thrash out "the most palatable options." There "has to be incentive within the university" to control such costs, she says. Just what those incentives might be, no one seems willing to say. Nonetheless, whatever measures are eventually deemed acceptable will need to be implemented uniformly throughout federal granting agencies, she believes.

Meanwhile, although the GAO's report will force HHS negotiators to keep better records of indirect cost rate changes, the pressure to do anything major to curb their growth is off. The scolding implicit in the report—as well as a requirement, enacted last year by Congress, that indirect costs be stipulated in NIH grant award notifications to researchers—could, however, act as a subtle curb on indirect cost growth.

—JEFFREY L. FOX

The Procrastinator's Power Source

The fuel cell beckons in the 1990's not just with cleanness and efficiency but as a way to put off coal and nuclear investments

The fuel cell is an admirable invention. It is an electric power generator that is perfectly clean and quiet, has no rotating parts at its core, and promises to be more efficient than any other fossil fuel plant on the market. It can produce electricity without contributing to acid rain and might make it possible to defer construction of new coal and nuclear plants for this century.

The manufacturers say it could become commercially viable by 1990, for large-scale models are expected to cost no more than coal or gas plants: $1200 to $1600 per kilowatt of installed cogeneration (heat and electric) power, or $850 per kilowatt for electric power only.

But the fuel cell has a couple of nagging problems, both of which seem to have an impact on image and morale. One is that the biggest demonstration plant, a trend setter built for Consolidated Edison of New York, has run afoul of a series of nuisance breakdowns and is now at least a year late for start-up. The other annoying fact of life for fuel cell builders is that their single biggest bankroller, the Department of Energy (DOE) keeps saying it intends to cut back its finances. This amounts to a nagging threat only, not a real one, because it has never been carried out.

DOE's objections are mainly ideological. The department views the first generation fuel cell (containing phosphoric acid) as an extremely efficient device for burning fossil and synthetic fuels but also as an overfed baby. For several years DOE has argued that the idea should leave the federal nest. It is time for private industry to pay for the "commercialization" of fuel cells, DOE says, and time for the government to withdraw its subsidy.

But the industry sees things differently, and Congress follows the industry's lead on this matter, not DOE's. This year, once again, the fuel cell program will be boosted to three times the size DOE would like, from DOE's budget request of $13.7 million to around $40 million. The House Science and Technology Committee marked up the new budget in April. One DOE staffer said afterwards, "The lobbyists, that is, the manufacturers, got essentially what they asked for. I don't know of anyone who thinks you should spend more than $40 million a year on fuel cells."

For several reasons, DOE's attempts to cut funds have failed 5 years running. The program is a flyspeck on DOE's $4 billion civilian budget, and it has some influential congressional backers from Pennsylvania and Connecticut, where the manufacturers—Westinghouse and the United Technologies Corporation (UTC)—are headquartered. Perhaps most important for its survival is its glittering promise. If the sponsors are correct, the fuel cell could become a glossy new electric technology in the 1990's, having an appeal like that of the nuclear reactor in the 1960's.

> It is time for private industry to pay for the "commercialization" of fuel cells, DOE says, and time for government to withdraw its subsidy.

The fuel cell has much to recommend it. Because its chief wastes are clean water and carbon dioxide, it is an environmental dream. It is quiet, unlike combustion or steam generators. However, as Westinghouse project manager Donald Newby points out, the plant does look something like a small refinery, and in urban settings it will have to be housed in sheds for camouflage. But it is the only system (other than solar panels) one can imagine building in a city today. Aside from cleanness, the important selling points are the speed with which it can be installed and its tremendous efficiency. The fuel cell is more productive than any other fossil system, even when running at low power. Conventional rotor systems lose efficiency as they lose speed. The heart of the fuel cell has no moving parts. It converts hydrogen and oxygen by an electrochemical process to electricity and water.

