again.

Issues

Cost. Because of technology improvements, in the last dozen years the cost of PV electricity has dropped 40 fold, from $15 to 30 cents/kWh.

To bring PV into wide use, there are two important cost goals. The first is 10 to 15 cents kWh, which should be reached within the next three years with economies of scale as companies build larger, new automated manufacturing facilities (10 MW/year). This will make PV systems cost competitive for most distributed uses and for some utility peaking power applications. The second goal is 6 cents/kWh, which we should reach within the next decade. This will make PV competitive with all conventional sources of utility power.

Market. The drop in cost, coupled with PV advantages, has led to ever-widening applications. The PV market has grown from nearly zero twelve years ago to $400 million per year. About 40% of this is for consumer products, and the rest is for power modules ranging from small applications to central utility.

The future potential market for PV power modules is billions of dollars per year. This will be divided between distributive and bulk power uses. Markets in developing nations will lean toward distributive uses while developed nations will lean toward central power.

Both markets are extremely important. As developing countries continue to expand their economies, they will need adequate power. Photovoltaics are appropriate for this for several reasons: all areas of the world have the resource; many inhabitants of developing countries live in remote regions where conventional supplies are costly and uncertain; PV systems are versatile and can be designed and built to fit any application; PV systems are easy to install and maintain; turnkey manufacturing facilities can be built and run locally.

The thousands of systems currently in place testify to the versatility and facility of photovoltaics. There are systems in Bolivia that provide power for communication; in West Africa replacing diesel generators and providing energy for water pumping, lighting, and computer; in Mexico producing solar electricity for lighting, radio, and television; in Nigeria supplying electricity to refrigerate vaccines; in India for pumping water; and in Saudi Arabia providing village power. And the list goes on.

World Environment. Widespread use of this technology has just begun. A prices fall and reliability increases and financing becomes more available, we will see the use of PV systems spiral, both for distributed and central applications.

Widespread use of photovoltaics is important also for the world environment. For example, every quad of PV electricity would displace about 3 quads of coal, allowing the world to avoid adding 75 million tons of carbon to the atmosphere. Similar calculations could also be performed for the emissions of SO_2 and NO_x. Such displacement could have major ramifications for global warming, acid rain, and waste disposal.

For PV to substantially help stem environmental degradation, it must become a major factor in all nations, especially the developing nations.

Storage. Photovoltaics will not reach its full potential until researchers solve the problem of inexpensive storage. Without storage PV will not be suitable for baseload utility power, since sunlight is intermittent. Several storage technologies are being investigated. The leading near-term contenders are lead-acid battery storage, pumped hydro, and compressed air storage. In the future, fuel cells, electrically generated hydrogen production, and superconducting magnetic energy storage are of great interest. The latter two, while technically very challenging, offer unique advantages as storage systems. With superconducting magnetic energy or hydrogen storage systems, PV power systems could completely displace conventional electrical generating systems.

The future

Solid-state PV technology is open-ended in the sense that we do not know to what limits it will spiral. But recent progress has demonstrated that we can go well beyond where we are. For example, not too long ago very few people suspected that amorphous silicon could exhibit any PV characteristics. Now amorphous silicon is just one of dozens of new PV materials to have been discovered in the last decade. Dozens more should be discovered and developed in the decades to follow.

In our fast-paced technology, research breakthroughs not only happen, they should be expected. We may even be able to do what some pioneers in amorphous silicon envisioned: spray a photovoltaic material on houses, much as we now do paint, electrically connect it, and have cheap, abundant, non-polluting electricity. Such a vision may not be so far off. We already have materials that can be stored in gaseous form for thin-film photovoltaics. We are using spray fabrication techniques with some materials.

Such developments could revolutionize not only our energy systems, but the way the entire world lives.

Fusion and the Future

Albert A. Bartlett

The process that has been called "cold fusion" was announced to the news media in late March 1989 by Pons and Fleischmann. In mid-April short statements by two professors of physics at another university came to my attention. These statements dealt with the implications of the possibility that fusion might provide the human race with nearly unlimited energy far into the distant future.

