The panel, it was reported, "rejected virtually all of the Air Force's hypotheses" during a 3-day review and outlined seven theoretical roadblocks that would prevent development of a particle beam weapon. Keegan's team then set about assembling evidence that the Russians have overcome each of these seven roadblocks and in fact are "years ahead" of the United States in most of them.

The article reflects Keegan's view that his ideas have not received fair consideration from the various scientific reviewers. Most of the physicists who would not accept his data are "older members of the scientific community," who were involved in Project Seesaw, the unsuccessful attempt to develop an electron beam, and whom Keegan accuses of believing the Russians could not succeed where Americans had failed.

As to how the defense would detect incoming missiles and aim the beam at precise targets, *Aviation Week* suggests that precision aim is unnecessary. All that is needed is for the beam to saturate the broad areas or "windows" through which the warheads must pass. In the Keegan view, such windows can be detected by the Soviet radars which have already been deployed in violation of the SALT agreement. The typical energy levels that would be required for use with a beam weapon are "10^{12} joules per pulse, with the energy of a particle of the beam from 1 to 100 giga electron volts," the article reports.

Keegan's hypothesis rests on a mix of technical and intelligence information which is too esoteric for easy evaluation. Keegan declines to identify his scientific supporters, and *Science* has been unable to do so independently. Sources have indicated that the Foreign Technology Division at Wright-Patterson Air Force Base is the chief source of Keegan's technical advice, but chief scientist Anthony Cacioppa declines to make any comment. Another rumored adviser, William Drummond of the University of Texas, says he knows Keegan and has advised the government in the past, but that "We are not the advisers of whom he speaks—where he gets his information is way beyond my ken." Drummond and M. L. Sloan, a young physicist at Austin Research Associates, are developing an accelerator capable of generating intense beams under a contract from the Ballistic Missile Defense Agency.

Skeptics of the Keegan hypothesis are easier to find. A physicist who is prominent among the goverment's scientific advisers describes as "absurd" the suggestion the Russians would use nuclear explosions to power a beam. "That is nonsense because the 10 megajoules you would need to destroy a target could just as well be obtained from a conventional high explosive," he says. "I believe there is really nothing to worry about in this case, and that the information provided there [in *Aviation Week*] is a hodge-podge of things which, since you don't know what they are for, can be put together to mean almost anything."

A similarly definite dismissal was delivered by Secretary of Defense Harold Brown at a recent press conference. To turn particle beams into a practical weapon, let alone an operational system, Brown said, "requires that each of a number of theoretically conceivable but practically very difficult steps be carried out. From what we can see of the evidence, and I have seen all the evidence there is, a number of those remain far from achievement both by us and by the Soviets. And therefore, I don't think that there is such a weapons system in prospect in the foreseeable future."

In a further effort to shoot down the *Aviation Week* article, the Defense Department held a 16 May briefing about Soviet and U.S. progress with particle beam weapons. A Pentagon scientist who asked not to be named remarked on the absence of certain "key pieces of information" which would be expected if the Russians had made substantial progress. He declined to identify them, but presumably the testing of a nuclear-powered beam would leave more traces than just a few puffs of hydrogen. Soviet progress with beam weapon-type accelerators is "about equivalent" to that of the United States, leading in some areas and lagging in others, the official said. The United States spends about $7.5 million a year on beam weapons, but a prototype is many years away.

Reaction in Congress seems likely at present to follow similar lines. A staff member of the research and development subcommittee of the Senate Armed Services Committee said the beam threat had been exaggerated and was not likely to become an issue.

The evidence presented in *Aviation Week* establishes at most the possibility that the Russians are experimenting with development of a particle beam weapon. It is presumably the job of intelligence analysts to fit together strands of disparate evidence and make exactly the kind of creative deduction that Keegan has done with the particle beam. But most such hypotheses presumably turn out to be wrong. Keegan's arguments have evidently proved less than compelling to a majority of the intelligence community, but he or his team believe so strongly in the rightness of their case that they have taken it to the public, despite the risk that open discussion of intelligence matters may jeopardize sources and reveal the extent of American knowledge about Soviet activities. The evidence of the *Aviation Week* article seems a tenuous basis for so decided a step.—NICHOLAS WADE

"Soft Technology" Energy Debate: *Limits to Growth* Revisited?

