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ARTICLES

POWER INDUSTRY

Britain's New Energy Sources

by George F. Ray, London

In 1966 the total inland fuel consumption of the United Kingdom amounted to the equivalent of 297 million tons of coal; of that quantity, 174 million tons were coal, some 11 million tons (in coal equivalent) was the contribution of various other sources such as hydro-electricity, nuclear power and imported natural gas; the rest was consumed in the form of various petroleum products.¹

In 1960, the share of coal in total British primary fuel consumption was 75 per cent; in 1966, only six years later, that share declined to around 60 per cent of total usage. Even more dramatic has been the fall of coal's share in the final consumption (i.e. excluding coal used in the power industries): direct use of coal in 1966 was just over 20 per cent of all energy consumed by the final users.

The import bill on liquid fuel amounted, in 1966, to £ 625 million, including transport costs. In the last ten years, from 1956 to 1966, the volume of liquid fuel imports rose 8 per cent a year, which means doubling in nine years.

Similar trends are not unknown in other countries of Western Europe; the special significance in Britain of the trend away from coal and towards petroleum fuels stems from the fact that the ever growing imports present a great burden to the balance of payments which have been in a precarious position for some time.

New energy sources are naturally very important in any country; for the above reason they attract additional attention in the case of Britain.

The main purpose of this note is to describe the present position, and to analyse the future prospects and the implications of the foreseeable future developments, of two relatively new sources of energy: nuclear power and natural gas from the North Sea. The latter is the result of entirely novel developments; nuclear power is not 'new' in the same sense but its application on a significant scale begins only now to have some impact on the energy economy in Britain.

(For the first time in 1966 more than one tenth of all electricity generated came from nuclear sources.)

Nuclear Power Generation

Total nuclear power generating capacity in the whole world is estimated to have been about 6,800 Megawatt around the end of 1966; of that, 3,450 MW are in Britain (apart from new stations in construction). The USA is second, with 1,170 MW, followed by the USSR (900 MW), Italy (610 MW) and France (370 MW). Thus, the United Kingdom has, by the end of 1966, built more capacity for the peaceful use of nuclear energy—and has actually generated more electricity by nuclear power—than all other countries in the world together. This situation is likely to change rapidly: nuclear power stations are being built on a large scale in the USA and also in various countries of Europe.

In the course of the development of the nuclear generation industry, innumerable obstacles had to be overcome. The fundamental problem was: how to make efficient use of the enormous energy released by nuclear fission. Since this energy takes three forms: the heat created which has to be harnessed, the radioactivity whose harmful effects are to be eliminated, and the additional neutrons which sustain the reaction—the problems involved were manifold and in some respects very different from those of the conventional power generation. A large number of entirely new processes had to be devised and mastered; these required new materials and new types of instruments. Metallurgical, civil and electronic engineering, insulation and other problems had to be solved. Furthermore, economics came in since nuclear power generation was supposed to break even with conventional coal or oil firing methods in terms of generating costs.

It is the latter aspect which is the main concern of the following sections of the present report. Generating cost is obviously one of the most important considerations when creating a view of the potentialities of any new source of power.

¹ The conversion is based on the method used by the British Ministry of Power, i. e. 1 ton of liquid fuel equals 1.7 tons of coal.

Britain has now two sets of nuclear programmes: the first for the five years ending 1970, and the second for the following five years. Both of them have a target of 5,000 MW nuclear capacity in each of these five-year periods. The first nuclear power programme will be complete by 1969 when Britain will have a total nuclear capacity of about 5,000 MW. That first batch of 5,000 MW will, however, consist of stations of very different design, performance and cost characteristics.

The first step in design was the Calder Hall type magnox station. Following the successful experiments at Calder Hall, Berkeley and Bradwell were the first two power stations built. These oldest stations produce power at a cost of 1.27d and 1.11d per kilowatt-hour. The latest and most economical station now under construction, at Wylfa in Anglesey, is expected to produce electricity at a cost of 0.64d per kWh. Within five years generating costs were halved by improved design. But that is certainly not the last word. It is estimated that costs will be still lower from the AGR (Advanced Gas-cooled Reactor) type stations. The AGR is supposed to replace the magnox type as the basic design of the second generation of nuclear stations. The very first of these stations (Dungeness B), for which detailed tenders were analysed in July 1965, actually brought revolutionary changes in the

attitude towards nuclear generation. The estimates showed that generating costs there will be 0.46d per kWh, some 10 per cent cheaper than from any coal or oil-fired station in the UK.

The main indicators of the cost comparison are given below. Dungeness B is compared there with the data referring to the Cottam coal-fired station, the most up-to-date in this country.

Comparison of the Main Indicators¹

	Unit	Dungeness B nuclear	Cottam coal
Fuel cost	d/therm	1.1	3.8
Thermal efficiency	per cent	41.5	37
Assumed life	years	20	30
Capital costs ²	£/kW	92	43
Annual capital charges, fuel and other costs when operating in merit order ³	£/kW p. a.	12.5	10.7
Effect on operating cost of remaining plant on system ⁴	£/kW p. a.	-4.7	-1.7
Effective average annual cost to the system	£/kW p. a.	7.8	9.0
Load factor (average over life)	per cent	75	38

¹ There is no simple way of comparing these figures with calculations made in other countries (such as Germany) because of differences in the methods of calculation.