Physicist A said, "If fusion becomes self-sustaining, we've got an energy source that is almost unlimited. It would be incredibly beneficial to mankind if it is true." Physicist B said, "If the Pons-Fleischmann breakthrough is for real then it will be one of the greatest disasters ever to befall mankind."

We can't be surprised that the public is puzzled over scientific issues, when experienced university physics professors respond so differently to news of science.

The outcome of fusion experiments will have a major bearing on the future of industrialized and emerging societies. In any discussion of physics and society we need to study the implications of finding a source that might provide energy "too cheap to meter (1)."

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Western civilization is built on growth. In some circles, continued population growth is regarded as good (2). Rates of growth of gross national product (GNP) and of the rates of consumption of non-renewable natural resources are an almost universal measure of progress, and some have defined a "recession" as a period in which the annual growth rate of the GNP falls below 2%. The idea of limits to growth was widely rejected by economists and business leaders, some of whom felt that the idea of limits was too terrible to contemplate. Others said flatly that there are no limits (2). Some say that technology will solve all our problems.

If an enormous source of low-cost energy is discovered, it is easy to predict what the immediate consequence would be. Our political and economic leaders would collectively breathe a great sign of relief and would then discard all notions of energy limits. They would rejoice over the advent of a period of uninhibited growth in global rates of energy consumption.

In order to estimate the consequences of likely rates of growth of global energy consumption, we must remember that essentially all of the energy released by human activity winds up ultimately as heat in the environment. First we need some data. The solar power incident on the earth can be calculated by multiplying the solar constant (1.35×10^3 W/m^2) by the projected area of the Earth (pR_e^2). This gives 1.7×10^{17} watts, of which 34% is reflected back into space (3), leaving 1.1×10^{17} watts of solar power entering the earth's atmosphere. Romer (3) shows that the rate of energy use by humans is 8×10^{12} watts. A simple quotient shows that human activities put into the Earth's atmosphere about 10^{-4} of the power the sun puts into the Earth's atmosphere. The simple arithmetic of growth shows that one would gain a factor of 10^4 in 14 doubling times. At a growth rate of 3% per year the doubling time is 23 years and 14 doubling times would take only about 300 years (4). The arithmetic would suggest that at this modest growth rate, in 300 years human activities would put about as much thermal power into the Earth's atmosphere as the sum puts in! The absurdity of this situation is obvious. Independent of the "greenhouse effect," global warming from this direct heating would likely render the Earth uninhabitable long before the passage of 14 doubling times.

One must now ask, if we had unlimited energy resources, are there any indications that humans could act in unison to limit the energy consumption growth rate in order to protect the planet? The signals here are mixed. The good news is that we have seen an international agreement to reduce the use of chlorofluorocarbons which pose a major threat to the global atmosphere. We see growing concern about growth of CO_2 and other greenhouse gases, but the bad news is that it is hard to imagine any effective program to reduce the use of fossil fuels, one of the main sources of atmospheric CO_2. Is anyone going to tell the People's Republic of China that it can't construct the large numbers of coal-burning electric generating plants needed to modernize its society? Is anyone going to tell Americans that we can't use our automobiles as much as we want because the CO_2 from the exhaust is harming the global atmosphere?

There is no threshold such that, if pollution exceeds that threshold, people will universally recognize the need for dramatic remedial action. In our cities, people adapt to growing smog and air pollution while political leaders wring their hands and advocate vigorous pursuit of every manner of minor remedial measures while they ignore the fundamental causes. Automobiles are a large source of pollution. The total pollution from autos is proportional to the product of two things; the pollution each car generates each kilometer it is driven, multiplied by the total kilometers driven per unit time by all people in a population. Our political leaders are willing to require that the automakers reduce the pollution per kilometer driven but are unwilling to stop the population growth and the corresponding growth in the number of kilometers driven per unit time. They don't seem to recognize that the benefits of a 5% reduction in the pollution per kilometer of our automobiles are cancelled by a 5% increase in the number of kilometers driven each year.

