

science and education holds the key to future economic health, and that tough financial times are precisely when support for science should be the strongest. When society perceives a need, the money is found to meet it, says Lederman. Although it will take an additional \$10 billion to meet his doubling goal, "It isn't a matter of money," he says. "It's a matter of choice."

Frank Press, president of the National Academy of Sciences, agreed that doubling federal support for science will pay back as an investment. But, he added, "No nation can write a blank check for science." Echoing a theme he first sounded 2 years ago (*Science*, 23 December 1988, p. 1626), Press insisted that "scientists must participate in establishing priorities," something Lederman's report does not discuss.

Others emphasized that it is important for researchers not to appear as just another special interest group begging for a bigger share of the federal research pie. Robert L. Stern, secretary of the industrial science section of AAAS, warned that although Lederman's report could be a rallying point, it could also be perceived as self serving by a Congress besieged with pleas for money. He argued that emphasizing the importance of science for the economy will make it easier for politicians to support the report's conclusions. Senator Albert Gore, Jr. (D-TN) took up this theme, saying that Congress' willingness to support an ambitious expansion in federal spending on science will depend on whether the public believes "it will pay off, not only in advancing the frontiers of science, but also in the collateral benefits that have accrued in the past"—specifically products and services that will benefit economic growth.

The decision to send Lederman's report to all 140,000 members of AAAS is an unusual step for the association. When asked if this signalled an intention to increase lobbying efforts on behalf of federal spending for science, AAAS executive officer Richard S. Nicholson denied that the report represented an attempt to lobby, repeating instead a rhetorical question posed in the report: "Is it not the obligation of societies like AAAS to bring the state of science to the attention of policy makers and the public that pays for and ultimately benefits from research?" Although AAAS paid an estimated \$30,000 to publish and distribute the report, it is Lederman's personal statement and has not been formally endorsed by the AAAS board of directors.

For his part, Lederman is not sure what his next step will be. The report will be presented to the AAAS board of directors at its next meeting in February. "I guess I'd better have an action plan ready by then," he says.

■ JOSEPH PALCA

Skeptics and Visionaries Examine Energy Saving

Some say new, efficient appliances could save enormous amounts of energy—and solve the greenhouse problem. But will they be used? There's the rub

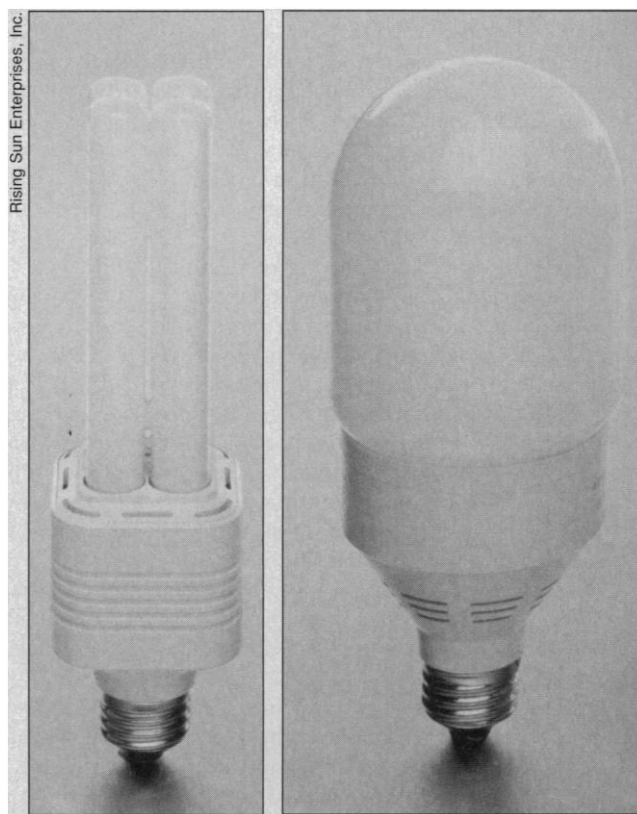
BERLIN—NO SUCH THING AS A FREE LUNCH? Try this. Replace one 75 watt incandescent lightbulb in your home or office with a modern 15 watt compact fluorescent tube. You get the same amount of light for 13 times longer, cut your lighting bill by 80% to 90%, and over the lifetime of the tube save enough coal-fired electricity to keep about a ton of carbon dioxide out of the atmosphere. Factor in reduced maintenance costs, and the compact fluorescent tube costs about 0.6 cents less per kilowatt-hour than the incandescent bulb it replaced. "This is no free lunch," says Amory Lovins, director of research at the Rocky Mountain Institute in Snowmass, Colorado, "It's a lunch they pay you to eat."

