

The clinopyroxene mineral spodumene ( $\text{LiAlSi}_2\text{O}_6$ ) is the most important lithium mineral. It occurs particularly in a small number of large unzoned pegmatites in North America. Lepidolite mica ( $\text{KLi}_2\text{Al}(\text{Si}_4\text{O}_{10})(\text{F},\text{OH})_2$ ), eucryptite ( $\text{LiAlSiO}_4$ ), petalite ( $\text{LiAlSi}_3\text{O}_{10}$ ) and the phosphate amblygonite ( $\text{LiAl}(\text{PO}_4)(\text{F},\text{OH})$ ) are the only other lithium minerals of economic importance. These minerals tend to occur as replacements in the central zones of smaller, zoned pegmatites which occur in Southern Africa and elsewhere.

Lithium also occurs concentrated in certain surface and underground brines. For example, the underground brines at Silver Peak, Nevada contain about 300 ppm Li, the Great Salt Lake, Utah contains about 60 ppm Li and the Salton Sea geothermal underground brine in California contains about 210 ppm Li. The Silver Peak brine is the largest known single reserve of lithium in the world and contains identified possible reserves of 2 million tonnes lithium metal. Lithium supply has recently become dominated by production from brines, and is likely to remain so in the future.

Unlike sodium and potassium, lithium does not occur in economically significant concentrations in marine evaporites because the concentration of lithium in sea water is low (about 0.2 ppm) and the solubilities of its salts are high.

For comparison with the estimates of cumulative Western world demand

for lithium by the year 2030 given in Table 1, information on resources of lithium in economically workable concentrations (ore and brine deposits) is summarised in Table 2. This suggests that Western world reserves of lithium which are identified at the present time are about 5–7 million tonnes of metal. The amount of lithium in undiscovered deposits would add a considerable, but unknown, amount to this figure. In the past there has not been a large demand for lithium and, as a result, exploration for new deposits has not been particularly rigorous or extensive. The likelihood of discovering new large lithium ore deposits, therefore, is reasonably strong.

The figure of 5–7 million tonnes for identified Western world lithium reserves is comparable to the estimate of 3–12 million tonnes for Western world cumulative lithium demand up to the year 2030. Providing that exploration for new lithium-enriched brines and ore deposits is as successful as would seem probable, it can be concluded that the Western world's resources of lithium are capable of sustaining a programme for the generation of power by controlled thermonuclear fusion. However, the fact that the figures for cumulative demand and presently known sources are similar suggests that there is no cause for the complacency shown in recent assessments (see, for example, Hubbert, M. K., *Scientific American*, 225, 61–70; 1971, and Proceedings of the Fourth

International Conference on the peaceful uses of atomic energy (Geneva) 7, 467 (UN and IAEA, Geneva; 1972)). This is particularly the case for the European countries which possess no presently identified significant lithium resources. This fact suggests a necessity for exploration in Europe if dependence on imports is to be minimised.

Four other conclusions may be drawn:

- Non-fusion demand for lithium is likely to be greater than or equal to fusion demand.
- Demand for lithium is certain to rise, and, therefore, lithium production will have to increase quite considerably. If, for example, the total growth rate in demand were maintained as high as 10% over the next fifty-five years, as over the past fifty-five years, production capacity would have to increase by a factor of about 200.
- A large amount of liquid lithium metal must be tied up in the blanket of each new fusion plant. This represents a sudden, large increased demand equal to one-quarter of current annual consumption. This capital demand for lithium has invariably been overlooked when assessing the availability of lithium supplies for nuclear fusion.
- The future demand for lithium will be relatively inelastic since the important new uses being developed are all based upon specific and unique properties of the metal. There are, therefore, no known lithium substitutes which could significantly depress projected growth figures. □

## UK ENERGY

# A question of balance

*The widely heralded public debate on the national energy strategy opens next Tuesday, one week after publication of the Department of Energy's report singling out the coal and nuclear industries as crucial factors in the country's energy future. Allan Piper reports*

ON the premise that the best way of planning a forward march is to stand well back and view the terrain ahead, Britain's Energy Secretary, Mr Anthony Wedgwood Benn, has started mapping out the nation's energy strategy with his feet in the right place. Consider the position. The country is caught in industrial recession, and inflation is at an uncomfortable level. The demand for energy has slumped. The coal industry, committed to an ambitious expansion plan after years in decline, is producing more fuel than the country can burn, and is staggering beneath the expensive burden of record stockpiles.