Many people have modified their attitudes so that they now accept smog. In the same way, some people now seem willing to accept global warming and are now asking how we can adapt to a warming of a few degrees. For example, in a recent conference in Denver, one of the topics was, "Will Colorado still be the ski capital of the world if the average temperature of the planet rises 3-8 degrees centigrade? How can we prepare for that?" It would be unpleasant to talk about how we might reduce Colorado's contribution to global warming, so instead we choose to talk about how we may adapt to the change.

I believe I agree with Professor B in thinking that if an abundant source of low-cost energy is found it may be the worst thing that has ever happened to the human race.

Whether or not the present efforts in "cold fusion" are successful, we should alert our students to these simple calculations so that they can play a role in the preservation of our global environment.

I wish to thank Professor George Dulk for calling this conflict of ideas to my attention.

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REVIEW

The New Oil Crisis and Fuel Economy, Preparing the Light Transportation Industry for the 1990's, by Deborah Lynn Bleviss.

Quorum Books, 88 Post Road West, Westport, Connecticut 06881, 268 pages, $49.95.

The U.S. has magnificent research programs in most areas of science and many areas of industry, and has begun to move in civilian engineering research. Setting priorities among competing research goals is a prominent issue for science and engineering policy. This discussion of priorities is beset with claims about the importance of particular areas of research to our economy. And yet, as I think we all suspect, our economy fails to make good use of the research that is done. Deborah Bleviss' excellent book enables one to examine this central difficulty of our economy in the case of innovation in the fuel-efficiency of automobiles and light trucks.

The weak link between the large R&D budgets and the products of General Motors and Ford is discussed by Bleviss in terms of the nature of the competition, the means of raising capital, industry maturity, corporate culture, R&D management, product liability, energy perspectives, and government policies. It is instructive to have all these different perspectives brought to bear in a single compact discussion. There is no pat answer to the slow pace of innovation in US manufacturing, but there is much to learn.

The discussion of innovation by the auto industry is only one part of Bleviss' book. The main theme is the major opportunity we have to improve fuel economy and thereby sharply reduce energy and environmental problems. In my opinion, her focus is the correct one for the US: the petroleum-fueled personal passenger vehicle, rather than alternative fuels or alternative modes of transportation. Bleviss shows that there is a technological ferment, new technologies in every stage of development, potentially affecting every aspect of the vehicle. An astonishing number and variety of technologies is presented. While this is not a technical book, with no equations and few quantitative figures, physicists will find plenty of information and explanation to consider.

I enthusiastically recommend this book to everyone interested in motor vehicles. Bleviss shows that improved technology can, in principle, go a long way toward solving some important problems for this society. She clearly presents the economic, corporate and public-policy context in which decisions on adoption of new technologies will be made. We must understand this context and act on the basis of that understanding if we are to realize the benefits of the new technology soon. Or we can wait to act after the next crisis does its damage.

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NEWS

Minutes of the 1 May 1989 Meeting of the Forum Executive Committee

We met in the Hyatt-Regency Hotel, Baltimore MD. Members present were B.G. Levi, R. Scribner, H.H. Barschall, D. Hafemeister, S. Brush, M.B. Einhorn, A. Fainberg, A.V. Nero. Members absent were E.W. Colglazier, P.F. Craig, D.Schroeer, G.R. Garrar, R.R. Freeman. Present as observers were A. Hobson, R.H. Howes, H. Lustig, R. Roy, V. Thomas, P. Zimmerman. Levi called the meeting to order at 8:50 a.m.

Minutes of the 19 April 1988 executive committee meeting (*P&S* January 1989) and of the 15 January 1989 special meeting (*P&S* April 1989) were approved.

Barschall reported on the Forum fixed income fund. Balance 1 April 1988: $14,782. Income: dues $10,353, registration fees $5,198, short course $4,187, interest $1,502, and contributions $102. Expenses: newsletter $8,400, short course $4,983, missile study $3,957, energy study $4,154, operating expenses $2,624, and speakers $1,357. Balance 1 April 1989: $10,649.