One of the strongest undercurrents of energy policy in recent months has flowed from a remarkable critique put forward by Amory Lovins, a physicist turned environmental advocate for Friends of the Earth. The critique encompasses technical, economic, social, and philosophical aspects of energy policy and appears likely to have a lasting impact on the rhetoric, if not the substance, of the energy debate. It has provoked rivulets of reaction that include congressional inquiries, official studies by the Energy Research and Development Administration (ERDA), detailed and often impassioned rebuttals by many of the elite of the energy establishment, and even imitation by President Carter's speechwriters.

The sequence of events is strongly reminiscent of those following publication of the 1972 Club of Rome report, *Limits to Growth*, which was also vigorously debated and heatedly condemned. The similarity may, in fact, go further,

because while *Limits to Growth* was eventually discredited as technically unsound, it had an undeniable philosophical impact; in retrospect, it may have marked the end of unquestioning acceptance of high energy growth projections. In a similar way Lovins raises questions about the degree of centralization of energy supply and the emphasis accorded electric power production that will not easily be turned aside, even though his principal thesis—that the United States could now abandon centralized energy sources and turn instead to "soft" technologies—seems certain to be discredited by the flaws that critics and some supporters see in his arguments.

The reaction to Lovins is interesting for what it says about the character of the energy debate in the United States. Many of the ideas espoused by Lovins and most of his data base do not originate with him, a fact he acknowledges. But Lovins has a definite way with words and his often compelling prose and well-marshaled arguments have had an effect on government energy circles denied other environmental advocates—an effect enhanced by the publication in *Foreign Affairs* of what has become the most widely read version of his critique.* Perhaps because of this prominence, Lovins' analysis has itself been the subject of critical analysis even by those who would normally ignore it, such as one conservative economist who privately describes Lovins' thesis as "a piece of crap."

Soft technology, in Lovins' appealing phrase, turns out to mean primarily solar heating and cooling, wind and hydroelectricity, and fuels from renewable biological materials. Equally important to Lovins is that the kind of energy and the technology used to produce it should match the end-use need—in the quality of energy, in the scale of the technology, and in the location. For example, he says that about 35 percent of the energy used in the United States is in the form of low-grade heat (less than 100°C), and he argues that it makes very little sense to burn fuels at high temperatures or to use electricity to provide that heat when low-grade solar heat is readily available; likewise he argues the advantages of producing the heat right where it is needed rather than at large, remote power plants or synthetic fuel facilities. In fact, Lovins sees relatively little need for electricity other than to run lights, motors, and electronic equipment—uses that comprise only about 8 percent of U.S. consumption—and he believes this modest amount could easily be provided with a network of windmills and hydroelectric plants. For transportation and where high-temperature heat is really needed, Lovins would use biomass fuels, not electricity. Lovins looks favorably on some interim uses of coal, especially for the cogeneration of heat and electricity on a local scale, but opposes centralized power stations of any ilk and saves his harshest invective for nuclear power.

It is thus not surprising that scientists and energy analysts closely identified with nuclear power have reacted strongly to the Lovins critique. Ralph Lapp, for example, calls it "irresponsible." In an exchange of letters in *Foreign Affairs*, Hans Bethe charges Lovins with misrepresenting the economics of the energy alternatives; specifically, he cites evidence that Lovins has overstated the capital cost of nuclear and other conventional technologies by a factor of 2 or 3 and understated the cost of solar energy by a still greater margin. Bethe finds a number of points of agreement with Lovins, such as the need for conservation and realistic energy pricing, but he decries what he calls "combining 'soft' arithmetic with wishful thinking." Lovins disputes the charges, citing counter-evidence.

