The Fissile Society

Energy, Electricity and the Nuclear Option

Walter C. Patterson

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Earth Resources Research

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Walt Patterson**,** Amersham, April 1977.

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Assuming, then, that we are capable of learning as much from Hiroshima as our forefathers learned from Magdeburg, we may look forward to a period, not indeed of peace, but of limited and only partially ruinous warfare. During that period it may be assumed that nuclear energy will be harnessed to industrial uses. The result, pretty obviously, will be a series of economic and social changes unprecedented in rapidity and completeness. All the existing patterns of human life will be disrupted and new patterns will have to be improvised to conform with the nonhuman fact of atomic power. Procrustes in modern dress, the nuclear scientist will prepare the bed on which mankind must lie; and if mankind doesn't fit - well, that will be just too bad for mankind. There will have to be some stretchings and a bit of amputation - the same sort of stretching and amputations as have been going on ever since applied science really got into its stride, only this time they will be a good deal more drastic than the past. These far from painless operations will be directed by highly centralized totalitarian governments. Inevitably so; for the immediate future is likely to resemble the immediate past, and in the immediate past rapid technological changes, taking place in a mass-producing economy and among a population predominantly propertyless, have always tended to produce economic and social confusion. To deal with confusion, power has been centralized and government control increased. It is probable that all the world's governments will be more or less completely totalitarian even before the harnessing of atomic energy; that they will be totalitarian during and after the harnessing seems almost certain. Only a large-scale popular movement toward decentralization and self-help can arrest the present tendency toward statism. At present there is no sign that such a movement will take place.

Aldous Huxley,

Foreword (1946) to

Brave New World

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1 Introduction: conventional wisdom

The future is electric. So, at least, say energy planners everywhere. The arguments advanced by official planners in Britain are much like those advanced in other countries:

Fossil fuels are going to run out; in any case they should be reserved for use as chemical feedstocks.

Dependence on imported petroleum makes a country dangerously vulnerable.

Energy demand will continue to rise, and must be met.

The only way to prevent the opening of an "energy gap" between demand and supply is to proceed with the development of nuclear energy.

An increasing proportion of energy will be delivered as electricity; an increasing proportion of this electricity will be produced from nuclear energy; and an increasing proportion of nuclear energy will be produced by plutonium-fueled fast breeder reactors.

The rate at which these various developments will occur is still a matter for discussion; but they are widely regarded as inevitable. If for any reason they fail to take place, or are prevented from doing so, the consequence - say the planners - will be drastic changes in lifestyle, possibly leading to social breakdown.

Official acceptance of such counsel is of very recent vintage. It dates essentially from late 1973. The Organization of Petroleum Exporting Countries (OPEC), with selective interruption of international petroleum commerce and quadrupling of prices, caught energy planners utterly unprepared. Suddenly the industrialized countries realized that their ever-increasing imports of low-priced oil had placed their economies in jeopardy. Until this time planners had regarded price as the dominant criterion, and emphasized energy sources of lowest cost. Abruptly, after the shocks of late 1973, "security of supply" took precedence. "Energy independence" became a catchphrase. Energy conservation became respectable. Countries looked with renewed favour on their indigenous energy supplies, even when these had hitherto seemed unduly costly compared to oil. "Energy policy" became an everyday concept, although in practice it remained elusive.

Above all, there burst forth a surge of enthusiasm for nuclear energy. It was the province of the leading industrialized countries. It had been waiting in the wings for two decades, its economics in question, while oil sold at $3 a barrel. Suddenly oil at $12 a barrel made nuclear energy look much more appetizing. Nuclear energy, according to its proponents, was cleaner, safer and cheaper than coal, more dependable than imported oil, and more abundant than natural gas. In their view its advent could not have come at a more propitious time. Nuclear energy would save the world from the energy gap, and help everyone everywhere to live better electrically.

The argument was - and is - tidy. But it omits significant details, and involves a number of debatable assumptions. Planners know, or have a good idea of, the limits on future use of coal, oil and natural gas. They have ample historical data on rates of discovery, extraction and technological development, and on problems of politics, economics and environment. They can say with some conviction that it will be impossible to expand production of coal beyond a certain level within a certain time; that the capital cost of bringing offshore oil ashore will remain high and may increase, and that accessible supplies of natural gas are unlikely to last indefinitely. They know that it will therefore be extremely difficult to sustain fossil fuel supplies at the level required to fulfil the demand they anticipate: hence their enthusiasm for nuclear energy. However, it may just be that - whereas they know the limits on supplies of fossil fuels - they have as yet only a tenuous idea of the limits on supplies of nuclear energy. Is the grass really greener on the nuclear side of the fence? Or are appearances deceptive?