The treasurer reported that during recent years the Szilard and Forum Award expenses have been paid out of the Forum Award fund, which, as a consequence, has a balance of only $415. The executive committee voted to transfer this year's award expenses for the award fund to the income fund. By reading the past minutes of the APS executive committee and of the APS council, the treasurer found that the council had approved the appropriation of funds to the Forum, but could not find any record of the transfer of funds. The executive committee of the Forum requested that the APS treasurer look into the history of these APS Council actions to determine whether the Forum ever received the funds that were appropriated.

The executive committee instructed the Forum treasurer to present a budget for the following year at the 1990 executive committee meeting.

Levi presented the report of the Chair. The revision of the Forum bylaws awaits action at the Forum business meeting. The principal changes involve the Forum newsletter editor. The purpose of the changes is to make the bylaws consistent with actual practice. In addition the revision removes the use of the male pronouns from the bylaws. The missile study was completed. The energy study is progressing, but no new studies have been proposed. Forum members are encouraged to make proposals for studies. The Forum has sponsored very successful sessions of invited papers at APS meetings. The Forum newsletter is well run and is interesting.

Scribner reported on POPA activities. POPA is sponsoring a Mediterranean Physics Conference, which will bring together physicists from many countries including Arab countries and (continued on next page)

Ballot on ByLaw Changes

Proposed Forum ByLaw Changes were published in the April 1989 newsletter and discussed at the 2 May 1989 Forum business meeting in Baltimore. Now it is time for your vote. Please indicate your vote below, sign your name as evidence of your membership in the Forum, clip (or photocopy), and mail (in your own envelope) to the address given.

__ I vote *for* the proposed ByLaw changes.

__ I vote *against* the proposed ByLaw changes.

Clip (or photocopy), sign your name below, place in an envelope, and mail to:

H. H. Barschall, Sec-Treas
Dept of Physics
Univ of Wisconsin
1150 University Ave
Madison WI 53706.

(Your signature will be removed before the votes are counted).
I am a member of the Forum on Physics and Society.

Signed: ________________________________

Israel. The APS president wrote a letter to the president of the National Academy of Sciences to encourage NAS to carry out a study of automotive efficiencies. POPA is convening a workshop for planning new studies.

Hafemeister reported on APS council actions. The planning study is going forward. The proposed changes in APS governance are undergoing further changes. The pattern of APS meetings was discussed extensively.

Barschall reported on problems the Burton Award task force (which he heads) has had in agreeing on criteria for the award. Lustig expressed surprise that what he expected to be a non-controversial proposal had led to the present impasse, but he hoped that agreement could soon be reached.

Levi and Hafemeister discussed efforts to endow the Szilard Award and reported some encouraging results.

Hobson asked if he could increase the length of the newsletter from 16 to 20 pages. The executive committee voted to allow a 20 page newsletter no more than twice per year. Some of the material published in the newsletter may be appropriate for the APS newsletter, to be published starting next January.

Zimmerman reported that the awards committee had received ten documented nominations and had difficulties selecting only two candidates. A problem the committee encountered was that a large number of letters in support of one candidate was received. The executive committee voted that in the future no more than three letters in addition to the nominating letter should be considered by the award committee in support of a given candidate.

Fainberg presented the nominations committee report. Barschall suggested that in the future voters be required to put their name on the outside of the letter containing the ballot so the secretary could check whether the voter is a member of the Forum. The executive committee approved this requirement.

Nero discussed criteria for APS fellowship and what number of candidates the Forum should propose. The executive committee felt that only candidates whose qualifications are based on their contributions to societal issues should be proposed by the Forum, while candidates who are nominated because of their contributions to physics research should be proposed by the appropriate division. The number of candidates proposed by the Forum in recent years appears to be reasonable.

Howes reported that the energy study is making good progress and the she expected to have camera-ready copy ready at the end of the summer.

Roy proposed that the Forum co-sponsor the Conference on Technological Literacy organized by the National Association for Science, Technology and Society (NASTS) to be held in Washington in February 1989. Present co-sponsors include AAAS and the American Society for Engineering Education. The Executive Committee endorsed this proposal, but was not sure whether the Forum had the authority to do so. Hafemeister will explore whether APS might be willing to co-sponsor. Roy also proposed a symposium on science for the non-scientist at an APS meeting.

