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*Physics and Society* is the quarterly of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and reviewed articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum. Contributed articles (2000 words maximum, technicalities are encouraged), letters (500 words), commentary (1000 words), reviews (1000 words), and brief news articles, are welcome. Send them to the editor: Art Hobson, Physics Department, University of Arkansas, Fayetteville, AR 72701, 501-575-5918, fax 501-575-4580, bitnet AHOBSON@UAFSYSB. Typist: Sandra Johnsen. Layout: Page Perfect of Fayetteville.

# LETTERS

## Gulf War Debate, Continued

"The Gulf War: Appeal from French Scientists" (July 1991) scaled new heights, even by French standards, for disingenuous hypocrisy. For starters, France provided the technical leadership for Iraqi nuclear weapons development. The record amply documents that the French pursued this heinous activity despite overt evidence of Iraqi intentions to use the weapons to "liquidate the Zionist entity [Israel]," and even after Saddam himself publicly voiced this intention. It is worth noting that French scientists aggressively pursued the "opportunity" to give Iraq nuclear know-how after the USSR had rejected Saddam's demands for it. In at least this instance, Russian sagacity, if not ethics, triumphed over that of the Fifth Republic. France led the world in a vituperative attack against Israel following her elimination of Iraq's French-technology reactor designed to provide raw material for nuclear bombs.

Actions speak louder than words. The French scientists' appeal reminds me of nothing so much as the rogue who, having murdered his parents, throws himself upon the mercy of the court as an orphan. French scientists have played a (if not the) major role in bringing the outlaw state of Iraq to the brink of nuclear capability. Rather than "appeals" full of platitudinous blather, let our French colleagues look in the mirror to find the villain in this sordid affair. Better yet, let them act to rid France of its twin vices of craven slavishness to the despots of the Arab world and the lingering anti-semitism which has estranged them from Israel.

*Bernard H. White, Ph.D.*
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Levi, Hafemeister, and Scribner (April 1991) suggest that the Forum must choose issues that have higher technical content than political content. No argument on that, if such a precise "spectrometric" separation could be made on issues that impact the society. They further assert that as physicists, we must confine our contributions to technical matters. This is nonsense. Since I have no technical expertise in making an omelette, I should shut up and swallow. I should not criticize the chef. Then I would suggest dropping the word "Society" from the name of the journal.

For hardcore physicists, Art Hobson's editorial may appear highly emotional. But after all, ethical and moral issues pertain to the heart, not to solid state physics.

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*Response:*

Obviously, we intend no such fine distinction as Veluri's "spectrometric separation." The works of the Forum, the Panel on Public Affairs, and the APS itself amply demonstrate the broad and useful range of the "spectrum." On Veluri's other point, we think that in his sophistry he missed ours. By his own words, he would not say to the hapless cook, "Speaking as a chef myself, your omelette is not good." Veluri presumably also would not say "Speaking as a physicist, your omelette is not good," yet by his words he would say just that! Of course, as citizens of a free and democratic society we all have our "lay person's" right to "criticize the chef." The question we address is how should we as physicists, acting under the imprimatur of a society of physicists, judiciously use and not abuse our institutional forms to effectively contribute to informed debate on public policy issues? We as physicists can do little good and perhaps much harm, particularly within our professional organizations, if we assume the mantle of expertise and knowingly allow ourselves to be perceived as speaking with special authority in areas where we have neither special knowledge nor weight.

*David Hafemeister*
*Barbara Levi*
*Richard Scribner*

## Aneutronic Fusion

Concerning aneutronic fusion (July 1991), the issue is what fuel should be burned. Should it be a mixture of deuterium with radioactive tritium (the D-T fuel) or with nonradioactive Helium-3 (the D-He3 "aneutronic" fuel)?

Dr. Holt's article used two quotes out of context. First, in his critique of D-$He^3$ fuel, Dr. Holt quotes a portion of a sentence from the 1987 report of the National Research Council (NRC) (1). He edited a conclusion which is favorable to D-$He^3$ in such a manner that it appears unfavorable. The full text of the conclusion, partially quoted by Rush Holt, is:

> The committee concluded that the prospect for achieving aneutronic fusion is doubtful, but the use of advanced fuels like D-$He^3$ appears more feasible and offers many advantages for space applications.

Dr. Holt's text reads:

> Several years ago the Committee on Advanced Fusion Power of the National Research Council considered alternate fusion fuels and various configurations proposed for burning them and concluded that "the prospect for achieving aneutronic fusion is doubtful.."

Although this section of Dr. Holt's article purportedly deals with D-$He^3$ fuel, he has removed the portion of the NRC conclusion that refers to D-$He^3$ fuel and kept the part irrelevant to it, that dealing with pure $He^3$ fuel (zero D admixture). The NRC clearly stated that it considered only the $He^3$ -$He^3$ reaction (pure $He^3$ ) to be aneutronic, defined as a reaction producing 1% or less power in neutrons. D-$He^3$ was not at that time considered aneutronic but was instead considered to be an "advanced fuel" because its neutronicism (percentage of fusion power in neutrons) was then estimated to be greater than 1%. Subsequently, elaborate fusion reactor simulations of high-beta plasmas (colliding beams and field-reversed configurations) indicate the neutronicism of D-$He^3$ fuel to be in the range of 0.3-1.0%, for beta = 0.95 and ion energy of 100-300 keV (2,3,4). Beta is the ratio of kinetic-to-magnetic energy density. For comparison, Tokamak requires beta≤0.05 for stability; a "second stability" region is predicted at beta=0.3.

Second, Dr. Holt presents the high neutronicism that is peculiar to Tokamak as a general feature of D-$He^3$ fuel. He states: "D-$He^3$ fusion with the associated D-D reactions would release 5 percent or more of the energy in neutrons." High neutronicism is, however, specific to low-beta systems. They cannot have diamagnetic effects that suppress radiation losses and, hence, require high deuteron concentrate for ignition. Only high-b systems can be ignited, with a lean D:$He^3$ mixture of 1:3 required for being aneutronic. The very reference that gives 5% neutronicism for Tokamak gives a neutronicism of 0.9% for beta=0.9 at an ion energy of 200 keV (Figure 1 in (5)). Burning high-beta fuel in a low-beta device is similar to injecting high octane gasoline in a low compression engine; the high grade fuel remains unburned.

Confinement of such energetic (≥ 200 keV) ions may turn out to be easier than for "thermal" (~keV) ions. In a self-collider, 730 keV deuterons have been routinely confined for 20-30 seconds (6), stabilized by oscillating electrons (7). Albeit at low density, such energies and confinement times are unheard of in Tokamaks where "anomalous transport" causes instabilities. In self-colliders, entropy is minimum (both ion and electron motions are ordered); ion energy is imparted externally (accelerator) rather than via gas heating; ion orbits have large Larmour radii and confinement time is independent of device radius (in Tokamaks it is proportional to $r^2$) so that the plasma volume is ~100 $cm^3$.

Independently, recent experiments with Tokamaks indicate that energetic ions (@ 200 keV) slow down and diffuse *classically* (do not exhibit anomalous transport) in the presence of turbulence (8,9).

As a separate matter, I would like to add an item to my own article. Contrary to established belief, there is a large inventory of terrestrial $He^3$. Proven and accessible reserves of 4,000 tonnes are found in the atmosphere, and 1-10 million tonnes are likely but unproven in the earth's mantle (10). Seawater samples from the ridges in the eastern equatorial Pacific, collected by submarine, were found to be almost 50% supersaturated in $He^3$ (11,12). $He^3$ is produced in the earth's mantle from lithium bombarded by alpha particles. Using D-$He^3$ fusion, this supply of $He^3$ could meet the world's electric power needs for up to 10,000 years.

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*Bogdan Maglich*

*Response:*

Numerous scientific reviews have concluded that tokamaks fueled with deuterium and tritium (DT) offer the most promising avenue now to fusion power reactors, as I discussed in my article. There are myriad possibilities for improvement in succeeding generations of reactors, using various non-tokamak confinement schemes and various fuels producing fewer neutrons than DT. This variety of possibilities for improvement is one of the appeals of fusion research.

The point of my piece was that even the first generation of DT reactors can offer significant advantages over other types of energy generation that will be available several decades from now, especially with regard to safety and environmental considerations.

Let me turn to the specific items raised by Dr. Maglich. The 1987 NRC committee report defined aneutronic fusion as that "involving insignificant neutron release." Fusion of D-$He^3$ was not included in this category because the committee determined that "2-15 percent" of the energy would be released in the form of neutrons and the committee could not call such a reactor aneutronic. The committee even changed its name from "aneutronic fusion" to "advanced fusion" so that it could consider D-$He^3$. I believe my article, including skepticism about an aneutronic reactor, captured the sense of the NRC report, and I am not aware of any research that supersedes the panel's conclusions. In particular, Dr. Maglich seems to have neglected my succeeding sentence, which reads "The panel went on to say that because *low-neutron* [italics added], high power density devices could be important for future space missions, the US should maintain a modest research effort in advanced fuels as an auxiliary to the standard fusion program." Neither the NRC panel, nor I, would preclude research in D-$He^3$ fusion.