Uncertainties abound. One of the major consequences of 1973 was the demolition of the erstwhile foundations of energy forecasting. Planners are still picking through the ruins, trying to cobble together a persuasive replacement. They cannot henceforth ignore that, just as forecasts influence policy, so policy influences forecasts; in particular policy can influence demand as well as supply. The "energy gap" postulated has two sides, both amenable to adjustment to keep the gap from opening. Throughout the 1950s and 1960s world petroleum prices were absurdly low, natural gas was cheap and the real price of electricity was falling. Under the economic influence of such energy prices, and with other criteria in abeyance, industrialized countries built up an infrastructure - buildings, transport systems, industrial processes - which is lavishly extravagant with energy. Now the ground rules have changed: different criteria apply. "Lifestyle" is a vague term, impossible to define. But lifestyles everywhere have been undergoing accelerating changes, for good or ill; such changes seem unlikely to slow down. What is at issue is the direction they will take. How will lifestyles change in the absence of abundant nuclear energy? How will they change in its presence? For change they assuredly will, nuclear energy or no nuclear energy. Planners tend to assume that the changes entailed by the absence of nuclear energy will be more severe and disruptive than those entailed by its presence. The evidence does not necessarily support the assumption.

In essence, the rapid expansion of nuclear electricity supply is perceived as the only way to press on with the pattern of changes which have taken place in the last 30 years in the industrialized countries. Whether this rapid expansion is in fact possible under any circumstances is at least debatable. The historical performance of civil nuclear technology is far from reassuring, likewise its economics. Be that as it may, many planners consider nuclear electricity the key to the future. For this reason it is important to identify the characteristics and trends associated with nuclear electricity, and examine how they interact with the social, economic and political system. Nuclear electricity seems to dictate certain patterns of planning, finance, employment and social organization. There will, to be sure, be other factors involved. Nevertheless, nuclear electricity offers a paradigm for one of two alternative directions of social and economic development, which may soon become mutually exclusive. Either direction is presently available. Neither should be taken by default.

2 Electricity, the energy user

As energy policy has become a public issue, it has become commonplace to talk of "energy consumption". But energy is never consumed, merely used. All processes - physical, chemical, biological, whether or not they involve human participation - are driven by the conversion of energy from one form to another. The total amount of energy involved is the same after conversion as it was before. But, whether or not the process has accomplished something "useful", the energy emerges from it "used". The net quality of the energy is invariably diminished. It is now less useful than it was - less well organized, perhaps, or cooler. It cannot be used again to drive a similar process.

Human beings have learned to use energy - that is, to control and direct energy conversion - for an astonishing variety of human purposes. Some require that the energy supplied be of high quality: for instance running an electric motor, or smelting metal from ore. Others require only that the energy supplied be of comparatively low quality: for instance domestic space and water heating. Sources of high quality energy include sunlight - by far the most important source of energy for the whole earth - and materials in which the energy of sunlight has been chemically stored, including wood, coal, oil and natural gas. The energy thus stored can be released in a chemical reaction - "combustion", that is, burning - to produce heat at high temperature, a high quality form of energy. Within the last three decades we have also learned how to produce high temperature heat from certain heavy metals, particularly uranium, by bringing about a "nuclear chain reaction" in the metal. A material from which useful energy can be derived is called a "fuel". Until this energy is desired the fuel can be stored.

High quality energy can also be produced by promoting lower quality energy. However, the quality thus added to one unit of energy must be taken from another. For every unit of energy whose quality is raised, at least one unit must have its quality lowered. The collective net quality of all the energy involved will be lower after the process than before. But a fraction of the energy will now be of higher quality, which may make the process useful. One of the commonest energy conversion processes of this kind is the generation of electricity from heat. Electricity is a very highly organized, high quality form of energy; its quality is even higher than that of the heat produced by burning coal. Accordingly, for every unit of electricity produced by burning coal, perhaps two units of disorganized low temperature heat will also be produced - the left-over energy whose quality has been transferred into the unit of electricity. This left-over energy is less useful than the electricity, and indeed is often simply discharged into the surroundings as "waste heat".