Barschall asked about royalties to the Forum from publishers of Forum studies. The Forum incurs considerable expense in the preparation of its studies and presents the manuscript in camera-ready form to the publisher. If the Forum is to continue studies, it would be helpful to get a return on successful publications. There was agreement that this question should be raised with the publisher. Alternatively the publisher might be asked to provide free copies of Forum studies for distribution to relevant legislative and executive branches of the government.

The executive committee expressed its gratitude to Barbara Levi for her outstanding performance as Chair. The meeting adjourned at 2 p.m.

Call for Awards Nominations

The Szilard Award is given to an individual or group who has applied physics in the public interest, while the Forum Award is given to an individual or group who has promoted the public understanding of the relation of physics to society. The awards will be presented at the Spring 1990 meeting of the APS. In 1989, Anthony Nero of Lawrence Berkeley Laboratory received the Szilard Award for his research on a broad spectrum of problems involving physics, the environment, and public health, including radon health hazards, indoor pollution, nuclear proliferation, and reactor safety. James Randi, "iconoclast" (as his name tag announced), received the Forum Award for his defense of science and the scientific method against psuedoscience, frauds, and charlatans, and in particular for his use of scientific techniques to refute suspicious and fraudulent claims of paranormal results.

Nominations for the Szilard Award and the Forum Award, with supporting material, should be sent by 1 September 1989 to: Elmer W. Colglazier, Energy Environment and Resources Center, University of Tennessee, 327 South Stadium Hall, Knoxville, TN 37996.

Call for Officer Nominations

Forum elections will be held in January 1990, with terms to begin in April 1990. We will be electing a vice-chair, a secretary-treasurer, and two executive committee members. Send your nominations, by 1 September 1989, to Samuel F. Baldwin, Center for Energy & Environment, Princeton University, Princeton, NJ 08544.

Forum's Missile Study Published

The Forum's new study, *The Future of Land-Based Strategic Missiles,* edited by Barbara G. Levi, Mark Sakitt, and Art Hobson, (287 pages, American Institute of Physics, 1989, clothbound, $28 for AIP or APS members, $35 nonmembers) was released at the recent Baltimore APS meeting. It is the second published Forum-sponsored study.

The future of strategic land-based missiles has been under debate for many years, but there is still no clear choice for what is to succeed the current force of Minuteman missiles. The options include large multiple warhead missiles, small single warhead missiles, superhard silos, mobile trucks, railroad cars, as well as missile defense of silos, launch on warning, no changes in current deployments, and moving away from land-based missiles toward a bomber/submarine "diad."

To promote informed debate, the study group has collected background material on these and other options, and has evaluated each. The book gives a brief summary of study findings, historical background for the missile debate, a discussion of current strategic doctrine, brief evaluations of 10 options, and 12 research articles. It is designed for educators, interested non-specialists, and policy analysts.

For a more detailed description, see *Physics and Society,* April 1989, p. 12.

The International Physics Group

Like the Forum, the International Physics Group (IPG) stands outside the general structure of APS Divisions and Sections. IPG is an APS unit for all members interested in international aspects of physics. Of its 5000 members, some three quarters work in the US. Although dedicated to fostering communication and understanding among physicists of all countries, in practice IPG has focused on developing countries. These physics communities are small, geographically remote, low on resources, and so lacking in outside communication that third-world colleagues find themselves effectively outside the international community of physicists.

IPG has developed many activities to help address these problems. IPG concerns are largely social, even political, although the programs address these concerns through professional activities. This is the sense in which the Forum and the IPG occupy a special place within the APS; they are the only two membership organizations whose work stems from a concern with sociological and political issues in physics.

The IPG executive committee reports to its membership through a newsletter that is published periodically in the Bulletin of the APS. Please watch for it. Our continuing programs include:

•*Journal and book exchange* with scientists in developing countries who would benefit from these materials.

•*Travel awards* for US physicists invited to speak at conferences in developing countries, or for physicists from third world countries invited to speak at APS meetings.