Lovins, high priest of energy efficiency, was spreading the gospel at a Dahlem Conference convened last month to ask how to control the accumulation of atmospheric carbon dioxide, and thus minimize the feared additional greenhouse effect.* His answer: Look after energy, and CO₂ will look after itself. Lovins makes an even grander claim: He says his institute has identified 50 energy-saving technologies that, if implemented worldwide, would cut global energy use in half.

Lovins has been saying much the same thing for years, and critics have always charged that the costs are far higher, and the savings far lower, than Lovins claimed. John Reilly, an economist with the U.S. Department of Agriculture's Economic Research Service, spoke for some of the other Dahlem participants when he asked bluntly: "If it's so damn good, why isn't anyone using it?" The answer is, they're starting to. The reasons became apparent at

the meeting: technology is improving rapidly, so that some of Lovins' more outlandish claims have become more possible; and econometricians like Reilly have begun to see that they really can start to think seriously about energy-saving technologies.

Reilly represents the classical econometricians' top-down view: They look at past trends in energy use—for example, after the price hikes of the 1970s—and see no evidence that



Lighten up. Compact fluorescent bulbs are brighter—and more efficient—than incandescent bulbs.

people can be convinced to use the most energy-efficient technologies, even when to do so would be in their long-term economic interest. Instead, the econometricians observe, short-term costs play a disproportionate part in consumer decisions.

Lovins, on the other hand, represents the engineer's approach: from the bottom up. He calculates overall savings by measuring each device and assuming the best devices would all be used; if they aren't, that only

*The Dahlem Workshop on "Limiting the Greenhouse Effect: Options for Controlling Atmospheric CO₂ Accumulation" was held in Berlin from 10 to 14 December 1990. The results will be published by John Wiley & Sons Ltd., Chichester, England.

shows how irrational consumers are.

The top-downers worry that reduced demand for energy will lead to lower prices and that might just stimulate demand. The bottom-uppers don't like the fact that top-downers rely on historical data to forecast the future. So, the two groups have had difficulty finding common ground—until now. Gradually, the econometricians and the engineers are beginning to see each other's point of view, and that was the news at the meeting.

Throughout 4 days of intensive workshops, the 39 invited participants—who included energy analysts, economists, political advisers, and even a few climatologists—wrestled with the problems and potential of global energy saving. They agreed that it could be done, but wondered how—and if—it would be done. And finally, they heard ominous warnings that the benefits of energy efficiency—if somehow achieved—could all vanish in a cloud of automobile exhaust.

The difficulty with any grand scheme to save the planet by saving energy lies between what the French Nobel laureate François Jacob called the possible and the actual. Nobody doubts that vast energy savings are possible; everyone doubts that the energy will actually be saved.

Looking at just three sectors—lighting, motors, and appliances—the possibility of saving two-thirds of the total U.S. demand for electricity exists right now, according to Lovins and his energy research group at the Rocky Mountain Institute. Regarding lighting, Lovins reckons that compact fluorescent tubes could save 10% of the electricity used in the United States. Another 12% could be saved by improving existing fluorescent tubes. In all, Lovins said, more efficient lighting could save a quarter of U.S. electricity and save money into the bargain.