Despite the formidable difficulties D-$He^3$ fusion presents (I quoted, for instance, the 1990 report of the European Community that called it "too ambitious at present") and despite problems of fuel availability, it has important potential advantages for the longer term. However, as I wrote, a reactor designer, even with D-$He^3$, would not be freed from considerations of neutron bombardment. For example, one of the best recognized studies of advanced-fuel reactors, conducted by a group from the University of Wisconsin (Kulcinski et al, Fusion Technology **19**, 793 (1991)), projects that more than 6 percent of the power of the design reactor (Apollo L3) would be released in neutrons, much less than in a DT reactor, but far from insignificant. The reactor would operate at an ion temperature of 58 keV. It is worth noting that tokamaks have reached ion temperatures of 35 keV.

*Rush D. Holt*

# ARTICLES

## Symposium: The Forum's Energy Study

The following three articles are based on invited talks given at a Forum-sponsored session at the April 1991 APS meeting in Washington, DC. The session reported some of the results of the Forum's energy study, recently published as *The Energy Sourcebook: A Guide to Technology, Resources, and Policy*, edited by Ruth Howes and Anthony Fainberg (American Institute of Physics, New York, 1991). The first article is abstracted by Howes from the study's conclusions, and the other two articles are based on the contributions by Fainberg and Dave Hafemeister. Study group members are: Samuel Baldwin, US Office of Technology Assessment; Heinz Barschall, University of Wisconsin; David Bodansky, University of Washington; Alan Chachich, MIT Lincoln Laboratory; Jamie Chapman, independent consultant; Gary Cook, Solar Energy Research Institute; Janet H. Cushman, Oak Ridge National Laboratory; John Dowling, Mansfield University; Gerald Epstein, Kennedy School of Government at Harvard University; Anthony Fainberg, US Office of Technology Assessment; Dave Hafemeister, Senate Foreign Relations Committee; Evans Harrell, Georgia Institute of Technology; George Hinman, Washington State University; Ruth Howes, Ball State University; John Ingersoll, Hughes Aircraft; J. Warren Ranney, Oak Ridge National Laboratory; Marc Ross, University of Michigan; Malcom Sanders, Yale University; William Vogelsang, University of Wisconsin; and Leonard Wall, California Polytechnic State University.

### Overview of the Forum Energy Study

*Ruth Howes*

Nearly three years ago, a group of Forum members began a broad study of energy technology and policy. Like all Forum study groups, we operated with funding only from the Forum on Physics and Society. The resulting study is the responsibility only of the members of the group and is not formally endorsed by the APS or the Forum. Not all members of the group would endorse every chapter nor even every conclusion of the study. But the degree to which we were able to reach consensus came as a surprise since we represent a variety of backgrounds and political views.

As a starting point, we took a wide look at the changes in energy technologies since the first energy crisis in 1973. We were struck by the fact that in recent years fewer and fewer pieces of information on energy crossed our desks. In the late seventies and early eighties, college physics teachers were inundated with energy information. During the later part of the decade, the flood dried to a trickle and gradually decreased to a slow drip.

We also felt that while some individual technologies had been recently surveyed, there was a need for the broadest possible look at the US energy situation. Our goal was to present the state of the art in energy technologies. We looked at both source and end use technologies as well as the critical issues of energy storage and risk assessment.

Our initial finding is that *the underlying energy problems that caused the crises of 1973 and 1979 have not disappeared.*

Our conclusion is well supported by the recent fluctuations in the petroleum market caused by the Persian Gulf War. The US imports slightly more than 50% of its petroleum, much of it from politically unstable regions. In addition, there is a broad consensus that increasing the effective $CO_2$ atmospheric concentrations will lead to global warming. While current atmospheric models cannot predict the exact amount of warming or the specific effects on any location, warming is likely to cause global climatic disruption that will have severe impacts on food supplies and other living conditions.

Our second conclusion is that *the nation needs long-term planning and coordination among all sectors to deal with the future supply problems and the global environmental change that stem from our energy practices.*

Since World War II, US energy policy has been shaped by a series of popular "magic bullet" solutions to the twin problems of supply and environmental damage. The US urgently needs a long-range comprehensive energy policy. The nation is increasingly dependent on and politically vulnerable to imported oil. Nuclear fission cannot make up the short-fall for at least a decade since it takes at least that long to construct new plants. It takes a similar time to construct major power plants of any kind. Laboratory breakthroughs require testing in pilot plants which must then be scaled up to production facilities. It is not unusual for unforeseen technical problems to appear during the scale-up process. Thus basic research underway today cannot be expected to provide commercially useful energy during the next two decades. Finally, new plant construction requires commitment of enormous capital. Investors are understandably reluctant to gamble on new technologies. It is fortunate that increases in end use efficiency are generally both quicker and less capital intensive.

Since today's energy decisions will impact our energy picture only after a decade, it is important that energy planners think at least a decade ahead. Research programs started today will form the foundation of 2010's energy infrastructure. We must carefully and consistently invest in research and development for at least a decade to ensure energy supply for the next quarter century. Protecting the global environment will require even better planning since it will require international cooperation, and since atmospheric time scales are several decades.

*We cannot rely on any one or two energy sources or end-use technology timprovements alone to solve future problems. Many sources and actions are needed.*

In energy policy "there is no free lunch." Every energy source has environmental problems. It is difficult to predict future economics of specific sources, let alone the future at all. Unforeseen problems may decrease the contribution of any technology. An effective energy base will require flexibility to meet an unpredictable future. Putting all our eggs in one energy basket leaves us vulnerable to future economic shocks such as OPEC production cuts and nuclear power accidents. Energy history demonstrates only too clearly that there is no "magic bullet."

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*Improving the efficiency of end-use technologies should continue to play an important, indeed increasing, role.*

Although in the final analysis efficiency cannot replace energy sources, improving the efficiency of energy use can stretch existing sources and buy time to develop new ones. Increased end-use efficiency can also reduce our dependence on imported petroleum and hence emissions of toxic chemicals and $CO_2$. And the time to bring efficient end-use technologies into widespread use with significant energy savings is some two or three years, compared to fifteen years for new sources. Improvements in end-use efficiency are generally much cheaper than developing new sources. Finally, improvements in end-use efficiency come in smaller increments. These small bites are generally more digestible to the public than the large changes required for new energy sources. These characteristics led to a 28% decrease in the US energy/GNP ratio during the 1970s and 80s. Without these savings the US would use 40% more energy than it uses today.

## *Taxes, incentives, regulations and other policies should be established immediately to reduce fossil fuel dependence.*

Concerning future energy sources, we make these findings:

*Coal and oil are environmentally undesirable and should be minimized. Taxes, incentives, regulations and other policies should be established immediately to reduce fossil fuel dependence. A shift from combustion is desirable.*

Combustion is increasingly used to generate electricity. Remote power generation seems desirable as it removes local pollution to less populated areas, but the pollution and $CO_2$ still enter the atmosphere and contribute to long term global effects.

This recommendation clearly diverges from the Bush Administration's National Energy Strategy (NES), which stresses increasing domestic oil production. The NES holds US oil consumption level, but does little to actually reduce it. Furthermore, the NES advocates opening the known petroleum reservoirs of Alaska, including the coastal plain of the Arctic National Wildlife Refuge and the Alaskan North Slope, to drilling and production. According to the NES, exploitation of the North Slope could "add an estimated one billion barrels of recoverable oil and condensate to domestic oil production over the next several decades." To put this number in perspective, the NES projects US oil consumption for the year 2000 to be around 17 million barrels per day. This means that annual oil consumption will be around 6 billion barrels. The new North Slope oil will be a drop in the bucket of our projected oil needs.

*A tax on carbon dioxide production should be seriously considered.*

A carbon tax would provide incentives for immediate action to mitigate global warming and reduce pollution. Although it may not prove a desirable course of action, a carbon tax should be immediately considered. If nothing else, the debate will focus attention on long-term energy policy trade-offs.

*In view of the coming inevitable decline in domestic oil and natural gas production and of increasing dependence on foreign oil, it is time for a new look at energy R&D priorities, both in absolute and in relative terms.*

No production expansion will do more than delay the demise of domestic fossil fuel supplies. While production expansion can perhaps buy a few more years, this provides no long-term stable solution. Even if we find ways to burn our large coal reserves with no pollutants other than the inevitable $CO_2$, and to liquify coal for transportation, increased coal use will deplete coal resources within a few decades. It is urgent that the physics community educate the American public to the immediacy of the problem since research is needed now if we are to have future options.

*Increased funding and attention should be given to renewable sources that show promise of providing a significant fraction of our energy budget in the near future.*

Many established technologies can provide useful energy to specific regions of the country with minimal pollution. Options such as increased wind power, natural geothermal steam fields, and re-opening old hydroelectric facilities, can be useful in certain regions. Solar thermal and photoelectric technologies have made exciting technical progress since 1973 and must not be neglected.

## *It is probable that the need for nuclear power will increase over the next decades. We should take steps now to be able to achieve the expansion.*

There are no new nuclear fission reactors on order in the US. Thus nuclear power, which currently provides about 20% of our electricity, cannot significantly increase its contribution for at least a decade. Public distrust arising from Three Mile Island and Chernobyl, the discovery that nuclear fission cannot produce limitless cheap power, unexpectedly high costs, and a complex and uncertain licensing procedure, have made electric utilities very skeptical of investing in new reactors. The real political and technical problems in nuclear waste disposal have cast doubt on the long-range practicability of nuclear power.

