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-

0036-8075/78/0217-0756$01.00/0