Next, he pointed to motors: "Over half the electricity in the world turns motors," says Lovins, and very inefficiently, too, he adds. New electronic speed control systems, new materials and designs, new drive trains, new bearings; all can save nearly 60% of the electricity bill for motors. And the costs are not high: an average motor consumes its own capital costs in electricity every few weeks. A new motor would pay for itself in 16 months. After that, all the savings are profit.

Appliances offer less savings than lighting and motors, but only because there are fewer of them. In the home, for example, refrigerators consume more electricity than any other device (except electric space and water heaters), and yet savings of 90% are not hard to achieve, Lovins says, primarily by means of better insulation. He explained to the Dahlem participants that there are at least five new insulators available for refrigerator walls, all of

Hope for Eastern Europe?

In the industrialized world, those who would cut CO₂ emissions via energy efficiencies are scratching their heads over the cheap cost of energy: It encourages profligacy. In the Third World, the quandary is of a different sort: There, "Capital doesn't retire," says Ogunlade Davidson, an energy analyst from Sierra Leone in West Africa, "it stays in use lower down the chain. And in much of the developing world there's no benefit to an energy efficient new car if you have to drive it on old roads."

So is there no hope in a world facing an energy-induced CO₂ high? Look to problem-plagued Eastern Europe. There, opportunities exist in what are coyly called the formerly planned economies. Igor Bashmakov, an economic analyst at the Institute for Energy Research in Moscow, is blunt: "Energy conservation is the only way to solve all the other problems in my country."

But there are formidable obstacles as well as incentives. One is the lack of meters—nobody knows how much energy various sectors use. Another is pricing—citizens pay a fixed (and heavily subsidized) cost for heat. That, combined with a lack of control technology, encourages them to use their windows as thermostats—the ultimate in space heating. A third hurdle is lack of turnover in industrial capital, 2% or 3% a year, rather than the 7% or 8% common in the West. This means that outmoded technologies continue to waste energy far longer.

Still, there is the potential for rapid and impressive energy savings, thanks partly to an efficiency lever. As Bashmakov sees it, a 1% saving in demand could lead to a 10% increase in output, not least by freeing fuel that can be sold abroad for hard currency that can in turn be used to buy more energy efficiency. And, given the inefficiency of Soviet electricity generation, lower demand saves even more CO₂ there than it would in the West.

■ J.C.

which are hundreds of times more efficient than freon-filled foam.

Lovins and his group have now examined more than a thousand energy-saving technologies. Just 35 would save a quarter of the world's electricity, they say. Utilize another 15, and you'd save half the energy worldwide. Says Lovins: "Saving energy is a bit like eating a lobster. You get big returns easily from the claws and the tail, but unless you disaggregate you miss half the quantity."

Lee Schipper, an international energy analyst and senior staff scientist at the Lawrence Berkeley Laboratory, who has long listened to both sides, said at the meeting that Lovins was right that much greater savings could be achieved, but that the econometricians were right that the savings probably will not be as large as Lovins hopes. "Amory's position is probably necessary to get the economic pessimists to move slightly further than they have been prepared to," said Schipper. And there did seem to be some movement in evidence at the Berlin meeting.

Lovins is willing to concede half of his savings; that still leaves more than enough to cope with the CO₂ problem. Climatologists, like Graeme Pearman of the Australian CSIRO Division of Atmospheric Research, and organizer of the meeting, agreed: "If we could get half of [Lovins'] savings, worldwide, that would probably do." And the econometricians, like Rich Richels, an economist at the Electric Power Research Institute

in Palo Alto, say they are looking again at their models to see whether they can incorporate some of the new data on consumer behavior. The two sides even reached common ground on one key point: energy is too cheap.