² Capital cost includes capitalised value of interest during construction and in the case of nuclear stations the net cost of the initial fuel loading.

³ Power stations are operated in "merit order" which means that the (usually oldest) stations with the highest generation cost are not brought into operation until winter peak load demand requires support from these stations; otherwise these are in the cold reserve.

⁴ This is the influence of the coming into operation of any new power station; new capacity permits even less reliance on the least efficient stations. The different load factor provides the main explanation of the difference between the saving thus achieved in nuclear and coal-fired stations

Implications on Production Costs

Capital costs have come down enormously since the beginning of the nuclear power station building programme: those required for the first two stations were around 150-160 £/kW whereas—as shown in the above table—by 1965 they were already around 90 £/kW. A further remark should be made in connection with the above comparison and that concerns the assumed life. The Central Electricity Generating Board assumes a 30 year life for conventional, coal or oil-fired, power stations; in the case of nuclear stations, however, they have decided on an expectation of 20 years only; this figure was selected some ten years ago, when of course nobody had any experience of large-scale nuclear generation. By now some experience has become available and this was fairly favourable in several respects. The early stations generated more electricity than originally envisaged; they stood up well to wear and tear, and they are likely to be able to provide power in unchanged conditions considerably longer than the assumed 20 years. It is uncertain as yet whether 30, or perhaps even

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more, years will be the right figure to take as a basis to amortising capital charges; but it will certainly be more than 20 years—and that improves significantly the comparison with coal and oil-fired stations in favour of nuclear power.

Something similar applies to the assumed load factor. This is likely to be in practice much more than 75 per cent. In both instances the yardsticks chosen reflect caution felt about the durability of these new plants, and also the feeling that it was possible that some might have to shut down relatively early in life because of some unforeseen mishap that would have been readily repairable in a conventional plant, but not in a nuclear one. However, nuclear operators have shown themselves adept at carrying out difficult maintenance operations inside reactors by remote-controlled means and such fears are receding.

It must be remembered that all components have been designed to have a life of 30 years at 85 per cent load factor. Therefore a bolder, but perhaps more realistic, view of the future generating cost may not be out of place, and is given below:

Generating Cost Comparison

Station	Fuel	Capacity, MW	Cost, d/kWh
Dungeness B			
(a) 20 years, 75 % load factor	nuclear	1,200	0.46
(b) 30 years, 85 % load factor	nuclear	1,200	0.38
Cottam	coal	2,000	
Drax	coal	4,000	0.52
Pembroke			
(a) with present tax on fuel oil	oil	2,000	0.52
(b) without tax	oil	2,000	0.41

All the above stations are under construction; they embody the newest technology in nuclear, coal and oil-fired power generation.

The comparable figures clearly demonstrate the cost advantage of nuclear generation—although it is quite clear that the technological advance, with all its implications on production costs, can be expected to be much faster in the case of nuclear than in conventional generation.

Another important factor to be considered is the price of the fuel used in nuclear reactors: uranium and plutonium. The world's resources are plentiful but the sources of relatively cheap accessible uranium and plutonium are limited indeed. The key to the question is the development of the fast breeder reactor, since it needs much less uranium, and in the short term may be able to afford high prices for plutonium since in the longer term it will cheapen it through breeding.

Nuclear capacity by 1969-70 will reach the target of the first programme: 5,000 MW. The second programme may be altered but even if not increased will secure another 5,000 MW by 1975. 10,000 MW by

1975 will be something like one sixth or one seventh of the installed generating capacity in Britain; however, since these up-to-date stations will carry base load and operate at a very high load factor, nuclear contribution to the country's power supply will be much bigger than suggested by the nuclear share in total capacity.

Gas Turbines

Although perhaps some would not consider gas turbines as a new source of energy, its application in the British power industry certainly is a novelty and deserves a brief mention.

The problems of power supply are much the same in any country. Two of them are: how to meet exceptional peak demand; and how to secure a base for restarting sections of the system in the event of wholesale shutdowns. The British electricity authorities believe that the gas turbine goes a long way in providing the solution.

It is now standard practice to install a gas turbine with each 500 MW set. These turbines are essentially aircraft-type jet engines (Rolls-Royce Avon turbo-jets); their rating is 17 to 25 MW. They burn distillate oil and are coupled to an expansion turbine driving a generator. Their primary function is to improve the reliability of the system; the gas turbines provide an alternative source of power for the electric motors and the other auxiliary plant essential for the continuous operation of the main unit. One of their main advantages is the rapid start and quick running up to full load. They also make a useful contribution towards meeting peak demands.