Nevertheless, *it is probable that the need for nuclear power will increase over the next decades. We should take steps now to be able to achieve the expansion safely and at a rate commensurate with future energy needs.*

Risk assessment, the formal study of accidents, has played an important role in discussing fission power. It is widely developed for nuclear fission, but much less so for other source technologies.

*Risk assessment could become an even more important tool in comparing the desirability of different energy options, but it is a complicated technique and not yet well developed.*

For example, questions such as how to quantify one human life versus the destruction of a square mile of wilderness are extremely difficult. So also are judgments of how certain an analyst can be that all risks have been considered.

Concerning the critical end-use technologies, the study's recommendations are:

*Research and development of alternatives to petroleum for transportation should be significantly increased.*

More than any other segment of the economy, transportation depends on petroleum. Petroleum accounts for 97% of our transportation energy, and transportation accounts for nearly two-thirds of our petroleum use. If we are to reduce our fossil fuel dependence, we must reduce fossil fuel use in transportation. We cannot rapidly shift transportation to fuels other than petroleum. We agree with the NES recommendation that we should develop new fuel technologies, and add that we should explore alternatives such as electric vehicles (where the Impact is a fascinating experiment), hydrogen-powered vehicles, and the construction and encouragement of mass transportation. Public transportation systems planned today will be available ten years in the future. Thus should we need public transportation to absorb a future oil shock, it will not be available unless we take steps today to ensure its presence.

We feel strongly that *the government should immediately imple-*

*ment higher CAFE standards and increased R& D to increase automobile fleet efficiency.*

Because transportation is so petroleum dependent, relatively small gains in the efficiency of the automobile fleet can produce large petroleum savings. Since 1973, fleet efficiency has increased from 14 to 28 mpg for new automobiles, and this increase has compensated the increased transportation during those years.

In buildings and appliances there is ample room for improving energy efficiency. For example, California appliance standards implemented after the energy crisis of 1973 have improved refrigerator efficiencies so that today's refrigerators consume half the energy used by pre-1973 models, and by 1993 will reduce consumption to one-third the 1973 level, saving the nation 25 GW of electricity.

*We should implement national building efficiency standards, such as building efficiency performance standards (BEPS) and appliance efficiency requirements.*

Conservation measures have proven useful since 1973 and are largely responsible for the fact that the current energy problem is not deeper than it is. However, we may have already taken many of the easy measures to reduce energy consumption. Much of the debate over conservation is conducted in slogans and sheds more heat than light.

*An unbiased study of the future economics of conservation is urgently needed.*

In summary, no "magic bullet" will solve the twin problems of adequate energy supplies and environmental preservation. Many energy sources must be used and research is needed so that options will be available when we want them. A continued policy of heavy petroleum use is unwise on both political and economic grounds. We cannot afford to put all our energy eggs in one basket.

On the other hand, optimism is justified because we can foresee many technologies that should each contribute one piece toward solving the puzzle. We can avoid the economic and social trauma of unpredictable and uncontrollable shortages in future petroleum supplies, and severe environmental damage. To do so, we must undertake the coordinated, long-term development of a variety of sources and make a concerted effort to increase end-use efficiencies. These efforts must begin immediately.

## Fossil Fuels

*Anthony Fainberg*

Fossil fuels such as coal, petroleum, and natural gas furnish 89% of the US energy supply. Their advantages include availability, transportability (especially for the last two), and relatively low cost. Their disadvantages are limited supplies (for the last two) and environmental degradation (particularly for the first two).

Currently, the US imports about half of its petroleum, a record high. It is a serious question whether the US should rely so heavily on imported oil, especially when some of it comes from politically unstable regions. The Gulf War illustrates the dangers of depending on unstable regions for the nation's life blood. Actually, the US got only about 6% of its total petroleum from Kuwait and Iraq, and this only for two to three years prior to the 1991 war (1). Far greater difficulties were experienced by some US allies, such as Denmark and Japan, who are heavily dependent on Persian Gulf oil. Such situations furnish a clear warning to US energy policymakers.

The US petroleum supply is declining rapidly. The North Slope has already begun its decline, which will steepen within the next few years. About one-third of proven US conventionally-recoverable oil resources remain. Under current conditions of consumption and imports, 28-43 years of domestic supply remain, including estimated undiscovered resources (Table 1) (2).

**Table 1. US oil resources (in billions of barrels)**

| | |
|---|---|
| Original proven conventional recoverable resources | 226 |
| Already produced | 142 |
| Remaining | 84 |
| Estimated undiscovered resources | 46 |
| Domestic production (per year) | 3 |
| Domestic consumption, including imports (per year) | 5.5 |
| Years left under current production conditions, and no increase in imports (note a) | 28-43 yrs. |

a. If imports decrease or use increases, the number of years left will be smaller. As supplies shrink, increasing costs will decrease use, so reserves will increase number of years left.

Natural gas is a cleaner-burning fuel. It produces only 58% as much $CO_2$ as coal does, and 69% as much as oil. It produces virtually no sulfates and lower amounts of $NO_x$. And natural gas is in better supply. About 17-18 trillion cubic feet (tcf) are consumed each year. This would leave only about 20 more years supply. However, each year, 14-15 tcf are added to the provable domestic supply. Table 2 shows estimates of remaining supplies with years left still the figure of merit.

Table 3 shows world resources of natural gas and petroleum. More time is available on a global scale. However, world demand is likely to increase considerably, barring massive efforts to develop alternate energy sources, as poorer, populous countries expand their economies.

**Table 2. US natural gas resources (in trillions of $ft^3$)**

| | |
|---|---|
| Proven conventional recoverable resources (including Alaska, and at less than $5 per thousand cubic feet) (note a) | 384 |
| Production rate (per year) | 17 |
| Recent yearly addition to proven recoverable resources | 14-15 |
| Estimated total remaining conventionally recoverable resources (lower 48) | 400-900 |
| Estimated unconventional recoverable resources (price of recovery not determined, but probably high) | 140-700 |
| Total estimated resources | 540-1600 |
| Years left at current rate | 35-95 |
| Years left at double current rate | 17-47 |

a. Current cost of natural gas is about $1.70 per thousand cubic feet.

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**Table 3. Global resources.**

| | |
|---|---|
| Oil (in billions of barrels) | |
| Original resources | 1900 |
| Produced | 673 |
| Remaining (note a) | 1227 |
| Production (per year) | 21 |
| Years left at current rate | 60 |
| Natural gas (in trillions of cubic feet) | |
| Estimated remaining resources | 8100 |
| Production rate (per year) | 68 |
| Years left at current rate | 120 |

a. Undiscovered and unconventional resources could approximately double the total but at undetermined cost.

There is enough coal to last the US and the world for centuries. But coal is the worst environmental offender among fossil fuels. Of particular interest is greenhouse warming. If warming turns out to be significant during the next century, the US cannot resort to this plentiful resource since it produces far more $CO_2$ per unit energy than anything else. Also, coal aggravates acid rain problems. Although sulfate releases can be mitigated in coal-burning facilities by means of new equipment and technologies such as fluidized-bed combustion, they cannot be eliminated.

There are vast opportunities for reduction in consumption. Improved insulation of buildings, utilization of technologies for increased lighting efficiency, maintaining efficient furnaces, and increased use of heat pumps will all help reduce fossil fuel use. More efficient industrial processes and increased cogeneration will help in the industrial sector. And increased efficiency in transportation, possible with today's technologies, will play a major role.

The US will have to make some hard energy choices soon. These will be forced by economic, political, and environmental considerations. Petroleum will be partially displaced by other fuels, probably liquid fuels (liquified natural gas, methanol, ethanol) and natural gas. But this is a stopgap measure, since natural gas is also limited. Eventual solutions will rely heavily on conservation, the easiest and cheapest alternative in the short run, and on alternative energy supplies. These will include currently used ones, such as nuclear power and hydropower, but a greater role will be played by renewable resources, such as solar electric, wind, and photovoltaic.

### Notes

1. This supply disruption could have been solved by conservation, redirecting purchases, or a greater rate of exploitation of domestic resources. However, the matter would have been more serious if Saudi supplies had been put in question. These were then one-third of oil imports, about 17% of total US consumption.
2. The number of years remaining is, of courses, unrealistic, functioning only as a figure of merit. First, as supplies decline, prices will rise and use will drop, extending the number of years of domestic supply. After 20-30 years, the price of oil may be so high that economics will force the use of alternate sources if rational planning does not accomplish this earlier. Second, if alternate sources are not emphasized and if conservation is not pushed, the requirement for the resource will increase, not decline, with time, depleting it faster.

## Energy Conservation Standards for Buildings

*Leonard Wall and David Hafemeister*

Energy standards for automobiles, appliances, and lighting are now in place and operating at a cost advantage to the American public. The automobile standards will ultimately save us 50% of the auto fuels (relative to 1975), or about four million barrels per day, twice the Alaskan pipeline. The refrigerator standards will save two-thirds of former refrigerator energy usage, amounting to the power from about 25 GW of power plants. As improvements in technologies enter the market place, the standards should be strengthened on a cost-effective basis. Several states now have energy efficiency standards for buildings, and they seem to be very successful. The Administration and the Congress should determine if such standards would be advantageous on a national basis. To the extent that the Building Efficiency Performance Standards (BEPS) can be shown to have net benefits to the society, taking into account cost, environmental gains, and enhanced energy security, these standards should be adopted on a national basis.