The nuclear programme, years behind target and way over budget, is beset by niggling technological teething troubles, and faces powerful environmentalist opposition. Additional competitive pressures stem from the rosy opportunity for national energy sufficiency offered by North Sea oil and gas. But both must be carried through to the 1990s, when North Sea reserves will be running down and high world prices make energy imports undesirable.

It all means that when Mr Benn moves onwards from next Tuesday he will be juggling as he goes. Clutching the medium-term North Sea opportunities firmly in one hand, and manipulating nuclear options with the other, he must all the while keep the coal industry safely off the ground. Neither can he afford to drop any of the five realistic alternative possibilities—solar, wave, wind, tidal and geothermal power. Fusion is regarded as too distant. Thus, by the time the energy gap looms, the whole act must be sufficiently well coordinated to allow just one firm

step across.

Events of the past fortnight have shown that the Energy Secretary will be jostled from every side. In the build up to the coming energy forum, organisations as diverse as the coal industry, the UK Atomic Energy Authority (UKAEA) and the Confederation of British Industry (CBI) on the one hand, and Friends of the Earth (FOE), consumer groups, and trades unions on the other, have deluged his department with a welter of initial positioning statements. They indicate clearly that few of the 120 participants involved will fail to adopt attitudes largely of self interest.

### ACORD report

The simultaneous publication of a long-awaited Department of Energy (DEN) report on energy research and development (R&D) strategy may help, however, to keep the energy secretary on a firm footing. Its recommendations, while arguably as predictable as those of the various positioning papers, are at least based on wider considerations. Put together by a working group of the Advisory Council on Research and

Development (ACORD), the report identifies coal and nuclear technologies, together with energy conservation, as outstanding long term R&D priorities. At the same time, it calls for the priority development of technologies to optimise the medium-term benefits of North Sea resources.

The report's conclusions are not based on the conventional method of forecasting distant energy demands, by extrapolating historical trends into the future. Instead, the ACORD working group has considered seven possible "scenarios" and suggested strategies considered necessary to meet the challenges of each one. The scenarios range from a continuation of present social, economic and technical trends until 2025, through a pattern of low worldwide economic growth, to one of high worldwide growth.

The picture that emerges suggests that whichever scenario prevails Britain is unlikely to get by comfortably without well developed coal and nuclear technologies. Even with a continuation of present trends, the report finds, the UK's installed nuclear capacity must rise to almost 25 times the existing level of 5,000 MW by 2010 if substantial energy imports are to be avoided. This is so even though the coal industry should by then have reached its expansion target of 150 million tonnes a year (25 million tonnes above present levels), since the likely decline of North Sea reserves will shift coal's greatest economic contribution to its potential as a source of gas, liquid fuels, and other hydrocarbons.

If the analyses are correct—and ACORD must feel reasonably assured of a wide response to the report's invitation for alternative scenarios from independent interests—the renewed emphasis on the crucial importance of the coal and nuclear options raises Mr Benn's greatest problem. As Walter Marshall, Chairman of ACORD and Chief Scientist at the DEN, put it last week, there is a danger that complacency in the face of adequate medium term North Sea supplies could delay major investment decisions until it is too late to retrieve the situation.

#### Coal

The coal industry's own solution to this thorny problem became available last week with the publication of a positioning statement for the energy debate from the National Coal Board (NCB) and coal workers' unions. It shows that the industry wants the Central Electricity Generating Board (CEGB), coal's biggest single customer, to review forward orders for coal fired or dual-fired generating plant. But as the CEGB Chairman, Arthur Hawkins, pointed out when the issue was first raised in February, his utility can

hardly pull the plug out of the North Sea market, nor the rug from under the nuclear industry, which between them should eventually supply the constant CEGB demand baseload.