Westinghouse predicts that in the 1990's it will be able to install a 7.5 megawatt (MW) fuel cell plant and have it running within 2 years of an order, and additions will be available in 7.5 MW modules. This means that utilities that wish to expand by buying fuel cells will be able to avoid committing themselves to the enormous, decade-long construction projects that are wrecking their finances today. (These big plants come in sizes about 100 times larger than the Westinghouse fuel cell.) The new technology allows for less construction time, more flexibility, and greater control over cash flow. As one advocate says, it allows an electric utility to opt for a "strategic delay." Because of a deep uncertainty about the future, many utilities see this stalling option as a good thing, even if expensive.

There is another kind of generator that permits delay: the gas or diesel combustion turbine. Utilities are buying many of them at the moment, for the same reasons they may later want fuel cells. Turbines will remain cheaper to install than fuel cells by at least $600 per kilowatt.

According to Newby of Westinghouse, the fuel cell will have two clear advantages over the turbine in the 1990's. First, it will be available for purchase in smaller "bites"—7.5 MW each from Westinghouse and 11 MW each from UTC—as opposed to large bites of around 50 MW each for turbines. Second, the fuel cell consumes less fuel, converting natural gas to electricity with an efficiency of around 40 percent.

Turbines run at less than 30 percent and thus cost more to feed. When turbines are operated at less than full throttle, the efficiency drops further. Yet a fuel cell continues to produce at 40 percent even when operating at a sluggish one-third power. UTC is designing its small plants to recapture waste heat as well, so that these machines will have an overall efficiency of about 80 percent.

The fuel cell has other good qualities. It is adaptable and will run cleanly on a variety of fuels, including synthetic gas and methanol, potentially abundant coal products. One test shows that the system is even more efficient on methanol than on natural gas, running at an unprecedented 45 percent fuel-to-electricity conversion rate. Its unique environmental virtues mean that it can be placed in the midst of a busy neighborhood at the site where the power is to be used, or at a "clean" site where environmental standards are strict. This may bring about other efficiencies, such as less power lost in transmission and less building of power lines.

In addition, the gas utilities are developing a small fuel cell that could put them in direct competition with electric companies for customers. This "dinky" unit, as a competitor called it disparagingly, would be just large enough (40 kilowatts) to take care of a big laundry, a restaurant, or a small apartment complex. The economics are expected to be such that—at least at the time of installation—the gas company could provide electricity for the same price charged by the electric company. But the fuel cell would also produce abundant heat, essentially as a bonus.

In the last 8 years, federal taxpayers have invested over $250 million in the fuel cell, not counting money spent during the 1960's to develop the small machines used in the space program. The utilities and the manufacturers have spent roughly the same. What has the money bought?

William Podolny, vice president of UTC in charge of fuel cells, declines to discuss what he calls the private, "programmatic" details, but he does like to say that this is about the only new technology funded by DOE that has lived up to its promise. "This is probably the most successful program the DOE has ever run," he claims.

With help from the government, the Gas Research Institute, and the Electric Power Research Institute, UTC has developed two prototypes, the "dinky" model for natural gas companies described earlier, and another prototype 100 times bigger, for electric companies. These water-cooled, gas-fueled systems represent the closest representation of a commercial design yet made. Podolny seems to view them as a thorough success but not everyone sees them this way.

The flagship of UTC's line was to have been an electric plant built for New York City's Consolidated Edison (Con Ed) at the tip of Manhattan Island. Putting a good face on it, Podolny says the plant has proved "95 percent" of the points it was designed to prove. The problem is that the 5 percent of what it has not done includes a failure to produce electricity. Con Ed's project manager, Leonard Gelfond, has been struggling to bring the fully finished plant on line for over a year.

Podolny and Gelford stress three sources of trouble: the anxieties of the New York City Fire Department, the builders' inexperience with freezing temperatures, and UTC's ignorance about what happens to a fuel cell when stored for a long period. Because Con Ed was installing a brand new kind of power plant, and doing it right in the city, the local politicians shifted all responsibility for public safety onto the fire department. According to Podolny, the department dealt with the situation by requiring the plant to go through an "unorthodox" proof of safety, including a demanding water pressure test. As a result, the plumbing had to be modified and parts of the plant redesigned.