Price is the overall barrier to energy efficiency; energy costs too little and efficiency apparently costs too much. But the barrier of price subsumes many smaller hurdles. One of the most obvious is the different time scales of consumer and supplier. Energy utilities plan their investments over 20 years or more. The consumer wants to save within a year or two. So the consumer buys a \$1 incandescent bulb rather than a \$20 compact fluorescent tube, even though in the long run the tube will save much more than its extra cost. And the utility, faced with what looks like ever increasing demand from consumers, plans to bring another 100 megawatt power plant on line in 20 years time. The "payback gap" is rational for both parties, but causes misallocation of funds. "We end up buying too many power plants and not enough efficiency," says Lovins.

There are signs of change, though. Utilities are beginning to offer customers incentives to save energy. Southern California Edison has given away more than 800,000 compact fluorescent lamps. In Massachusetts, the Taunton Municipal Lighting Plant leases these lamps to customers for 20 cents a month, and replaces them for free. The customer enjoys

lower bills, the utility saves the cost of extra supplies, and the atmosphere, almost as a side-effect, is relieved of a considerable burden of CO₂. On the West Coast, utilities have joined together and are about to offer refrigerator manufacturers a golden carrot, a gift of perhaps \$100 for each of the first 100,000 refrigerators sold that beats the current average efficiency by two-thirds. That will bring down the cost of tooling up for production and encourage manufacturers to push more

selves as service industries, providing cold beer or hot showers and making their profits by cutting their costs. And regulators are helping them make the shift. In California, for example, the Public Utilities Commission recently agreed to allow Pacific Gas and Electric to keep 15% of any money saved by efficiency programs.

Selling such ideas to the rest of the world is another matter, meeting attendees heard. According to Ogunlade Davidson, an energy

one thing that could bring the whole plan for energy—and therefore CO₂—reduction to a grinding halt is the human quest for leisure. “That’s where you get the most energy use per minute,” warns Lee Schipper. “Where and how we play in future” is the great unknown.

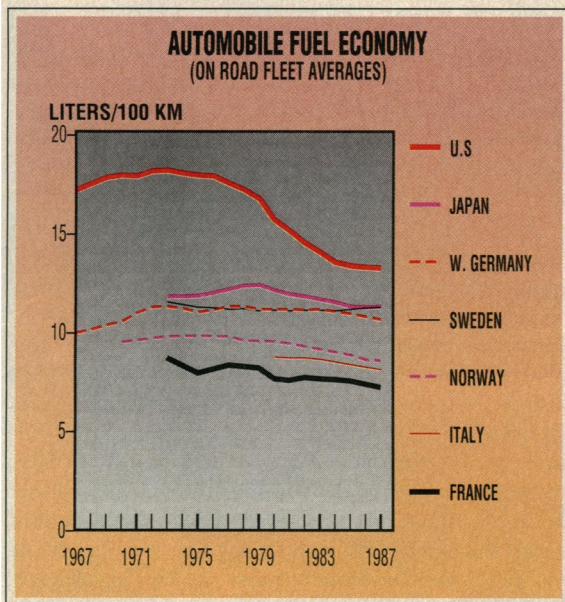
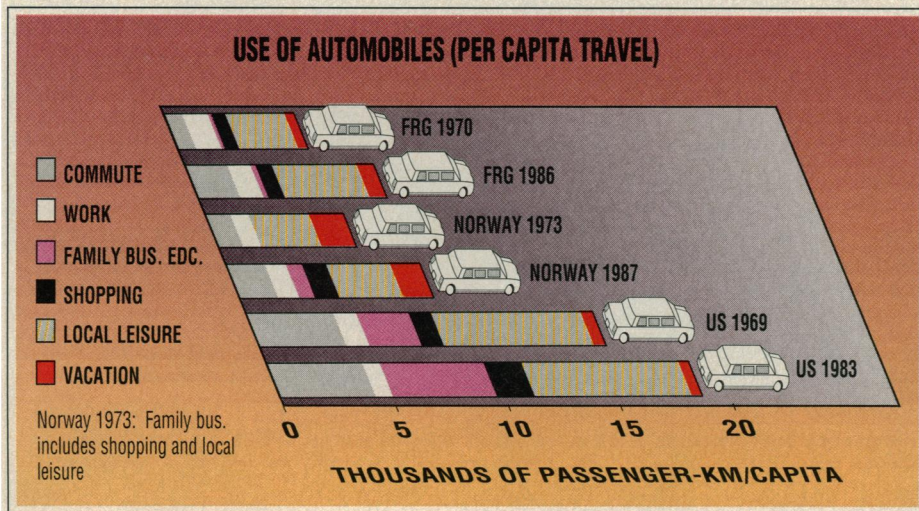
At the heart of leisure is travel. In the United States, people drive an average of 23,000 kilometers a year. In doing so, they use ten times more energy than they do by staying inside a building. Furthermore, in many industrial countries distances driven for leisure have increased in recent years, canceling out possible energy savings from more efficient autos.