•*International meetings and sessions*, including a planned sequence of "international sessions" at regular APS meetings, perhaps in the style of Forum sessions and possibly in collaboration with the Forum.

•*Hospitality suites* at APS meetings, as there are for regular divisions and sections, where physicists who share IPG's interests naturally gather and talk.

•*Promoting APS activities*, such as the matching membership program providing free membership for physicists in developing countries, and the STEP program that supports conference attendance for foreign graduate students who are studying in the US.

For further information, contact: Alwyn Eades (Chair), Materials Research Laboratory, University of Illinois, 104 S. Goodwin, Urbana IL 60801.

Promote Science and Society Awareness! Inform Others About the Forum

Distribute *Physics and Society* to others, either by loaning or photocopying your copy, or by writing to the editor (address on page 2) and requesting any number of copies, from a few for acquaintances to as many as 100 (if available) for distribution to physics departments or at meetings. If you distribute very many copies it would be helpful to make an announcement, or to enclose in each copy a note, encouraging Forum membership.

Urge others to join the Forum. *Physics and Society* is sent free to all Forum members, and Forum membership is free to APS members. To join the Forum, APS members need only indicate their desire to join on the annual APS membership renewal notice, by listing "Forum" on the front side of the notice as described under "renewal instructions." Alternatively, APS members can join the Forum by filling out the following statement of intent and mailing it either to the editor or directly to the APS:

I am an APS member who wishes to join the Forum:

NAME (print) ________________________________

ADDRESS ________________________________

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Physics libraries may receive *Physics and Society* free upon request by writing to the editor. The Forum hopes that libraries receiving *Physics and Society* will keep it permanently. Forum members should request that their libraries do this.

Individuals and organizations who are not members of APS may receive *Physics and Society* free upon request by writing to the editor; voluntary contributions of $10 per year are welcome. Make checks payable to APS/Forum.

COMMENT

Liberal-arts Physics and the Meaning of Quantum Theory

The long debate over the meaning of quantum theory has had fascinating exposure recently in two widely read physics journals. The question raised boils down to whether or not quantum theory is very "odd" (non-classical, acausal, probabilistic, discontinuous). Answers range over the spectrum from "not odd at all" (1), through "slightly odd, but this has been grossly exaggerated" ((2), letters from Milonni and from Feshbach and Weisskopf (3)), to "yes, it really is odd" ((4), remaining letters in (3)). I wouldn't want to imply that democracy rules in science, but in this particular exchange the majority opts for "really odd" by a vote of 8 to 4. Although I have no statistics to prove it, I believe that most physicists agree that quantum theory implies a conceptual view profoundly different from classical physics. Most physicists, that is, who bother to even think about it, for I fear that all too many never bother.

Any introductory physics course claiming to deal with concepts should place heavy emphasis on modern physics in general and the interpretation of quantum theory in particular. Certainly, every "generally educated" college graduate should be on speaking terms with energy levels, quantum jumps, wave-particle duality, the wave function and its probabilistic significance, the uncertainty principle, quantum acausality, and the thoughts of Bohr, Heisenberg, and others about all of this.

In our Physics and Human Affairs course for liberal arts students (5), we spend several lectures on the conceptual and experimental foundations of quantum theory. This is followed by two lectures on the quantum theory of hydrogen (we don't do the semi-classical Bohr theory) and, by extension, the other elements, in order to show that this strange theory is not just philosophical talk, but has specific and breathtakingly precise real-world implications.

A unifying theme of the entire course is that modern physics, defined by relativity theory and quantum theory, represents a profound conceptual break with Newtonian physics. During the first half of the course we develop the Newtonian world view of the universe as a machine composed of many independently existing parts, operating in accordance with deterministic and complete laws. The electromagnetic theory of light provides a transition into post-Newtonian physics. In relativity we emphasize the role of the observer (e.g. time is what observers measure on clocks), and in quantum theory we emphasize also nature's randomness. The central idea of quantum theory, the reason in fact for the existence of quantum theory, is taken to be the inescapable interaction between observer and observed, and its expression in the uncertainty principle.