Our chapter in the Forum's study covered the technologies for energy conservation for buildings, appliances, windows, and lighting, as well as a discussion of the market place for energy conservation using the concepts of "cost of conserved energy" and "energy conservation supply curves." Since these topics have been covered in other places in varying degrees, we will focus in this article on some of the details of energy standards for buildings, which are not as well known. If, indeed, we are to save some 50% of the 30 or so quads of energy used in buildings, it is our view that cost-effective building standards are the way it will happen since market forces are not as elastic as the economists have told us. More energy can be saved with buildings than with automobiles, so let us get on with the task.

### Building standards

Mandatory energy efficiency standards applicable to all new buildings throughout the country have never been established by the U.S. government. Instead, building codes incorporating standards developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) have been adopted and are enforced by state and local governments. In addition to ASHRAE, the state of California and the Northwest Power Planning Council have shown leadership in the development of building standards. Energy regulations for all new federal buildings are being updated and implemented. The organizations involved in standards development (ASHRAE, California Energy Commission, NW Power Planning Council, and the Department of Energy) have interacted with each other, with private industry, and with the public to agree on continually-evolving building efficiency rules and guidelines.

*The authors are with the Physics Department, California Polytechnic State University, San Luis Obispo, CA 93401. A complete bibliography and reference list can be found in the original article "Energy Conservation in Buildings and Appliances," in The Energy Sourcebook.*

In 1974, at the urging of the National Conference of States on Building Codes, ASHRAE accepted the challenge of writing a consensus energy standard for new buildings based on a criteria document drafted earlier by the National Bureau of Standards. This model standard was published in 1975 and became known as ASHRAE Standard 90-1975, "Energy Conservation in New Building Design." Most of the original standard was revised and released in 1980 as ASHRAE Standard 90A-1980. The next revision of the standard began in 1982, with the support of the Department of Energy (DOE). There are separate documents for the energy-efficient design of new commercial and new high-rise residential buildings (Standard 90.1P) and for the design of low-rise residential buildings (Standard 90.2P). Differences, accounting for energy savings of 15-30%, exist between the proposed revision and the 1980 revision. As of early 1989, Standard 90.1P had undergone a third public review and is nearing the completion of the very slow ASHRAE consensus process, whereas 90.2P is about to start public review. Compliance with ASHRAE Standard 90 is voluntary, but building energy codes and standards throughout the country at the local and state government level are based on Standard 90. It is clearly the dominant influence on U.S. efficiency standards. In addition to Standard 90 for new buildings, ASHRAE has established energy conservation standards for existing buildings, ASHRAE Standard 100.

*More energy can be saved with buildings than with automobiles, so let us get on with the task.*

Even though there are no mandatory national building energy standards, the federal government has been active for many decades in promoting energy efficiency in buildings. The Housing and Urban Development minimum property standards have existed since the 1950s and have been revised several times so that its residential building standards are reasonably energy efficient. In the early to mid-1970's the Government Services Administration (GSA) designated several federal office buildings as energy conservation demonstration projects. New technologies were tested, and the design resource energy budget was set at 55 $kBtu/ft^2 \cdot yr$, an ambitiously low use rate for that era of mainly 250-300 $kBtu/ft^2 \cdot yr$ buildings. Even though the demonstration buildings enjoyed only moderate success, GSA adopted energy efficiency guidelines for all new federal office buildings. Consumption data in subsequent years have shown some low consumers but no definite trend toward efficient new buildings in the federal sector.

In 1976 Congress passed the Energy Conservation Standards for New Buildings Act and required DOE to develop mandatory federal standards for new buildings. This was to be applicable to all buildings constructed with any federal assistance (essentially *all* new buildings) and was to take the form of BEPS standards whereby specific energy budgets (energy consumption per unit area per year) had to be satisfied, typically by computer simulation. DOE released the draft standard in late 1979, but the objections from private industry were so strong that in 1980 Congress backed down and designated the standards as models for voluntary state adoption. More recently in May of 1987 DOE published a notice that more stringent energy-conserving design requirements for new commercial buildings were being developed in parallel to ASHRAE Standard 90.1P and would be mandatory for all new federal buildings (approximately 10% of total commercial construction). These new standards are essentially completed and should be in force soon.

The state of California has been at the forefront of the development of building energy standards and codes since 1975. In that year the California Energy Commission released Title 24, which required certain energy efficiency measures in all buildings, both residential and non-residential. There have been numerous revisions of the standards, many of them innovative and also based on minimum life cycle cost. From an early prescriptive-style standard, the regulations evolved into a flexible set, allowing compliance via prescriptive, performance, or "points" approaches. In many cases the California standards are more stringent than ASHRAE Standard 90.

The Northwest Power Planning Council (Washington, Oregon, Idaho, Montana) has also been a leader in the development of standards and has served as a model for other regions. Although the Council's model conservation standards are based on ASHRAE Standard 90, its cost-effective regulations go beyond ASHRAE standards, particularly in the case of lighting efficiency. The implementation of conservation programs by the Bonneville Power Administration in response to the Council's policy decisions has clearly demonstrated the potential savings from improved building energy efficiency.

Building standards fall into three categories: prescriptive, performance, and combinations of the two. ***Prescriptive*** standards involve the specification of each individual building component that influences energy consumption (levels of insulation, type of glazing, efficiency of conditioning equipment, etc.), usually in the form of various component "packages." ***Performance*** standards require that the design energy consumption for a building fall below a numerical energy budget established by building type, occupancy level, and climate zone. Computer simulation is required to demonstrate compliance. *Combinations* of the two approaches can be handled by a "points" system whereby the effects of component trade-offs have been calculated by computer modeling. The prescriptive approach has the advantages of both easy implementation and easy demonstration of compliance, whereas the performance approach allows more design flexibility in reaching a required efficiency level.

ASHRAE Standard 90-1975 was primarily a prescriptive standard, whereas BEPS was primarily a performance standard even though both standards allowed compliance via the other approach. California's Title 24 was originally prescriptive in nature but by 1980 had also incorporated the performance approach. The proposed ASHRAE Standard 90.1, the new DOE regulations for new federal buildings, and California's Title 24 all allow compliance by any of the approaches. Computer methods and performance standards appear to be growing in popularity.

Primary emphasis for residential buildings has been for increased levels of insulation in the thermal envelope, restrictions on the amount and type of glazing, decreased rates of air infiltration, and better appliance efficiencies, including space-conditioning equipment. For non-residential buildings the measures have included improved efficiencies for service hot water, lower lighting levels and power densities, more efficient energy distribution systems, and the usual thermal tightening of the building envelope. Ideally the standards should be set at the economic optimum for the building, which would vary depending on local construction costs, fuel choices, and local fuel costs.

ASHRAE Standard 90-1975 was not a very restrictive nor economically optimal standard. It was the initial effort, and evolved through a consensus procedure. The present California Title 24 standards are the most stringent in the country for residential buildings. In addition, the Northwest Power Planning Council's standards and the new ASHRAE standards are also close to the optimum conservation combination of residential measures. Allowances are given in California, but not by ASHRAE, for passive solar features such as thermal mass. In the non-residential sector the most discussed feature is lighting, with the difficult factors of illumination levels and mixing between fluorescent and incandescent sources added to equipment efficiency requirements. Lighting standards are typically expressed in terms of power density—connected watts per square foot of illuminated area—and are also dependent on the particular space use or task. Whole-building power density limits or room-by-room calculations are allowed. The ASHRAE lighting standards are not as stringent as the California standards.

*Superinsulated homes which use less than $200 worth of fuel per year have become commercially viable in some regions.*

ASHRAE Standard 90-1975 was estimated to lower energy usage in new residential buildings by an average of 11% and in new non-residential buildings by 40-50%, when compared to conventional practice in the 1970s. The application of ASHRAE 90-1975 did not appear to increase initial construction costs, but did increase design costs. Overall, annual energy savings clearly offset any increase in design costs during the first year of building operation. The proposed (but never implemented) BEPS was estimated to result in energy savings of 22-51% in single family residences and 17-52% in commercial and multi-residential buildings, when compared to mid-1970s buildings. The first ASHRAE Standard 90 update (90A-1980) was calculated to provide small 4-5% energy and cost savings over Standard 90-1975, but the second revision (90.1P) has been estimated to result in an average 16% savings over 90A-1980 for new commercial buildings. Standard 90.1P has been shown economically feasible via payback and life cycle cost analyses. The new proposed DOE standards for federal buildings have been developed in parallel to 90.1P and should result in comparable energy savings.

Actual measured energy performance data for buildings verify that energy is being saved due to the promulgation of standards over the past 14 years. In the Northwest, Bonneville Power Administration's new model conservation standards houses have been shown to use 45% less space heat than newly-constructed conventional "control" houses. Lawrence Berkeley Laboratory's compilation of energy data indicates that new office buildings complying with the ASHRAE 90.1P standards use 50-80 kBtu/ft$^2$•yr of site energy for all end uses, or about half the average energy use for existing U.S. office buildings. The best new buildings, which have energy features beyond the standards, are considerably below this level, using as little as 20-40 kBtu/ft$^2$•yr in site energy (or less than 100 kBtu/ft$^2$•yr in resource energy).