Even more dubious, according to the critics, are Lovins' numbers on the production of fuels from biological matter and electricity from windmills. Lovins asserts, for example, that the biological production of alcohol by fermentation in the beer and wine industry is already so substantial that a 10- to 14-fold expansion of fermentation facilities would produce enough ethyl alcohol to replace U.S. gasoline consumption in the long run (he also assumes a threefold improvement in the average miles per gallon of U.S. autos). Calculations by Daniel Kane, president of the independent, energy-oriented Council on Energy Independence, suggest that the amount of alcohol required is at least ten times higher, even given Lovins' optimistic target for improved efficiency.

More surprising, perhaps, is that a number of scientists who very much agree with Lovins' overall philosophy and his criticism of centralized energy sources and excessive electrification also believe that he has oversold the case for soft technologies. John Holdren of the University of California at Berkeley, a prominent analyst of alternative energy technologies, believes that Lovins has done a great service in formulating the case against a high-electric, highly centralized energy future in such a way that it could not be ignored. But he expresses reservations about the costs and even the availability of some of the soft technologies that Lovins espouses. "I regard many of these as more uncertain than Amory does," Holdren says, adding that he thinks it is premature to talk of abandoning existing and prospective fossil fuel and nuclear technologies. Likewise, J. D. Balcomb, a respected solar energy scientist at Los Alamos Scientific Laboratory, says that Lovins' figures for solar energy are very "overoptimistic." And although he wholly agrees with Lovins in most respects, he believes that "no good is done by making exaggerated claims."

Indeed, some of the harshest reaction to Lovins comes from the solar energy camp. In a forthcoming volume of ten critical essays on the Lovins thesis, Sheldon Butt, president of the Solar Energy Industries Association, describes what he calls "a lengthy series of distortions and even misrepresentations of physical and scientific fact." In the same group of essays, solar energy pioneers Aden Meinel and Marjorie Meinel declare that "we are chilled at the actions advocated by this seductive and well-written article." The collection of essays was assembled by Charles Yulish, a management consultant in the energy field; he is paying publication costs out of his own pocket because he finds the Lovins position—which he calls "a political manifesto"—so upsetting.

ERDA, in response to a query by Senator Henry Jackson, notes some points of agreement with Lovins, such as the attractiveness of conservation, solar power, and cogeneration, but disagrees with the contention that hard and soft technologies as defined by Lovins are mutually exclusive. The agency also defends centralized generation of electricity on the grounds of its flexibility and disputes Lovins' estimates of the relative costs of hard and soft technologies. ERDA also points to a number of questions for which, it says, the data are simply not yet available to allow a definitive answer, such as the reliability of distributed, on-site power generating equipment and the land-use requirements of supplying transportation needs with fuels from biomass. The agency analysis is low-key and undogmatic in tone, but concludes that "it is far from established that the complete 'soft' energy path advocated by Mr. Lovins is economically

*"Energy strategy: The road not taken?," *Foreign Affairs* (October 1976). A more detailed version of the critique is contained in "Scale, centralization, and electrification in energy systems," presented at a symposium held in Oak Ridge, Tennessee, 20 and 21 October 1976, under the auspices of Oak Ridge Associated Universities.

or technically sound; nor is it established that the 'hard' path is as grim as he would have us believe. . . . ERDA sees no reason not to develop both sets of technologies and let them compete in the market place for specific applications."

Despite ERDA's criticisms of Lovins' proposal, the agency is at least going through the motions of considering the ideas in greater depth. It has announced a series of contracts with university and other research groups to look into the potential of soft technologies and distributed systems in greater detail, and Lovins has been retained as a consultant. Other evidence that Lovins is having at least a superficial impact is to be found in President Carter's energy message to Congress, which cited in support of the cogeneration of heat and electricity the "fact" that 29 percent of West Germany's power is produced by this method—a number that appeared in Lovins' *Foreign Affairs* article. In fact, the correct figure is closer to half of that, as Lovins himself acknowledges in a later paper. Overall, however, the Carter energy proposals reveal no fundamental shift toward soft technologies.