Liberal arts students can follow these ideas, are excited by them, and find the post-Newtonian perspective surprisingly relevant to their own lives. Most non-scientists, and most scientists too, persist in assuming that it is "scientific" to think of the universe as a predictable machine composed of tiny parts, so that a scientific approach to life involves figuring out how this machine works and manipulating it to one's advantage. This is true regardless of whether or not this view actually does follow from Newtonian physics. Once students have a broad view of the conceptual foundations of quantum theory, they see that the machine-like view is at odds with fundamental physics and that, if they desires a metaphor for the universe, then the universe is like an organism.

References

1. M. Gardner, *American Journal of Physics*, March 1989, p. 203.
2. H. Feshbach and V. F. Weisskopf, *Physics Today*, October 1988, pp. 9-11.
3. Letters from B. Brown, P. W. Milonni, K. V. Laurikainen, M. Singham, E. P. Gyftopoulos and J. L. Park, O. Piccioni et al, J. I. Berg, and reply from H. Feshbach and V. F. Weisskopf, *Physics Today*, April 1989, pp. 13, 15, 96-104.
4. N. David Mermin, *Physics Today*, April 1989, pp. 9-11.
5. A. Hobson, *Physics and Human Affairs*, John Wiley Inc., New York, 1982.

What's in a Name?

"Physics and society" implies two separate fields. But scientists studying real problems such as the greenhouse effect or energy efficiency are not studying two fields, they are in fact studying a single problem that happens to involve some of the concepts normally associated with the arbitrary compartment labeled "physics" and some of the concepts normally associated with the arbitrary compartment labeled "society." What such scientists are doing is more properly labeled "societal physics," or "sociophysics."

As an analogy, the study of the ethics of biology is "bioethics" not "biology and ethics." Similarly, we have biophysics, geophysics, physical geology, and socioeconomics.

Should this publication, or the Forum, find a more appropriate name? Send us your thoughts.

Awards: Why the Cash?

In an admirable *Physics Today* article (January 1989, pp. 9-11), N. David Mermin opines that science's system of prizes, honors, and awards "has run completely amok, absorbing far too much of the time and energy of the community in proportion to the benefits conferred." With tongue only slightly in cheek, he makes suggestions toward streamlining the system.

My suggestion concerns the award money.

I believe it was the Persian ruler Cyrus the Great who declared to his armies as they marched on ancient Greece that they should "beware these Athenians, for when they compete on their athletic field they compete not for gold but for a wreath of olive branches." Men of such honor, he believed, would be hard to defeat.

So why the gold? Isn't the honor of an award enough, without the cash? I mean, do PhD physicists need the bucks, or what? Perhaps it's just historical precedent, formed in a day when well-off philanthropists like Alfred Nobel, the father of dynamite, were the big supporters of science.

After all, award winners are successful scientists, people of far above average means. And the prestige of an award usually earns a nice pay increase back home. And money makes the award dependent on the pleasure of a benefactor: scientists, not benefactors, should determine the awards. And science is supposed to be about truth, not money. So what's the point of the cash?

No Way to Run a Meeting

The evening of cold fusion, on 1 May at the Baltimore APS meeting, was an exciting and potentially historical event. I too was fascinated by the detailed criticism of the Pons and Fleischmann experiment. Careful experiments had been unable to detect any evidence of the fusion reaction claimed by the University of Utah group: no neutrons, no helium, no gamma radiation, and no heat.

I too was entertained by the sarcasm leveled at chemists Pons and Fleischmann. According to Walter E. Meyerhof, professor of physics at Stanford University,

"Tens of millions of dollars are at stake,
dear sister and brother,
because scientists put a thermometer at
one place instead of another."

And according to Steven Koonin, theoretical physicist at Caltech, "we're suffering from the incompetence and delusion of Pons and Fleischmann." We all applauded.

But on later reflection, and after hallway conversation with colleagues, I wondered if this was any way to run a scientific meeting. The scientific facts and theories that evening surely spoke for themselves. There was no need to lay it on thick with verses and epithets. Name calling only confuses the issue, so that the debate seems to be physicists versus chemists, or Caltech versus Utah, rather than whether the experiment works.

Art Hobson