### Findings

- Insulation values in residences have been increased by about a factor of two, reducing the balance point of buildings. The energy usage for all households dropped about 17% between 1973 and 1983.
- Superinsulated homes which use less than $200 worth of fuel per year have become commercially viable in some regions.
- Passive solar design features (glass plus mass) have been widely adopted by architects. In gentle climates like California, it is relatively easy to use passive solar for most of the heating energy.
- Large office building resource energy intensiveness has dropped from a high of about 500 kBtu/ft$^2$•yr for some buildings and an average of 280 in 1979, to 100 or less in new buildings.
- Computer simulation programs can estimate energy usage to about 15%, helping architects to reduce energy costs of buildings.
- Thermal storage allows the heat of the day to be used to combat the cool of the night, and can negate the need for a heating system.
- Off-peak cooling and storage of water and ice in the evenings for use in daytime air conditioning is being widely adopted to save peak-power.
- Time-of-day rates for commercial and industrial electrical power is saving considerable peak-power.
- Research on indoor air quality has revealed the radon problem, and methods to mitigate it.
- Low-emissivity double-glazed windows with "R values" of 3 to 4 have strongly penetrated the market. Values as high as R-10 have been developed, but are not yet commercially viable.
- National energy standards have been adopted for appliances, lighting ballasts, and automobiles. The appliance standards will save about 25 GWe, and automobile standards will save about 4 million barrels per day in the steady state compared to 1973 values. There are no national building standards, but a number of states have adopted building codes that are more stringent, or comparable to, the standards adopted by ASHRAE. Because the lifetimes of buildings, appliances and automobiles are 50, 20 and 10 years, respectively, it will take many years to see the complete benefits of these standards.
- Life-cycle costing that takes into account the properly discounted costs and benefits has been accepted in judicial proceedings. Comparisons between production and conservation technologies are now evaluated in terms of the cost of conserved energy. Market forces for these economic advantages have been weak, as society has invested in large scale plants through rate bases.
- About 10-15 times as much has been spent on developing production technologies as compared to conservation technologies, with the latter producing much more tangible results. Conservation has done much better than the renewable energy sources.

Note added in proof: Standard 90.1P ("energy-efficient design of new buildings except low-rise residential buildings") was approved by the ASHRAE Board in June 1989, and is now designated Standard 90.1-1989. The "energy cost budget method" is introduced as an alternative to the prescriptive and performance paths. An excellent overview of 90.1-1989 is found in the February 1990 issue of the ASHRAE Journal, pages 26-35. The DOE standard parallel to 90.1-1989 was also completed in 1989. Standard 90.2P ("energy-efficient design of new low-rise residential buildings") has still not completed the slow ASHRAE consensus process as of July 1991 and is not yet ofrmally approved.

# REVIEWS

## The Forum's Short Course on Global Warming

On April 19-21 the Forum co-sponsored a short course, *Global Warming: Physics and Facts*, featuring lectures by experts. Its purpose was to teach physicists what is known, from measurements and models, about the possible threat of greenhouse gases. Participating with the Forum were the APS Panel on Public Affairs, the Georgetown University Program on Science, Technology and International Affairs, and the Georgetown Univerisity Physics Department. Each session drew 80-150 physicists and others, including representatives from industry groups not fully tapped in past Forum activities. The area explored, the global environment, was new for the Forum. A book containing all the papers, edited by the undersigned, will be published this fall by the American Institute of Physics. The following summarizes some highlights of the short course.

To gauge the effect of greenhouse gases on climate, imagine first a planet with no atmosphere but a reflectivity equal to Earth's 0.3. The temperature of this planet is determined by the energy balance that must be maintained between the incoming, unreflected solar radiation and the Earth's thermal radiation. One can approximate the Earth as a blackbody and write Earth's thermal radiation in terms of the Stephan-Boltzmann Law. If Earth had no atmosphere, this simple model requires Earth's temperature to be 255 K, or a chilly 33 K below the current average global temperature. The effect of greenhouse gases is to transmit solar radiation but trap outgoing thermal radiation. The preindustrial mix of greenhouse gases, primarily water vapor and $CO_2$, has kept the Earth at a habitable temperature.

The recent concern over global warming stems from the fear that increases in atmospheric greenhouse gases due to industrial activities and deforestation will trap still more thermal radiation and drive the Earth to a higher temperature than in the last thousand years. The effect could be especially devastating if the change occurred faster than ecological or social systems could adapt. An examination of the impact of increased greenhouse gases that takes account of convection, latent heat, radiation, latitudinal and seasonal variations, terrain, clouds, oceans, ice packs, etc., requires a sophisticated "general circulation model" (GCM).

Climate feedbacks can greatly enhance greenhouse warming. Water-vapor feedback is one example: Greenhouse gases warm the Earth, which increases evaporation and adds more water vapor, itself a greenhouse gas, to the atmosphere. A doubling of $CO_2$ alone might warm the surface by 1.2 K, but water-vapor feedback increases the temperature rise to 1.9 K.

Among the largest uncertainties in present climate models are the size and direction of cloud feedback, since clouds both reflect (and hence cool) and absorb (and hence heat). Under current cloud-cover conditions, the cooling effect is known to dominate. However, no one knows whether the *change* in cloud cover resulting from increased greenhouse gases will warm or cool the Earth. It depends on cloud types and altitudes. For example, high clouds (which radiate less because of their lower temperature) favor infrared trapping, a warming.effect. Computer models do not yet treat clouds realistically. In a recent comparison, the major GCMs agreed closely in the temperature predicted from a doubling of $CO_2$ under clear-sky conditions, but they varied by a factor of three when clouds were included. The recent International Panel on Climate Change estimated that the temperature rise produced by $CO_2$ doubling will be 1.9-4.4 K.

*An NAS study concluded "Greenhouse warming is a potential threat sufficient to justify action now."*

Is there conclusive empirical evidence that global warming has already arrived? The climate models predict that during the last 100 years the average global temperature should have increased 0.3-0.6 K. Temperature records over the past 100 years are roughly consistent with those values, but the rise cannot be distinguished from the natural temperature variation. Sea-level records also show a rise at a current 1-2 mm per year, but again this cannot be firmly attributed to global warming.

Carbon dioxide has increased from preindustrial concentrations of 280 ppmv to its present 350 ppmv. Other greenhouse gases—CFCs, methane, nitrous oxide—are also increasing rapidly. Although concentrations of these other gases are measured in ppbv rather than in ppmv, one molecule of, say, CFC-12, can be thousands of times more effective than one molecule of $CO_2$. The reason is that the wavelength region for $CO_2$ absorbtion is nearly saturated whereas the other gases open new absorption regions.

The major natural $CO_2$ sink is silicate rock weathering, and the major source is volcanic emissions. The present atmospheric infusion of 6-7 billion tons of carbon (as carbon dioxide) swamps the natural volcanic source. Of the manmade $CO_2$ emissions, 5-6 billion tons comes from fossil fuels and 0.3-1.2 billion tons comes from deforestation. About half of this $CO_2$ remains in the atmosphere and the rest is absorbed by oceans and Earth.

What should be done? A recent National Academy of Sciences study concluded "Greenhouse warming is a potential threat sufficient to justify action now." To dramatize the effort required, consider that, to compensate for his or her 5-ton share of US carbon emissions, a person would have to plant 1.5 acres of sycamore trees or drive 50,000 fewer miles each year. A single individual or action cannot solve the problem. Collective effort is needed. Because carbon is released about equally from our three major economic sectors, we cannot prescribe a single remedy. The Office of Technology Assessment assessed the $CO_2$ reductions that might result from a long list of technically feasible measures. They estimate that by 2015 the US can reduce the *increase* in its carbon emissions (currently 20% of the world's output) by about 35%, by adopting measures that are likely to save money. The nation could reduce its emissions to at least 20% below 1987 levels by adopting a package of measures whose costs range from below zero to about $150 billion.

If greenhouse gases indeed pose a threat, action will be required worldwide as well as nationally. The path-breaking Montreal Protocol to protect the ozone, which calls for an eventual worldwide ban on CFC production, was negotiated when the empirical data were still uncertain. It sets a precedent for a possible international pact on greenhouse gases.

*David Hafemeister, US Senate Foreign Relations Committee,*
*Barbara Levi, PHYSICS TODAY,*
*Richard Scribner, Georgetown University*

## Ozone Diplomacy: New Directions in Safeguarding the Planet, by Richard Elliot Benedick

Harvard University Press, Cambridge, MA 1991, $28 cloth, $11 paper

As late as the summer of 1986, prospects appeared slight for effective international agreement to regulate anthropogenic chemicals, such as chlorofluorocarbons (CFCs), thought to deplete stratospheric ozone. The concern was that reduced ozone would allow additional harmful ultraviolet radiation to reach Earth's surface. Overall, the "staggeringly complex" problem involved a network of scientific, economic, technological, domestic-political, and international-political issues. There was powerful opposition to any regulation from industry and several European nations. Against seemingly overwhelming odds, by September 1987 the Montreal Protocol on Substances that Deplete the Ozone Layer was a reality.