Meanwhile, in the People’s Republic of China, the average distance driven per year is 500 kilometers. The consequences of any increase over the size of the PRC’s population would be enormous. This may seem unlikely today, but in much of the industrialized world the “right to drive” is only starting to penetrate people’s attitudes and behavior.

As with other sectors, we have the technology right now to make considerable savings in driving efficiency. Existing devices, already scattered across different models of car, would offer almost 30% more efficiency if brought together in one model. Another 50% saving would come from the introduction of advanced technologies. But, says Schipper, “You can’t today buy an efficient car.” The obvious reason: fuel is too cheap. And the prognosis: poor. After all, between 1973 and 1987 there was no improvement in automobile efficiency in Europe. And in eastern Germany, during the Dahlem Conference, the managing director of a factory making Wartburg cars insisted that investment by Opel/GM in a new plant should not prevent him from selling his immensely inefficient automobiles to Lithuania, regardless of the lingering environmental cost. Modern auto manufacturers are falling over themselves to invest in the formerly planned economies. Will they export their current models, or will they take the opportunity to push for hitherto unimagined efficiency? Currently, it looks as if old technology is winning, although some auto makers are talking to Schipper about leapfrogging instead. “At least they’re thinking about it,” he said.

With a massive increase in energy efficiency, the world may be able to enjoy its free lunch and mitigate the worst of global warming without even thinking about CO₂. But, says Schipper, “Those of us who call ourselves energy analysts have made a mistake. . . we have analyzed energy. We should have analyzed human behavior.” If trends continue, he cautions, “Lifestyle changes could eat into everything you think you’ve saved.”

■ JEREMY CHERFAS



Running on empty. *The efficiency of automobiles in Europe has increased little in recent years (below), while leisure driving in many countries has increased (above). The use of energy in leisure pursuits could cancel out many other energy savings.*

analyst from Sierra Leone in West Africa, in the developing world “you mustn’t mention CO₂,” because if you do, people will assume you seek to penalize development. In the Soviet Union, said Igor Bashmakov, a mathematician and economist at the Institute for Energy Research in Moscow, most people know nothing about CO₂ and global

climate change. “They need to be told that through this technology transfer they will live better,” he said. And in Germany, according to Eberhard Jochem, energy policy analyst at the Fraunhofer Institute for Systems and Innovation Research in Karlsruhe, “You can sell the environment, but not energy saving.”

Consequently, the Dahlem conferees agreed that research now should concentrate on these human aspects of energy savings. Yet in spite of the appearance of at least a partial consensus among the theoreticians,

efficient appliances. The utilities pay only if the manufacturers reach the golden carrot’s target, and if they do the utilities know they will save at least that much energy in the future.

All around the United States, forward-looking energy suppliers are experimenting with various ways of saving energy, most of which require a radical shift in thinking. Instead of regarding themselves as classical utilities, making a profit on the volume of their sales, suppliers are beginning to see them-