Higher Education publishes long series of articles by him. In addition, Lipset has been quoted and cited uncritically in such places as *Newsweek*, *Science*, and the Washington *Post*. This acceptance of Lipset's work may be justified, of course, but a number of sociologists, such as Raskin and Levy, question the meaning of survey data in general.

Even if this small protest against Lipset and Ladd's survey has no further consequences, the types of objections to the survey and the fact that mathematicians are the primary objectors are of interest in themselves. Levy notes that mathematicians are trained to be scrupulously careful about the way statements are phrased and are well aware of the fact that sophisticated statistical analyses cannot make up for biased data. Robert Wuthnow and James Beniger, two sociologists at Princeton who were trained in survey research, say Lang's criticisms are good for the profession. They believe there is a trend toward emphasizing sophisticiated analyses of data rather than toward formulating good questions. They hope that the protest led by Lang will help swing the pendulum in the other direction.

—GINA BARI KOLATA

Science in Europe/Britain Opting for U.S.–Style Reactors—Maybe

After an argument lasting for almost 13 years, Britain is tiptoeing toward a controversial decision in favor of purchasing Westinghouse-designed pressurized water reactors (PWR). A firm order for a PWR is unlikely until the early 1980's, but even the vague commitment to the system which the government is expected to announce within the next 2 weeks marks a radical and traumatic shift away from the British gas-cooled reactors which have so far been the mainstay of the nuclear program.

The commitment might have been stronger but for a last-ditch defense by the Energy Secretary, Mr. Tony Benn, backed by several Cabinet colleagues, who favored continued reliance on the advanced gas-cooled reactor (AGR) despite the enormous problems which have delayed the building of the first five AGR power stations. They were opposed by another group in Cabinet, including the Chancellor of the Exchequer Mr. Denis Healey, who favored a switch to the PWR, which has emerged in the past few years as the world's dominant reactor design.

At a meeting before Christmas the Cabinet was split, and Mr. Benn, as the minister directly responsible for the decision, was sent away to devise a compromise acceptable to all. The result is a plan which offers comfort to both sides: two final AGR's will be ordered, one for Scotland and one for England; and a commitment to the PWR is made which falls short of an actual order but is definite enough to allow safety and design studies of the system to go ahead with the prospects of an actual order in about 1982.

The prospects of the PWR gaining a foothold were denounced by Friends of the Earth, the most vocal and effective environmental group operating on the nuclear issue in Britain. In a letter to the Prime Minister, Friends of the Earth director Tom Burke and its leading theoretician, Amory B. Lovins, said there were compelling reasons why the government should not buy pressurized water reactors. They claim that the PWR has been sold around the world not on technical or economic merit but by a process of "mutual intoxication"; Westinghouse's "agressive use of loss leaders" persuaded France to abandon its home-grown reactors and U.S. promotional institutions persuaded buyers all over the world that the claimed advantages of the PWR were real. All vendors of light-water reactors suffered losses, Friends of the Earth said, adding that "the notion that British vendors new to the game could out-Westinghouse Westinghouse is preposterous—save as regards potential losses."

Dudgeon over Dungeness

The battle against the PWR is part environmentalism, part nationalism, and part reluctance to abandon a line of reactor development with more than a quarter century of work behind it. The argument began in 1965 when, in a famous and much disputed "assessment" which compared the AGR with the light water reactor, the Central Electricity Generating Board found the AGR a cheaper option. As a result the board placed what was probably its most disastrous contract ever, when it ordered an AGR at Dungeness, in Kent. More than 10 years later, the reactor is still incomplete, hundreds of millions of pounds over budget, and still some way from producing power.

By 1974 the central board was so disillusioned with the AGR that it went flat out for the PWR, but ran into a blizzard of environmental and safety objections. Another "assessment" was made, and came up with yet another answer, this time favoring the steam-generating heavy-water reactor (SGHWR), a British design which had never been built as a commercial plant, only as a 100 megawatt (electric) prototype. The SGHWR was chosen, anointed, and made ready for ordering; but the detailed costing showed it to be hopelessly uneconomical and by mid-1976 its chances were dead.

This long history of indecision—or rather of decisions made and then as quickly abandoned—has left the nuclear industry demoralized. It has spent the past few years trying to build the five AGR power stations on order. Two are now complete and functioning, though neither is up to full power and one suffered a breakdown in one of its reactors when seawater was inadvertently allowed to leak into a cooling circuit. The other three are still under construction. Each differs slightly from the others, which means that the nuclear industry has in fact been engaged in building five full-scale commercial prototypes simultaneously, not a recipe for an easy life.

This was the setting for yet another assessment, launched by Benn in October 1976 to compare AGR, PWR, and SGHWR. The comparison was made by the National Nuclear Corporation, which concluded that the SGHWR was the worst bet economically, the PWR the best, and the AGR lay somewhere between the two extremes. The assessment eliminated the SGHWR but rather than coming down clearly for either of the other two systems suggested that both should be built.

This conclusion owes as much to political calculation as to economic logic. Most of the industry strongly favors the

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PWR, but to show too much enthusiasm could have been counterproductive, as it was in 1974. This time the industry played a more careful game, designed to appease the AGR supporters while obtaining the clearest commitment to the PWR that was politically possible. An argument which carried weight with some sections of the industry is that orders for one or two AGR stations could be placed immediately, providing much needed work, while a PWR order would be delayed by the need to get clearance from the safety inspectorate and the planning authorities.