Time has shown the wisdom of that agreement. It was thought perhaps too restrictive at its birth. Subsequently, at the 1990 London negotiation, it was further strengthened. Impetus for a CFC phase-out came from finding conclusive model-confirming empirical evidence of ozone depletion—the Antarctic "hole." But the data and explanation for this were not complete and released until after the Montreal agreement.

Ambassador Benedick has written an excellent, engaging, and impressively documented account of the struggle to reach that agreement, and to go beyond it. For students of environmental history and those interested in the details of negotiations and the agreement process, the appendices may be of particular interest. It is primarily an American perspective (this may at times rankle some readers) by the leader of the US negotiating team at Montreal. Benedick learned the physics and other science and technology he needed to understand the problem and effectively negotiate a solution. The book repeatedly shows his openness and willingness to learn the science.

The strength of the work is in the author's detailed, first-hand knowledge of governmental and diplomatic events as well as his willingness to deal with scientific and other aspects of the problem. The book's greatest value may be what it can teach us about how to deal with such problems in the future.

*Scientists must play an unaccustomed but critical role in international environmental negotiations*

*Ozone Diplomacy* tells of the increasingly important intersection of science and diplomacy. Interestingly, it is published in cooperation with the World Wildlife Fund, the Conservation Foundation, and the Institute for Study of Diplomacy at Georgetown University. Its lessons are important for the future as countries struggle to deal with global warming and other international environmental problems.

Benedick points out that before the Protocol, "The science was still speculative, resting on projections from evolving [and sometimes contradictory] computer models of imperfectly understood stratospheric processes—. The ozone layer showed no depletion, nor was there any evidence of—harmful effects." Yet he stresses that "first and foremost" the role of science in the negotiations was indispensable. While technology and industrialization was the cause of the crisis, without the scientific work the world would have remained unaware of the danger until it was perhaps too late. "Science became the driving force behind ozone policy. A community of scientists from many nations, committed to scientific objectivity, developed through their research an interest in protecting the planet's ozone layer that transcended divergent national interests." To Benedick, this is an amazing revelation, but to scientists and historians of science it may seem almost obvious and certainly not unprecedented. He also points out that the power of knowledge and of public opinion were powerful factors in the achievement at Montreal.

How, in the face of such scientific uncertainty and political opposition, were countries to act collectively and promptly? Most of this book is about politics, as you would judge from such chapter titles as "Spray Cans and Europolitics." It is about the forces at play in putting together negotiating positions, and the events leading up to the agreement. Throughout, however, is scientific information necessary to understand the problem as well as discussions of the participation of scientists and scientific organizations. The second chapter does a creditable job of discussing "The Science: Models of Uncertainty."

Understanding science's approach to establishing what is fact is not only a critical piece of this puzzle, but it will also be critical for other problems, such as global warming. Policy makers, seeking certainty, frequently become frustrated when scientific information is incomplete or double edged. In frustration, they discount it as irrelevant because it is not definitive. For some, their frustration may be intense, because they seek a scientifically certain answer to deliver them from difficult value-laden choices.

Benedick begins with "Lessons of History" and ends with "Lessons for a New Diplomacy." At the top of his list of ten essential elements of new diplomacy are "Scientists must play an unaccustomed but critical role in international environmental negotiations," and "Governments may have to act while there is still scientific uncertainty, responsibly balancing the risks and costs of acting or not acting." He cautions that "politicians must—resist a tendency to lend too much credence to self-serving economic interests that demand scientific certainty, maintain that dangers are remote and unlikely, and insist that the costs of changing their ways are astronomical."

This is an important book. It has a message and lessons for scientists and is well worth reading. However, its message needs to be heard more loudly among the policy and diplomatic communities. Benedick states that "The new environmental threats to national and planetary security—of which climate change appears to be the most far-reaching—challenge both traditional science and diplomacy. The UNEP director, Mostafa Tolba, an Egyptian scientist, described the Montreal Protocol as "the beginning of a new era of environmental statesmanship." The ozone protocol's greatest legacy and perhaps the greatest value of this book may be in pointing the way to undertaking difficult cooperative actions in the face of strong yet inconclusive scientific evidence—of accepting some economically painful short term costs, because to not act risks too high a long-term price.

*Richard A. Scribner, Associate Professor*
*School of Foreign Service*
*Georgetown University*
*Washington, DC*

# NEWS

## Minutes of the Forum's Executive Committee Meeting

We met at the Ramada Renaissance Hotel, Washington, D.C. Members present were T. Moss (chair), R. Howes (vice-chair), H. Barschall (secretary-treasurer), D. Hafemeister (Forum councillor), S. Baldwin, M. Sobel, R. Scribner, and V. Thomas. Members absent were G. Garvey, K. Gottfried, B. Levi, R. Roy, and A. Sweedler. Present as observers were M. Chonacky, A. Fainberg, A. Hobson, H. Lustig, and P. Zimmerman.

Moss called the meeting to order at 9:10 am, 22 April 1991. Minutes of the 1990 Meeting were approved.

Lustig reported on developments in APS, including the planned move to the Washington area, the formation of the American Center of Physics, and the APS budget. He noted that there were now two Forums so that *the* Forum was no longer an appropriate designation.

The executive committee thanked Levi and Hafemeister, organizers of the Short Course on Global Warming. Organizers of short courses need executive committee approval before announcing their plans.

The Treasurer presented the following report:

| | | |
|---|---|---|
| Balance 4/1/90 | | $9,782 |
| Income | | |
| Dues | + | 10,030 |
| Registration Fees | + | 6,393 |
| Interest | + | 1,154 |
| Contributions | + | 133 |
| Short Course | + | 1,100 |
| Expenses | | |
| Awards | - | 2,145 |
| Ballots | - | 1,844 |
| POPA Travel (TM) | - | 530 |
| Energy Study | - | 439 |
| Executive Committee | - | 1,126 |
| Newsletter | - | 8,824 |
| Speakers | - | 739 |
| Balance 4/1/91 | | $12,946 |
| Proposed 1991/92 Budget: | | |
| Income: | + | 18,000 |
| Expenses: | | |
| Newsletter | - | 9,000 |
| Awards | - | 2,200 |
| Ballots | - | 1,500 |
| Executive Committee | - | 1,200 |
| Short Course | - | 1,100 |
| Speakers | - | 700 |
| | - | 15,700 |

The proposed budget is quite uncertain. We do not know yet whether the Global Warming Short Course will break even and what the income from registration fees will be.

Howes reported that 8 invited sessions were organized at APS general meetings, 4 of them cosponsored by other APS units. Plans are progressing for future meetings. Since some of the sessions are of interest to high school students and undergraduates, it would be desirable to arrange for such groups to attend the sessions.

Barschall reported for the awards committee. A couple of years ago the executive committee voted to limit the number of supporting letters to three, after earlier letter-writing campaigns. This time hundreds of pages of supporting material were submitted for and by a candidate. The executive committee decided to authorize the chair of the awards committee, in consultation with awards committee members, to select the material to be considered. Last year the executive committee voted that the conference call in which candidates for awards are selected be followed by a written ballot. This procedure was not helpful when it was tried. The executive committee leaves the procedure to the awards committee, i.e. a written ballot is optional.

Efforts to obtain endowment for the Szilard and Forum Awards have been unsuccessful. The $250 stipend comes presently from Forum operating funds. This practice may be prohibited in the future. There is an APS committee reviewing all awards and prizes. The $250 appears so small as to detract from the award's prestige. So the executive committee voted to discontinue the stipend after 1992 (it has already been announced for 1992). (Following the Executive Committee meeting, this year's winner of the Szilard Award, Jack Gibbons, announced that he was returning his $250 check to be used to buy Szilard's biography and Szilard's *The Voice of the Dolphins* for future Szilard Award winners )

Last year the nominating committee was not appointed in time for the election ballots to be included with the January *Physics and Society*. This year the nominating committee is in place. It should send the candidates' names and their statements to the secretary-treasurer by the end of October so that the election material can be mailed with the January 1992 *P&S*. Two of the candidates elected to the executive committee this year were not members of the Forum. The nominating committee should check that all candidates are Forum members.

Hafemeister presented the Forum councillor's report. Some of it was covered earlier by Lustig. He discussed the impact of the new APS Bylaws and Constitution, the problems the APS archival journals face in view of their being the principal source of APS revenue, the Council resolutions on the Space Station and the SSC, the fact that AAPT will join APS at the Washington meeting, the resolutions of the council praising Art Hobson and Bill Havens, and the question whether the physics building committee should be continued. The executive committee did not take a stand on this last question. The executive committee expressed its appreciation to Dave Hafemeister for his contributions to the Forum and to APS.

There was extensive discussion of the Forum's newsletter, *Physics and Society*, resulting from the controversial editorial in the April issue. There was agreement that the matter had been resolved in a satisfactory manner, that every effort should be made to provide balance on controversial issues, and that the executive committee has final authority over the newsletter. Art Hobson indicated that he is glad to get advice from the newsletter's advisory committee.

A new Forum study of Conventional Weapons Technology was proposed and discussed. A prospectus should be distributed to the executive committee. The executive committee must vote on whether the study will be undertaken on the basis of this prospectus. The appointment of a review committee, not including authors of the study, was urged. All APS studies are reviewed in this manner before publication.