Con Ed found it impossible to remove all of the water from the system before winter. New heaters were installed. Then Con Ed underestimated the damage that would be done by the freezing weather. This led to unexpected delays, more modifications, adjustments, and leaks.

Finally, Con Ed and UTC discovered that these early cells had a built-in shelf life: the porosity of the materials used to contain the electrolyte (phosphoric acid) was such that the acid tended to migrate

The Fuel Cell: H_2 + O_2 + 150 Years

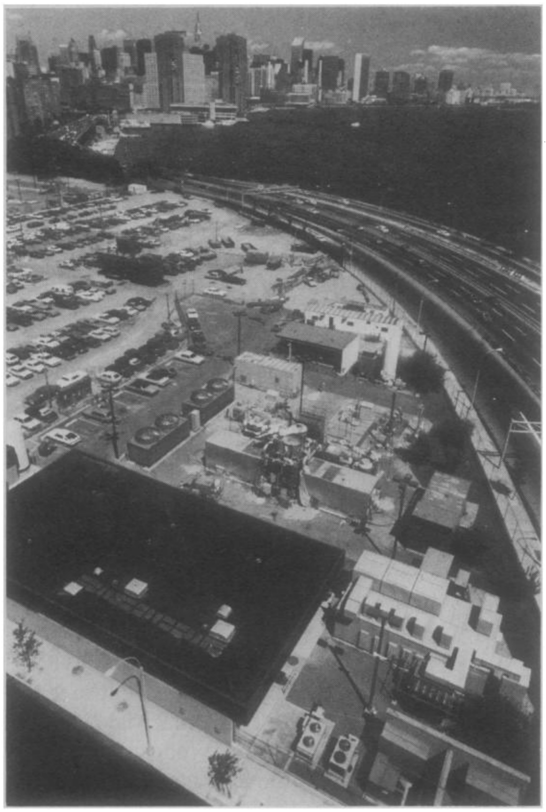
The fuel cell was invented in England in 1839 by Sir William Grove, who called it the "gaseous battery," to distinguish it from his other invention, the electric storage battery. Like the storage battery, the fuel cell combines substances to make electricity and chemical by-products. Unlike other batteries, the fuel cell does not consume its electrodes in this process but instead uses up gases (hydrogen and oxygen) fed continuously from outside the cell.

In the presence of an electrolyte such as phosphoric acid, the gases release electrons, generating heat and electric current, and then combine to make water as a by-product. The unique value of the technology is that it has no high-speed moving parts and can capture nearly all the energy generated by the oxidation of hydrogen. Commercial prototypes now in operation have sustained an efficiency of 80 percent. Conventional turbines capture only 30 percent of the energy released by burning fuel.

The technology lay fallow for many years until an engineer at Cambridge University, Francis T. Bacon, began working with it in the 1930's, eventually producing a 5000-watt cell in the 1950's. The fuel cell was adapted for use in U.S. space vehicles in the 1960's, providing electric power and drinking water for astronauts on Gemini V. In the early 1970's, American utilities became interested, spurred by the oil embargo. Federal developmental funding for power generators began to flow in earnest in the late 1970's ($21 million in 1977) and has kept flowing since then.

The first generation of commercial cells uses phosphoric acid as an electrolyte and will come in two versions: the water-cooled (United Technologies Corporation) and the air-cooled (Westinghouse). Existing models are fueled by natural gas, from which hydrogen is stripped, using steam generated by the cell itself. Oxygen is taken from the air.

The Department of Energy (DOE) would like to stop funding this commercial design, for the agency argues that it is far enough along for industry to support. But DOE is willing to put more money into advanced designs, the molten carbonate and solid-oxide fuel cells, which promise to be even more efficient than the phosphoric acid model.—**E.M.**



Manhattan's fuel cell

The largest fuel cell plant in the United States (4.8 megawatts) has been built for Con Ed in downtown New York. It is about a year late for start-up. A duplicate version in Tokyo has been running for a year.

away from the plates where it was needed to other parts of the cell where it was not. It is very difficult to remedy this failing in the existing plant, Podolny explains, but design changes have already been made for later models. Because of its limited life, the New York plant's tenure will be neither long nor productive.