Gas turbines were introduced in 1962 as generators in their own right as well. These jet sets (in units of 55 MW and 70 MW) are sited in existing power stations and their sole purpose is to supply power in time of peak demand; in that form they give useful support to the main units and secure an additional margin of security in winter peaks. Experience has shown that it is well worth carrying the relatively high running costs of the gas-turbines; but because of the high operating costs their annual load factor is not more than 2-3 per cent.

Natural Gas

It was probably the discovery of the huge natural gas field on the Dutch side of the North Sea which gave the idea of searching for gas on the British side as well. The enterprising spirit of the initiators has been well rewarded. We are still far from the full exploration of that area but the findings so far have been very promising indeed. Within the very near future natural gas will start to flow in sizable quantities. It is almost certain that in 2-3 years' time—around 1970—the daily flow of natural gas will be anything upwards from 2 million cubic feet a day; it may be 3 million, or more.

This welcome find of natural gas coincides with the revival of the gas industry. Until about 1964-5 the gas industry was in a state of stagnation. Demand did not rise appreciably and, generally speaking, gas was considered as a fuel belonging to an earlier generation. A few years ago, however, the gas industry succeeded in turning that outdated image into one of a progressive and attractive fuel. Oil gasification began to replace conventional coal carbonisation at a rapid speed and reduced production costs; the expansion of oil refining secured another relatively cheap source of supply: that of refinery tail gases which were taken over by gasworks for distribution; and finally, the Gas Council started to import natural gas from Algeria in frozen form, by specially designed ships.

These significant changes on the supply side ran parallel with a change of attitudes on the consumers' side; this particularly refers to household consumption. Rising standards of living aroused a desire for better heated homes and for comfortable heating methods, replacing the archaic system of heating houses by open coal fires. Central heating came to the fore, for which gas was a convenient medium; in recent years gas has made an impressive headway in space heating, whether central or not. Since 1963/64 demand for gas has been rising at an average rate of almost 9 per cent; the gas industry is now expecting an even higher rate of increase in demand for gas until 1972: about 12 per cent a year.

Many questions connected with natural gas are undecided as yet; among others, the price the Gas Council will pay for the forthcoming large quantities of natural gas. (One contract has been settled—but refers to a limited quantity only, and was signed at a time when hopes for natural gas were much lower than now.) According to present plans, some 1,250 miles of gas pipeline will have to be built for the distribution of the natural gas coming from the North Sea. That gas has a much higher calorific content than ordinary town gas; therefore appliances will have to be converted for the use of the new type gas, and at the same time the old-type gas enriched, or the natural gas reformed to bring it into line with the lower heating value level of town gas.

Natural gas will, of course, not be a preserve of the private consumer. It will provide ideal fuel for a number of industries (for example, the cement, brick, pottery, glass industries, metallurgy, etc.); it could be used at power stations, and it will be a welcome basic material for the petrochemical industry (it is, among others, the cheapest source of chemical fertilisers).

The allocation of natural gas will almost certainly not be left to free market forces alone, but will be influenced by Government policy.

At the present time it is highly speculative to be more accurate concerning the implications of natural gas and its effect on the British economy. Its quantity is uncertain, the timing of regular large supplies is uncertain as well. Some consequences, however, can already be tentatively foreseen. If by 1970 a flow of natural gas of the order of three million cubic feet a day can be established, this would replace 39 million tons of coal. It is unlikely, however, that the entire quantity of the available natural gas will be used at the cost of coal. It will be used as basic material for the chemical industry, and it will replace petroleum as well.

To assess the changes more firmly—though just for the sake of illustration—we start from the hypothesis that the quantity used for chemical purposes will be small, and that the newcomer in the energy field will replace coal and oil in equal proportion. That would mean a further fall in demand for coal to the extent of 18-19 million tons a year. At the same time, petroleum consumption will be 10-11 million tons less than it would otherwise have been. The latter will be a direct saving on the import bill of the order of about £ 70 million cif, valued at 1965 prices. (The saving in balance of payments terms is of course considerably different.)

The Implications for Coal

Welcome as these new sources of energy are from many aspects, their development cannot avoid having serious consequences concerning the future of coal. Once the basis of the industrial revolution in Britain, and until recently the main source of its energy supplies, coal has already lost appreciably its previous importance. That loss does not only mean a relative decline, or a smaller share in the energy market, but an absolute fall as well. Even without new sources of energy the continuation of recent trends—i.e. large scale substitution of oil for coal—would have resulted in a gradually contracting demand for coal. The new sources of energy will unavoidably lead to an accelerated fall in coal's share in Britain's energy supplies. In 1966 inland use of coal was 174 million tons; as soon as 1970 it is likely to be not much more than around 150 million tons.

Every contraction is painful if it affects a well established industry; it is even more painful when it touches on the social and human problems, perhaps unique to the coalmining industry, which are already well known in other coal producing countries of Western Europe. Such questions often have to be faced in the course of technical advance and major structural changes; their solution is costly and it must be approached with a great deal of sympathy, tact and goodwill in order to keep to the possible minimum the human problems of those involved.