Moreover, the CEGB has already given some ground to help relieve the coal industry's position. Under a payment deferral scheme it has agreed to hold coal stocks in excess of normal reserves—put at 50 days supply—so that it is now stockpiling nearly 17 million of the nation's total 31 million tonnes, a figure expected to have reached 20 million tonnes by the end of September. To offset this increase, at least in part, the CEGB will take advantage of the recent slight improvement in coal's economic competitiveness against imported oil to burn 70 million tonnes this year, an improvement of 3 million tonnes over last year's level. If the short-term investment hurdle can be cleared, the coal industry will argue, the way is open towards the targets for the future. Estimated UK reserves are put at around 45,000 million tonnes, enough to last for several centuries at current extraction rates, and the industry claims that future demand will be more than matched by production capacity.

Thus, it will be reasoned, a national energy strategy based on coal imports would be misguided. During the 1980s indigenous coal could resolve the burden of imported oil costs, and even, with the introduction of fluidised bed combustion and an increased uptake by the home steel industry, Britain could become a coal exporter as early as 1985. As to the less immediate future, the industry, like ACORD, foresees its greatest long-term economic potential in gasification and liquefaction techniques. NCB R&D spending into these fields and into integrated and remote mining systems is planned at £12 millions for this year.

#### Nuclear

The nuclear industry stands just as firmly behind its own position. Stressing its "excellent" safety record, the UKAEA will argue that because coal's greatest potential lies where it does there should be no major national commitment to its short term use as a generating fuel, and that the nuclear option provides the only realistic long term alternative that can be available in time and in sufficient quantity. To meet future demands, the UKAEA says, an independent R&D effort should be coordinated within the industry. The UKAEA also calls for some stability in the forward ordering pattern for power stations, while the Nuclear Power Company claims that orders must run at more than 1,000 MW a year if a rundown in construction and design work is to be avoided.



Walter Marshall: Britain's energy guru?

Recent developments on the nuclear front suggest that the CEGB might view this plea for increased nuclear capacity more favourably than it might have done even a few weeks back, in spite of its continuing pessimism over future levels of electricity demand. Last month it was announced that the troublesome Advanced Gas Cooled Reactor at Hinkley Point in Somerset is now producing Britain's cheapest electricity, at about one eighth of the cost of the most efficient fossil-fuelled station at Ratcliffe-on-Soar. Almost simultaneously, the Hinkley Point reactor obtained the long-overdue go-ahead to run up to heavy loads, and it should soon have reached 85% (about 475 MW) of designed operational output. The second reactor at Hinkley Point is also expected to come on stream soon, and it seems possible that the AGR at Hunterston on the Scottish coast could produce usable power before the winter.

Furthermore, Dr Marshall is ready to present a report on nuclear pressure vessels to the Chief Nuclear Inspector, concluding that they could safely operate in Britain without major design changes. While the finding provides an immediate fillip only to Westinghouse Electric, the US company responsible for the design and sales of the Pressurised Water Reactor, it will nonetheless indirectly boost national confidence in nuclear technology.

The CEGB may also be impressed by the ACORD analysis of the future role of nuclear power, as may Mr Benn. This indicates primarily that whichever future economic scenario is considered, an enlarged nuclear capacity seems virtually essential. The only non-nuclear scenario, that excluding nuclear plant beyond the 1980s, throws up a gloomy picture of economic growth restricted to "unacceptably low levels".

#### Fast Breeder

Should these favourable developments

lead to the general acceptance of plans for an enlarged nuclear technology, the vexed question of long-term uranium availability will certainly raise calls for the early introduction of the Fast Breeder Reactor (FBR), which uses uranium 60 times more efficiently than conventional reactors. The ACORD report does not consider the possible effects of an international moratorium on the FBR, but the oversight is something that the increasingly respectable Friends of the Earth, averse to the FBR in particular rather than nuclear reactors in general, may seek to amend. A government decision on whether to move from the prototype to the demonstration stage with the FBR is to be given in the autumn, and it is still possible that Britain could forego further independent development, opting instead to buy herself into other national programmes at a later stage. The CEGB is known to be engaged independently in ongoing negotiations with the French-German-Italian consortium involved in the Superphénix FBR.

### Conservation

On conservation, there is general accord, with calls from both the nuclear and coal industries for tightly controlled exploitation of North Sea resources. This would not only stretch oil and natural gas reserves, but should also provide the coal and nuclear programmes with a chance to regain a firm grip on the generating market. British Gas, however, will tell the Energy Secretary next week that such measures are largely unnecessary, suggesting that further gas finds could close the predicted energy gap completely.