Part of the attention accorded the soft technology thesis, despite the fact that it represents a radically different set of values and assumptions about the character of the energy problem, seems to be due to the force of Lovins' personality. He is young (29), obviously very bright and articulate, and comes over in public forums as a kind of wunderkind, impressing audiences with his command of a wealth of material. His confidence in his vision of the energy problem appears to approach arrogance—in a private exchange of letters with Bethe, according to a friend and supporter of Lovins who has seen the correspondence, Lovins is "unfortunately very rude" in his response to Bethe's efforts to come to some meeting of minds on one of their points of disagreement.

Environmentalists have often been criticized as quick to oppose but slow to endorse a viable alternative, and Friends of the Earth, Lovins' group, has been among the most adamant in opposing all forms of nuclear power and expanded use of coal. Lovins thus faced some formidable difficulties in contriving a coherent energy future that does not rely on coal and nuclear—difficulties that, to judge from his critics, he did not entirely overcome. His case against centralized power generation and what he calls the "diseconomies" of large-scale energy systems appears to be on somewhat firmer ground.

Lovins points out, for example, that 70 percent of the cost of electricity—by far the most expensive form of energy—is attributable to the transmission and distribution system. He argues that not only are the economies of scale for large power plants illusory, but also their reliability is less and their environmental impact and transmission costs greater than those of smaller generating units located closer to the point of use. Smaller units would also lend themselves to mass production rather than the laborious, lengthy field assembly of large power stations. Although not everyone will agree with the social and political side effects that Lovins attributes to excessive centralization of the energy supply system—such as fostering big government and an authoritarian, antidemocratic society—it seems likely that the national infatuation with "bigger is better" has indeed carried the trend toward ever larger energy systems to questionable extremes. Equally, the national emphasis on electrical energy rather than on fuels as the mainstay of the future is at least open to argument.

The cause for concern about the kind and the scale of energy systems is perhaps most clearly evident in the federal energy R & D effort. Despite growing domestic shortages of liquid and gaseous fuels, for example, more than 75 percent of the fiscal year 1978 research budget is devoted to new sources of electricity. What R & D effort there is on sources of fuels is largely devoted to coal-based synthetic fuels; investigation of biological sources of fuels is far more meagerly treated. Even within the solar energy R & D effort, the emphasis has been on large-scale, centralized systems for producing electricity, as Lovins points out.

For all its flaws, the Lovins critique is easily the most comprehensive and technically sophisticated attempt to put together an energy program compatible with environmental values. And the continuing reaction to it in Washington and elsewhere would seem to indicate that the intellectual vigor and political muscle of the environmental movement is far from spent, but rather is escalating from a purely defensive focus on particular sites and technologies to consideration of energy systems as a whole.

—ALLEN L. HAMMOND

Public Interest Lawyers: Carter Brings Them into the Establishment

When the history of President Jimmy Carter's first 100 days is written, more than passing notice may be taken of the fact that, during this period, Carter appointed more than a score of people from the relatively new field of public interest law to subcabinet positions and important jobs at the White House and the Office of Management and Budget.

Altogether, 24 persons with backgrounds in public interest law had, at last count, been chosen for high-level administrative or staff jobs—enough to indicate that, for all their past struggles with the powers-that-be on behalf of previously unrepresented interests and points of view, practitioners in this new field are themselves now becoming part of the political establishment (see box, page 962).

Until 7 or 8 years ago, public interest law did not exist in any general sense, although a few specialized kinds of public interest practice such as civil rights and poverty law had developed much earlier. Today, there are reported to be more than 90 public interest law groups across the country, with about 600 lawyers—together with some scientists, who work with the lawyers in preparing lawsuits and petitions on technical issues—engaged in this field of practice full time. What distinguishes it most from ordinary legal practice is that it involves actions, such as suits or petitions aimed at pollution abatement or utility rate reform, in which the plaintiffs have no greater stake in the outcome than does a wide public.

The appointment of so many practi-