Center at Huntsville. At his urging, the Committee on Science and Technology reported out the bill in May, saying that the "paper studies" being conducted by DOE and NASA should be augmented by a program of "technology verification" that would include some "limited space experiments."

Leading the opposition to the Flippo bill was Representative Howard Wolpe (D-Mich.), one of four science and technology committee members who filed dissenting or cautioning views about stepping up the pace of R & D on the SPS. In the House debate, Wolpe told his colleagues that his efforts in committee to eliminate from the measure any reference to "development" had been strongly and successfully resisted by the bill's sponsors.

"I submit that this bill is, in fact, the first step in an effort to commit us to the premature development of the entire solar power satellite concept," Wolpe said.

Wolpe argued that the proper course is to await the DOE-NASA report on the SPS concept next year before considering further action. His position is supported by some 40 solar advocacy and environmental groups who see the SPS as a monstrous perversion of their hopes for widespread small-scale solar applications that would be highly decentralized and socially and environmentally benign.

The Flippo bill is backed by the Sunsat Energy Council, a new Washington lobbying group that is headed by Peter Glaser and that includes on its board of directors people from aerospace companies such as Boeing, Lockheed, and Martin-Marietta. Sunsat is calling for "an expenditure of between $200 and $300 million over the next 5 years [to] cover the research necessary to determine the safety and feasibility of the SPS." According to Glaser, Sunsat members are not "so rash" as to wish to proceed with such development without knowing the potential effects of microwaves—or of lasers or any other alternative means of space-to-earth energy transmission—on communications and ecological systems.

In a letter to President Carter last July appealing to him to consider the SPS in national energy planning, Glaser said, however, that the "unknowns [in the case of the SPS] are fewer and less hazardous potentially than those . . . associated with our initial commitment to the Apollo program or those which still exist in connection with nuclear waste disposal or the carbon dioxide effects of burning fossil fuels." But the fact is, no one knows what the health and environmental effects of the SPS would be.

"We have nothing yet on the chronic health effects of low-dose, long-term nonionizing microwave radiation," Fred Koomanoff, director of the SPS project office at DOE, told *Science*. Experiments to determine these effects are still being designed. While investigations into the effect of microwaves on environmental and communication systems are further along, they remain inconclusive or incomplete. "We know that there will be a problem of interference with radio-astronomy," Koomanoff said, "but can mitigation measures be found?"

Large economic questions must be answered, too. For example, given major uncertainties as to future demand for electricity, there is the problem of matching the size of the SPS system to demand—and of providing backup power for a huge generating system that

Waiting for the Oil Bug

Alga ayatollahphobera is a remarkable organism. It secretes a fine emulsion of hydrocarbons that is convertible to high-octane gasoline at $2.50 a barrel. It grows in saltwater, a medium useless for food crops. It forms its hydrocarbons from carbon dioxide, thus helping to retard the worrisome buildup of the gas in the atmosphere. From nothing more than sea, sunlight, and waste gas, the industrious microorganism produces gasoline almost too cheap to meter.

The alga hasn't quite yet been invented, but with every new political crisis in the Middle East you can see it striving harder and harder to materialize. Oil, after all, came about through photosynthesis, plus a little geological history, and photosynthesis is the most logical way to make more. Congress ardently supports all forms of solar energy, biomass in particular, but its gaze is often focused on the near-term future. Ideas for fuel-producing crops are "exotic 21st century concepts," and the Department of Energy is spending far too much on them, Representative Floyd Fithian of Indiana complained to a House subcommittee on 15 November.

But fuel crops may not be as exotic as Fithian believes. There already exist a tree that produces virtually pure diesel fuel and an alga that generates hydrogen gas. These or other plants may one day lead to an economic fuel crop.

Photosynthesis student Melvin Calvin has been a leading proponent of fuel trees ever since he was caught in a gas line during the oil crisis of 1973. The diesel-producing tree, a native of the Brazilian forest, grows only in tropical climates (*Science* 26 October). Calvin's leading candidate for a fuel crop species is the gopher plant, which makes an emulsion of hydrocarbons that is convertible to a high-grade petroleum fraction at an estimated cost of $40 a barrel.

Miami BG7 represents another possible approach to a fuel crop. It is a blue-green alga that produces hydrogen from sunlight and seawater. Hydrogen has many advantages as a fuel, including the unique cleanliness of a substance that on oxidation forms only water. The alga was discovered, after a deliberate 4-year search, by Akira Matsui of the University of Miami. Other microorganisms that synthesize hydrogen tend to reabsorb the gas, but Miami BG7 is a stable producer. Matsui is now constructing an apparatus for hydrogen production with support from the National Science Foundation. He hopes to attain a solar energy efficiency conversion of 2 percent, which compares favorably with that of many crops.

The new techniques of genetic engineering hold unlimited promise. Might it be possible to design a microorganism in which the energy derived from photosynthesis is used to produce hydrocarbons directly? "Futuristically, it certainly is a very desirable thing to do. I would not say it will never be possible. At this time our lack of knowledge about the genetics of photosynthesis is the major hurdle," notes Ananda Chakrabarty, the University of Illinois microbiologist whose application for a patent on a genetically engineered microorganism is now a test case before the U.S. Supreme Court.

Miami BG7 and the gopher plant are both species that would not compete with food crops for resources. The gopher plant grows on arid land, the alga on seawater. That the economics of fuel crops seem at present unfavorable should be no surprise; it has taken thousands of years of cultivation for almost all present crops to attain efficiency. Conventional plant breeding is one potent tool for improving yields; genetic engineering may provide others. Fuel-producing plant crops may be an exotic concept and yet may lie not so far off as the 21st century.—NICHOLAS WADE

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