A sister plant designed by UTC for the Tokyo Electric Power Company has been running intermittently for the last year, with satisfactory results. Podolny attributes the difference in performance to the "silly rigors" to which the New York machine was subjected and the simple fact that "when you do something the second time, you do it better." Tokyo benefited from New York's mistakes. Then, in addition, the cells shipped to Tokyo were of a new design that does not have the porosity problems of those in New York. Podolny says the New York plant has passed all the tests it should have passed, except for making electricity, which he hopes it will do in "a few weeks." The Japanese have proved that the system will achieve its promised efficiency, he says. Proving its durability is the next goal. "Running in New York will be very important for the human side of the project," Podolny says, "but not so important for authenticating the concept or the technology." That has been done, he claims.

UTC has completely redesigned the system in Tokyo and is planning its next venture, the 11 MW plant, which is to be the final commercial version. None has been sold as yet.

The smaller plants designed for gas utilities are being installed right now, and the early returns are checkered. Among the first four or five of the roughly 50 to be deployed, more are working properly than not. Perhaps the most successful, according to the Gas Research Institute, is one in Portland, Oregon, being run by the Northwest Natural Gas Company. It has logged over 3300 hours of successful operation. Others in Connecticut and Southern California have been running smoothly and continuously since last year. But another one in California and one in Maryland have been plagued with pump, valve, temperature, and electrical control problems. Podolny says these are routine developmental troubles, just the kind the field test was intended to discover. He expects it will be at least a year before any pattern of performance emerges.

Westinghouse joined the game late and wants to leap ahead by building a large prototype that will also serve as the first commerical plant. Its scale will be halfway between UTC's prototype and its commercial plant. The cells themselves will be air- rather than water-cooled. According to Newby, the first of these 7.5 MW plants will produce only electricity and will be installed for Southern California Edison in mid-1987. The second, producing both electricity and usable heat, will be installed for the Southern Santa Clara power company by early 1988. Westinghouse is choosing its test sites with some caution. Unlike UTC, it will not immediately venture into a freezing climate or an inner city.

The consensus of the research community is that fuel cells have reasonably good prospects for catching on by the late 1980's. Robert Fri, the former deputy director of the federal Energy Research and Development Administration, DOE's ancestor, is the chief executive for 56 electric utilities that have formed a fuel cell users' lobby in Washington. (Fri also heads his own Energy Transition Corporation, an investor in a controversial peat-to-methanol project in North Carolina.) Fri is confident about the technology but less certain about the economics surrounding it. The time has come, he says, when "the industry has to step forward. We're trying to get the utilities talking about actually buying some of these things." There is a good chance that contracts will be signed this year, he believes, because the Electric Power Research Institute recently offered to pay about half the nonrecurring cost of installing prototypes.

However, even if the technology were in perfect order, the uncertainties in the financial world make it hard to predict what will happen to the fuel cell. Electric rates are rising and customers are responding by using less power. This leads to a kind of economic implosion in which ever more expensive equipment must be financed by an ever more recalcitrant group of ratepayers. Furthermore, the margin of surplus generating capacity is quite large in every district in the United States. It is so large that the traditional keeper of these data—the North American Electric Reliability Council (NERC)—has been told by its member utilities not to give out such numbers any longer. A spokesman, Blaine Vincent, Jr., explains that some companies found media reports on excess generating capacity to be misleading, and for that reason they asked NERC to refrain from giving out such information. The policy became official 2 years ago. "We don't even calculate the numbers anymore," says Vincent.

Estimates of the average surplus generating capacity range from 30 to 50 percent. In a sense, this is encouraging for the fuel cell, for it means that utilities' new plants are likely to be small. But in another sense, it is not encouraging, for state regulatory boards may well insist that new power plants be not just small in scale but cheap to install.

—ELIOT MARSHALL