The Forum Bylaws need to be revised this summer to conform to the new APS Bylaws. A committee consisting of Barschall, Howes, and Levi will draft the revision. Several issues were discussed. Currently the terms of the members of the executive committee members and of the secretary-treasurer are two years. The sample Bylaws suggest three-year terms. The executive committee favored three-year terms. Currently two councillors serve on the Forum executive committee. A better arrangement would be to have the past chair of POPA on the Forum executive committee, and to have the past chair of the Forum serve on POPA. The appointment and responsibilities of the editor and of the newletter advisory committee will be incorporated in the Bylaws. The APS Bylaws require that there be both a vice-chair and a chair-elect. The present Forum Bylaws include a membership and publicity committee, but no such committee has been active for some time. No decision on whether to have such a committee was made. The sample Bylaws suggest that all officers and members of the executive committee "must be members of the Forum for at least two years prior to nomination." The executive committee preferred that this period be only one year.

*Henry Barschall*
*Secretary-Treasurer of the Forum*

## Conference on Misconduct In Science

The American Association for the Advancement of Science, the American Bar Association's National Conference of Lawyers and Scientists, and the US Department of Health's Office of Scientific Integrity, will cosponsor a conference on issues in allegations of misconduct in scientific research. The meeting will offer perspectives on such topics as delineating boundaries between poor scientific practices and flagrant misconduct or fraud; the appropriate roles of univerisities and government in investigating allegations; various models used by universities and the government in conducting investigations; practical questions that arise in the course of a university or government inquiry; and the need to protect good-faith whistleblowers.

This conference will be of interest to all scientists, university administrators and counsel, government, funding agencies, attorneys, scientific societies, public policy makers, and students and scholars of the ethical dimensions of science.

Contact Deborah Runide, Directorate for Science and Policy Programs, AAAS, 1333 H Street NW, Washington, DC 20005; phone 202-326-6794.

## Join the Forum! Receive *Physics and Society*!

*Physics and Society*, the quarterly of the Forum on Physics and Society, a division of the American Physical Society, is distributed free to Forum members and libraries. Nonmembers may receive it by writing to the editor; voluntary contributions of $10 per year are most welcome, payable to the APS/Forum. We hope that libraries will archive *Physics and Society* ; Forum members should request that their libraries do this.

APS members can join the Forum and receive *Physics and Society* by mailing the following information to the editor or to the APS office:

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

NAME (print) ______________________________

ADDRESS ______________________________

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# COMMENTARY

## On Some Problems of Nuclear Disarmament

[The author is scientific director of one of the Soviet Union's nuclear weapons design laboratories. —Editor]

Nowadays it is, apparently, universally recognized that in the second half of the twentieth century nuclear weapons played the role of the mechanism of global stabilization and prevention of global conflicts. It is a bad mechanism as it itself bears the danger of global disaster and even the destruction of mankind, but another mechanism is not created yet. A policy of universal confidence, of absolute "transparency" of all states that ensures impossibility of secret preparations for nuclear attack or blackmail, can be the only alternative to nuclear equilibrium as a means of global stabilization.

It is necessary to advance to this goal and to develop a constructive dialogue between the two nuclear powers, the US and the USSR, on state, public, scientific, and cultural levels, for the purpose of enhancing confidence. It is necessary to reduce and finally to eliminate all types of closed zones: closed territories, closed enterprises, closed themes for discussion, closed scientific and technical directions. Reduction in all types of armaments and primarily nuclear weapons, and the elaboration of disarmament verification methods, are also needed.

*It should be helpful to organize international discussions —to work out recommendations for reduction and destruction of the most destabilizing weapons.*

However, until this objective is achieved and a new mechanism of global stabilization is created, it is indispensable to maintain nuclear equilibrium at all the stages of disarmament. Unfortunately, we don't know the stability limits of this equilibrium. That is, we don't know the degree of departure from equilibrium which would threaten global disaster. It should be helpful to organize international investigations and discussions on *global equilibrium stability problems*. The purpose would be to study the influence of different types of nuclear weapons, and to work out recommendations for urgent reduction and destruction of the most destabilizing weapons.

Mankind and governments haven't achieved complete moral perfection yet. Social, national, religious, and ideological conflicts appear from time to time at different points on Earth. And very often governments still desire to settle conflicts by resorting to military force.

Just the two main nuclear powers have recently revealed this aspiration strongly enough. The United States seems to have overcome the "Vietnam syndrome" and its scope of military actions has a rather worrisome upward trend (Grenada, Panama, the Persian Gulf, —?). In the USSR growing instability, economical chaos accompanying the first stage of perestroyka, opposition of the center and republics, the Gorbachev-Yeltzin conflict, all lead to popular discontent. As a result there is a danger that extremist forces and extremist leaders can access power. In fact in some regions attempts to solve national and social problems by military force have already taken place. Under these conditions the upset of strategic and especially nuclear equilibrium is extremely dangerous. Irrespective of the danger signs, either the stronger or the weaker sides could be tempted to a nuclear attack. The stronger side can expect to win the war, and the weak side perhaps to compensate its weakness by an advantageous first attack.

*The ... Protocol [and] joint verification experiment ... is an unprecedented step toward the confidence and "transparence" that is, I believe, the only means of replacing nuclear confrontation.*

So if the possibility of obtaining essential superiority in nuclear forces could appear as a result of some scientific discovery, I believe it would be expedient to freeze these elaborations or to publish information (rather generally, of course) about this possibility. Fortunately, the possibility of decisive progress in nuclear weapons efficiency is unlikely, to my mind, as too many intellectual and material forces have been spent in this field. To prevent the possibility of achieving unilateral nuclear superiority, it is useful to promote scientific contacts in those fields of fundamental science which serve as a basis for nuclear weapons technology.

Too hasty unilateral disarmament is also rather dangerous as it also upsets the equilibrium with unknown consequences. However the bilateral reduction of nuclear arsenals at least to the level comparable with levels of "small" nuclear powers (Great Britain, France, China) is undoubtedly of great use. Further reduction should be multilateral.

These considerations might seem to be too pessimistic. Positive trends should also be noted. First of all, the improvement of relations between the US and USSR and some very important agreements on disarmament are events of extraordinary significance. In nuclear weapons matters, we should mention the ratification of the Treaty of 1974 on the Limitation of Underground Nuclear Tests, and signing of the Protocol to this Treaty. These documents envisage rather reliable and informative measurements at test sites of both sides, which ensure verification of compliance with the Treaty. The drafting of the Protocol including the joint verification experiment at test sites in Nevada and Semipalatinsk is an unprecedented step toward the confidence and "transparence" that is, I believe, the only means of replacing nuclear confrontation

Further gradual but persistent advances toward limitation of nuclear weapons and methods of their development is highly necessary. The agreement on reduction in strategic nuclear weapons appears to be an important step. It would be reasonable to draw the two powers' nuclear weapons structures as as close together as possible, on the basis of the concept of equilibrium in nuclear forces. And it would be reasonable to correct imbalances as nearly as possible, not only in the whole but in separate types of these weapons. To perform this it would be expedient to draw the level of some strategic nuclear components down to or below the lower level of existing components. Advancing toward further nuclear test limitations is necessary as well. Immediate abandonment of tests is unreal and even dangerous. Nuclear weapons are as much in need of checking as any technical device, to ensure efficiency and safety in their normal operation.

Necessity for testing nuclear explosives is even more urgent than testing of other devices or other arms since the explosion occurs at pressures, temperatures, and densities of different radiation flows that cannot be achieved in any laboratory. Uncertainty in nuclear weapons reliability can be the destabilizing factor just the same as the quantitative lagging behind. Under present conditions, safety of nuclear weapons in relation to accidents or other unauthorized actions is of great importance. Both the US and USSR carry out research to increase safety, both sides being so interested in each other's progress that even joint attempts in this field are quite possible. This research requires a definite number of nuclear tests. Thus, the total cessation of nuclear explosions should be correlated with total nuclear weapons destruction. Rashness in this question, especially unilateral, is fraught with serious consequences.

It is very important to maintain the spirit of constructive cooperation which has resulted in successful ratification of the Treaty of 1974. Future advances in this sphere require practical realization of agreed verification methods, to check these methods and at the same time to prepare the scientific and technological basis for future political agreements. In principle, the further limitation of nuclear tests is possible in two directions: the reduction of the authorized yield threshold and the limitation of explosions number.

Both directions will require, first, development and improvement of seismic verification methods and, second, agreement on methods of identification of unannounced nuclear explosions, including onsite inspection using powerful geophysical and geochemical methods. Joint elaboration and co-ordination of these issues by American and Soviet scientists are useful as a basis for future political agreements. Thus, the task of nuclear disarmament will require a long period of time and should be solved gradually on the basis of bilateral and then multilateral steps. Serious international investigations are necessary for this task to be successfully accomplished.

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## Health Effects of Low-Frequency Radiation

Irving Lerch's letter (January 1991) focuses a multi-disciplinary light on the low-frequency electromagnetic field (EMF) versus human health issue. Lucidly pictured are the role of epidemiology, a requirement for consensus among national bodies, and the enormous challenge of biological covariates. These covariates span the spectrum of all biological and physical sciences.

John Snow plotted death sites during an 1854 English cholera epidemic and saw that most of the dying drew water from the same Broad Street pump. Disease from water was then an outlandish idea. Robert Koch was eleven years old when authorities shut the pump and the cholera abated. Some years passed before he identified the causative spirillum.