In any case, the immediate prize is less important than the long-term prospects for power station ordering through the 1980's and 1990's. In common with most industrial countries, Britain assumes that thermal nuclear plants will play a major role in energy supply toward the end of the century, and present projections suggest that by the year 2000 some £20,000 million will have been invested in such plants. Starting in the early 1980's, according to this plan, series ordering of nuclear plants will have to begin, and the PWR supporters have concentrated on making sure that they will be well placed to win those orders when the time comes. According to this view, the one or two immediate orders "lost" to the AGR matter less than the fact that the PWR will be designed, passed by the Nuclear Installations Inspectorate, and ready to build when the nuclear bonanza begins.

Benn and the AGR supporters are reasonably happy with the decision because it has at least delayed a firm PWR order for another few years—and the experience of British nuclear policy shows that that is time enough for several somersaults. Benn himself says he is skeptical that everything from the other side of the world is necessarily better, and muses about what would happen if some generic fault were to be discovered in the PWR. (His opponents say this fate is much more likely to befall the AGR, and point out that the term PWR now covers a multitude of different designs, so that any fault that did show up would be unlikely to affect them all.) "Should we throw away 27 years of experience of gas-cooled systems?" Benn asks. "Yes," say his opponents, pointing out that France had the courage to abandon her gas-cooled reactors in the 1960's in favor of light-water reactors and is now building and exporting light-water reactors successfully.

Whatever the merits of the argument on either side, the British nuclear experience provides a perfect example of the difficulty of pursuing an independent path in face of American influence and technological skill. If Westinghouse had developed the AGR and Britain the PWR, would the contest have had the same result? That question can perhaps be left to historians. What is becoming clear is that there are now only two generic types of thermal reactor surviving: the light-water reactors, and the Canadian CANDU system. The luxury of diversity has proved too expensive to enjoy.—NIGEL HAWKES

Erratum: In the 3 February issue (p. 508), the proposed budget increase for the National Institutes of Health was incorrectly given as $4.2 million. The correct figure is $42 million.

Erratum: In the report by F. B. Krasne and S. H. Lee entitled "Regenerating afferents establish synapses with a target neuron that lacks its cell body," there were two errors: in reference (*2*) the papers by R. D. Clark, *J. Comp. Neurol.* **170**, 253 and 267 were published in 1976, not 1977; and in reference (*3*), the paper by F. B. Krasne and S. H. Lee, *Brain Res.* **121**, 43 was published in 1977, not 1976.

RESEARCH NEWS

Tar Sands: A New Fuels Industry Takes Shape

The huge tar sands deposits of northeastern Alberta are covered by as much as 6 meters of muskeg, a semifloating mass of partially decayed vegetation. In summer, land vehicles are swallowed up by the morass. In winter, the muskeg freezes so solidly that the earth beneath is virtually inaccessible. To reach the tar sands, it is necessary to begin draining water from the muskeg at least 2 years before any digging is planned; the remaining vegetation must then be removed while it is frozen. Despite these difficulties, muskeg removal is one of the simpler problems which confront companies that attempt to exploit tar sands. The more severe problems include the inhospitable weather and the exceptional difficulties of handling the tar sands.

These problems have delayed exploitation of tar sands, but they have certainly not halted it. One by one, these problems have been overcome until, today, tar sands are the most promising near term alternative source of fossil fuels. One company has been mining tar sands and extracting oil from them for 10 years, the last 2 years at a profit. A second, much larger plant is now about 95 percent complete, and a third plant and a possible fourth are on the drawing board. More than 20 companies, furthermore, have operated pilot projects for in situ recovery of oil from the tar sands. About 16 of these pilot projects are still in operation and one commercial facility may be under construction within 2 years.

This is the last of three articles exploring unconventional approaches to fossil fuels.

The greatest immediate beneficiary of this activity will be Canada, where most of the work is taking place. Canada has the largest confirmed deposits of tar sands in the world—the equivalent of more than 900 billion barrels of oil, not counting some large, unexplored deposits in the Northwest Territories. By the 1990's, production of oil from tar sands could approach 1 million barrels per day (bpd), or nearly a third of Canada's domestic requirements. Little or none of this oil will reach the United States, but the experience gained in Canada will have application here and elsewhere. The United States has the equivalent of more than 30 billion barrels of oil embedded in tar sands, 90 percent of it in Utah. The equivalent of some 200 billion barrels of oil is known to lie in tar sands along the north bank of the Orinoco River in Venezuela, and some geologists speculate that there may be as much as 2 trillion barrels. Smaller deposits are scattered throughout the world, and it is thought that a substantial deposit exists in the Soviet Union.

Tar sands, also known as oil sands and heavy oil, are a mixture of 84 to 88 percent sand and mineral-rich clays, 4 percent water, and 8 to 12 percent bitumen. Bitumen is a dense, sticky, semisolid that is about 83 percent carbon. At room temperature, it does not flow and is heavier than water; at higher temperatures, it flows freely and floats on water.

Tar sands can be divided roughly into three categories, depending on their vis-

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