But, more broadly, ACORD has underlined that because of low energy conservation factors, which average around 40%, every unit of power conserved represents more than two units of primary energy. This is a proportion which may become critical in the energy climate of the late 1980s, and last week Dr Marshall announced that the portion of the DEN R&D budget set aside for conservation—included, incidentally, with the allocation for

alternative resources—is to be expanded by over £7 millions to £22 millions within the next four years.

For its part, the CBI will call for increased consumer influence in energy affairs, a theme also taken up by the National Consumer Council. On the other side of the political fence most of the unions can be expected to underline the already published call of the Amalgamated Union of Engineering Workers for complete nationalisation of North Sea resources. The AUEW also decries any extension of oil and gas use into electricity generation.

So it all begins on Tuesday with the shouting. Some may doubtless regard it as fitting that the Energy Secretary should launch his juggling act under a glare of national publicity. Others more charitably feel that if the right attitudes win through the event could be just the start of an effective exercise in "open government". Whatever the outcome of his eclectic approach one thing is abundantly clear: Mr Benn will need a cool head and steady eye to strike the necessary balance. □

## NUCLEAR TRADE

# Heavy water allegations

*The controversy over international trade in nuclear technology and materials continues in the United States. Colin Norman reports from Washington on the latest development*

THE long-simmering debate over nuclear export policies took an important new twist in Washington last week. Senator Abraham Ribicoff, chairman of the Senate Government Operations Committee, charged in a public statement that heavy water supplied by the United States to India in 1956 played a key role in India's nuclear explosives programme. Ribicoff, an outspoken critic of present US nuclear export controls, sharply criticised the State Department for failing to place strict safeguards on the heavy water sale, and he also condemned the department for failing to establish whether India used the material to produce its explosive device.

Though the State Department and the Energy Research and Development Administration (ERDA) have challenged the chief point in Ribicoff's analysis, his statement is likely to play an important part in public hearings on whether or not the United States should sell some 40,000 pounds of enriched uranium to India to fuel a large nuclear power plant near Bombay. The hearings have been postponed from June 2 to July 20.

According to Ribicoff, the United States sold India 21 tons of heavy water as a moderator for the Canadian-supplied CIRUS reactor, the source of plutonium for India's nuclear explosive. The material was supplied under an agreement that it be used only for peaceful purposes, and Indian officials have claimed that the explosive device detonated in May 1974 was produced without the need to resort to imported material.

The Indian assertion rests on the argument that heavy water in the CIRUS reactor degrades by about 10% a year, so that all the US-supplied material would have been used up and replaced by India's own heavy water (produced in a German-supplied plant) well before its explosives programme was begun. That argument was accepted by State Department and ERDA officials, who reiterated last week that they have no reason to doubt its validity. But Ribicoff claims that loss of heavy water in the reactor is much less than 10% a year, and that a substantial amount of US-supplied material was in the reactor while it was being used to manufacture plutonium.

Whatever the validity of Ribicoff's claims, the suspicion that US-supplied heavy water helped India to produce nuclear explosives is likely to be influential in next month's hearings on

the sale of reactor fuel to India. Though the reactor in question, the Tarapur Atomic Reactor, is operated under safeguards administered by the International Atomic Energy Agency (IAEA), critics of the proposed sale have argued that India should accept additional safeguards on its nuclear facilities before final approval is given to the deal.

The IAEA safeguards are designed to prevent plutonium produced in the Tarapur reactor from being used to manufacture explosives. If the United States refuses to supply fuel for the reactor, however, it is conceivable that India could claim that since its nuclear agreement with the United States had been broken, safeguards on the plutonium no longer apply. According to Ribicoff, the Indian Government may be using that possibility as a "subtle form of blackmail" to ensure that the fuel sale is approved, and he argued that the United States "should seek to end the present uncomfortable and uncertain situation by exercising an option we have to buy back the plutonium generated by these power reactors".

At least one of Ribicoff's claims is, however, incorrect. He argued that the United States "never publicly acknowledged exporting the heavy water to India", but ironically, the Atomic Energy Commission trumpeted the 1956 agreement in a press release since it was one of the first nuclear deals under President Eisenhower's Atoms for Peace Programme. □