Nancy Wertheimer and Ed Leeper similarly plotted childhood leukemia and electric power delivery in Denver. Their seminal 1979 report showed children with leukemia lived in high-current-configuration locales 2.57 times more often than controls. The University of Southern California Medical School did an analogous study in Los Angeles funded by the Electric Power Research Institute. Among EPRI's February 1991 conclusions is, "The association between wire codes and childhood leukemia, found in two previous studies in Denver, was also found in this study." David Savitz in 1989 found a 90% increase in leukemia among children who used electric blankets plus a 70% increase in leukemia and a 150% increase in brain cancer among children whose mothers used electric blankets during gestation.

Can the EMF analogue of the Broad Street pump be remedied? Industry provides one example and English power delivery another.

One manufacturer redesigned its electric blankets in 1989 to reduce EMFs 0.3 milligauss. Random looping was rejected in favor of placing supply and return circuit elements in close parallel paths so that their magnetic fields equalize.

Looping, although spawning EMFs which radial feeds avoid, is considered sound engineering practice among electric utilities. The nation is enveloped by their EMFs in much the same way as are individuals under randomly looped electric blankets. Neutrals are grounded at substations, transformers, service drops, utility poles and to water pipes inside buildings. The metal sheaths of telephone and TV cables are bonded to many of these points. Hazardous EMFs from robust 60 Hz currents in buried water, telephone and TV lines result from such looping and grounding. The lesson? Utilities might solve the EMF problem by emulating the redesigned electric blanket.

The British, with no 125 volt system, deliver 240 volt power mostly through buried cables having both a supply and a neutral line inside a steel sheath. The sheath is earthed extensively, but the neutral is earthed only at substations. A few volts potential is expected between neutral and earth at electrical outlets. The result? Since supply and return currents follow close parallel paths their EMFs mutually nullify.

### A new paradigm?

As Lerch noted, a new paradigm resulting in consensus among diverse scientific areas will likely precede establishing low-frequency exposure standards. A significant challenge exists as many physicists do not appreciate the remarkably subtle energies, which act as biological Zeitgebers. Experimental EMFs of only 0.3 mG may entrain human electrical brain rhythms. Ross Adey has extensively explored calcium ion efflux from brain tissue in response to ELF fields. Robert Becker observed cellular and organismal responses to EMFs and developed a clinical application of weak currents to aid healing in bone fractures. Carl Blackman's report of calcium ion release in response to AC magnetic components of only 0.69 mG in one study and an astonishing 0.09 mG in another illustrates the subtlety of nature.

Such weak fields are often exceeded outside power line right-of ways. They lack sufficient energy to be classified as ionizing radiation. However, they may play Zeitgeber roles in melatonin synthesis by the pineal as shown by Russel Reiter in San Antonio. Ion cyclotron resonance involving the geomagnetic field in conjunction with ac fields and ions of calcium, potassium, sodium, magnesium, lithium, and hydrogen explains a number of research results. Ion cyclotron resonance does not explain results observed with ac fields under a few milligauss. Chaos mathematics may be central to numerous subtle phenomena. Such observations, among many others, suggest that the quandary biophysics faces in controlling multiple covariates, plus fathoming those which are uncontrollable, will take decades of research for resolution. Only then can scientific consensus be reached and the establishment of exposure standards expected.

Galen described the pineal some 2,200 years ago, believing it to be the "seat of the soul." Dictionaries circa 1940 define it as "evidently a remnant of an important sense organ in ancestral forms." Melatonin was isolated from some 250,000 such bovine remnants in 1958. Electric blankets were shown to diminish this remnant's production of melatonin in humans by Bary Wilson in 1988. This may explain electric-blanket-related leukemia since melatonin is oncostatic. The pineal is no vestigial remnant. It has many functions. Paradigms, given enough time, change.

### Recommended action

Must we do nothing while awaiting that change? Twelve years have passed since the Wertheimer/Leeper report, time enough for some 10,000 children nationwide to develop leukemia related to low-frequency EMFs. Should we not emulate the example of the Broad Street pump and act upon present epidemiological evidence? What can we do?

This physician would prescribe ac milligauss sensors for every household. Milligauss meters cost $100 and up, kits for the hobbyist $85, and light-emitting-diode sensors $40. These permit locating and avoiding hazardous zones, such as areas measuring over 1 mG near TV sets, computer monitors, microwaves and other appliances. Older children could observe EMFs at school. College graduates might consult their physics texts on Biot and Savart's law. They could then compute the amperages underlying the wall wiring and plumbing EMFs found by these sensors. Some would remedy EMF hazards by having the bonding screw in circuit breaker panels removed (allowed under the National Electrical Safety Code 92 D.1.). Others would observe hazardous EMFs from underground water, telephone, TV and electric lines. Utilities will sometimes reconfigure power lines to ameliorate the EMFs documented by customers.

Milligauss sensors and some appreciation of elementary physics are but vehicles of information. Informed consumers can avoid the EMF analogue of drinking from the Broad Street well. Collectively they just might catalyze utilities to correct it.

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## Editorial: August Sixth

Most of us will probably agree that today's characteristic moral and political questions stem from science. The example most familiar to physicists is the Manhattan Project. Other examples are environmental problems, bio-ethics, and the Gulf War ("An Inappropriate Use of Physics," April 1991). Knowledge is power, and power is moral and political. Science cannot escape this. Science cannot be rendered amoral or apolitical. Attempts to do so can only render science *thoughtless*.

Some argue that only the *uses* of science, not science itself, are moral or political. I disagree. A distinction between science and its uses may be convenient for academicians, it enable us to efficiently pursue research and teaching unencumbered by broader issues, but the distinction doesn't exist in the real world. Such distinctions between means and ends have proven dangerous in our century. The union of science and its consequences seems as clear to me as medicine's reduction of the cancer rate, as clear as Hiroshima.

If science is moral and political, then scientists must, *as scientists*, be moral and political. They must concern themselves, *within their professional lives*, with the moral and political consequences of their work, however broadly or narrowly they construe their "work."

For proof, consider the converse: Suppose that the moral and political implications of one's work are *not* one's professional responsibilities. Then not only scientists but also lawyers, teachers, and so forth, would divorce themselves from the human implications of their work. For example businesspeople would do "pure" business, which means, I suppose, that they would just make money. We would in fact have the thoughtless world we mostly see around us. The idea that the consequences of one's profession are not professional responsibilities is a prescription for chaos, for it leaves the human implications of all the professions up to chance, and up to elected officials.

Who is to pronounce on the human implications of science, if not scientists themselves? Who will provide wisdom, insight? You may be sure that others, less scientifically informed, will give their opinions. Politicians, most of them lawyers whose views on science-related matters are far outside their legal professions, must pronounce daily on these matters. Surely it is then not only our right but our duty as scientists to develop wise opinions on such questions and to make certain these opinions are heard. It would be foolish to claim that scientific credentials can validate our opinions, but it is morally disastrous to avoid developing and voicing our opinions.

### Examples

Examples abound of scientists and their organizations speaking out on broader issues, while making no secret of their scientific credentials.

Einstein often used his scientific credentials to support peace and other causes. He joined a small minority of German intellectuals in signing an unpopular petition opposing his country's involvement in World War I. Following World War II he labored to establish a world government, and helped found the International Pugwash movement of scientists. He spoke out loudly during the McCarthy era, urging intellectuals to adopt civil disobedience and to refuse to testify. He actively supported Zionism.

Sakharov used his scientific credentials in publishing his wide-ranging controversial anti-government essay "Reflections on progress, peaceful coexistence and intellectual freedom." Although he wrote as a scientist, his opinions went far beyond "pure science."

Einstein and Sakharov were not only physicists, they were intellectuals. Their scientific background and human concern qualified, indeed required, them to offer their considered opinion on many topics. They knew that society needed the serious (in other words broadly intellectual) physicist's opinion on such questions. Where is the human race to turn for wisdom if not to its scientists and other informed people? Would it be better if none of us offered opinions, if we left it to elected officials and uninformed people?

Scientific organizations such as the Union of Concerned Scientists and the Federation of American Scientists use their scientific credentials in taking strong stands on controversial issues. Both were outspoken and active supporters of a nuclear freeze in the early 1980s, organizing grassroots political activities to influence voters and congress.

Over 600 French scientists recently published an appeal (republished in these pages, July 1991; see also the dissenting letter in this issue) to stop the Gulf War. France's strong intellectual tradition, a tradition that denies narrow "specialization," is one reason so many French scientists would sponsor such a strong statement.

The American Physical Society issued a statement in January 1991 (see *Physics Today*, March 1991, p. 79) on anti-Semitism in the USSR. Over many years, I have signed petitions from APS and other scientific organizations bearing similar statements. Although many of us including myself applaud this statement and believe that its APS sponsorship is quite appropriate, this issue has no specifically technical or scientific component. The rights involved are general human rights that are not particularly "scientific." The issue is less strongly science-related than for example the issue of the morality of the Gulf War.

My final example is this quarterly, where the articles lean toward so-called "pure" science, while the letters and comments lean toward opinion. It is not only your right, it is your responsibility as a scientist to take advantage of this and other outlets for your well-considered opinions.

*Art Hobson*