Of course, whether energy is "useful" depends on whether anyone wants to use it. It has become customary to refer to the "efficiency" of an energy conversion process, as a measure of how much of the original energy emerges in a useful form. If three units of coal combustion energy are converted into one unit of electricity and two units of unused heat, the efficiency of the conversion process is said to be one-third, or (more usually) 33 per cent. The word "efficiency", however, is often misused. All too often important stages in the process from initial energy to final use are omitted from the calculation of the efficiency claimed for a particular process. In any case, if efficiency depends - as by this definition it does - on the perceived usefulness of the output energy, it is to that extent a rather arbitrary concept. It should be used with caution, and viewed with scepticism. (There is now coming into use a more rigorous definition of "efficiency" which is worth keeping in mind. For any energy conversion process there is an absolute minimum loss of quality, if the process is carried out under unattainably ideal conditions - for instance infinitely slowly. Any actual conversion process will be less than ideal - for instance it will take place at a perceptible rate. Accordingly, more quality will be lost than the ideal minimum. The efficiency of an actual process can be described by comparing the actual loss of quality to the ideal minimum. Physicists call this the "Second Law Efficiency". By this definition of efficiency most of the energy conversion processes we use are less than 1 per cent efficient, some of them very much less. There is accordingly a great deal of room for real improvement.)

Electricity is a very high quality form of energy. However, despite official usage to the contrary, electricity is not a fuel. Except in trivial quantities electricity cannot be stored. If electricity is to be used, it must be generated continuously from some other form of energy, in precisely the quantity and quality required for use. It is therefore reasonable to consider electricity as essentially a way of delivering other forms of energy to their end use. If electricity is to be used on a small scale - for instance in an electric torch - the necessity for a precise instantaneous match between the electricity supplied and the electricity used poses no problem. On a larger scale, however, this essential characteristic becomes increasingly challenging. On the scale of present-day electricity supply and use the impossibility of storing electricity becomes a key determinant of technology and economics. Thus far, to be sure, it has largely been taken for granted by policy makers. But its implications are far-reaching and fundamental.

The first large-scale electricity supply systems consisted of a "generating station" or "power station", a transmission system to carry electricity in quantity, a distribution system to deliver it to customers, and a group of "loads" - light bulbs, electric motors et cetera - to convert the electricity into other forms of immediately useful energy. (The energy ultimately used is rarely in the form of electricity itself; it is usually heat, light or mechanical motion.) Electricity supply systems still consist of the same components; but their scale and proportions have undergone some significant changes.

The heart of a power station is a unit called an "alternator", which when set into rotary motion generates electricity. The alternator and its motive power are called a "generating set", or just a "set". An internal combustion engine, petrol or (more commonly) diesel, may be used to turn the shaft of the alternator. The energy of falling water can be made to turn a sophisticated water wheel called a "water turbine". The output from an alternator turned by a water turbine is called "hydroelectricity". A "gas turbine" is like a stationary jet engine; natural gas, fuel gas or high quality fuel oil is burnt to produce hot combustion gas, which expands through an array of fan blades to turn a shaft. The combustion gas from a gas turbine emerges from the turbine exhaust at a temperature still usefully high, a feature of increasing interest.

Most common of all, however, especially in the UK, is the "steam turbine". The heat from burning coal or oil or (occasionally) natural gas, or from a nuclear chain reaction, is used to boil water and produce steam. The steam then expands through the fan blades of the steam turbine, turning a shaft. The steam may still be vapour when it emerges from the output end of the turbine; alternatively it may emerge into a chamber where it comes into contact with piping full of cold water, and condenses. If the steam is condensed to water its volume decreases dramatically, producing a partial vacuum in the chamber. As a result the pressure drop through the turbine is greater, and the shaft is powered more effectively. On the other hand, if the steam is not condensed it may still be usefully hot when it emerges, at least for applications not requiring very high quality energy. Steam at a useful temperature may also be tapped off part way through the turbine if desired. The choice of turbine depends on whether or not the output heat is perceived as useful.

When electricity is generated by means of a condensing turbine, perhaps one-third of the original energy from the fuel is converted into electricity, and sent out through the transmission lines to customers. The remaining two-thirds of the fuel energy, now of very low quality, is collected in the water in the pipes of the condenser. This condenser cooling water may simply carry the low quality energy into a nearby waterway, making it somewhat warmer. Alternatively, the condenser cooling water may be allowed to trickle down through a "cooling tower", passing the low quality energy to the air rising through the slightly warmed tower.

An electricity system, like water supply or main drainage, is a natural monopoly. It does not make economic sense to connect a custorner to more than one electricity supplier. If an electricity system has only a single power station its customers have to expect interruption of the supply if the station has to be shut down for any reason. However, the philosophy of electricity suppliers for decades has been to guarantee supply 24 hours a day every day of the year. Customers have acquired the same attitude. Even brief interruptions are regarded as serious lapses, by both supplier and customers. As many essential services become electrified the philosophy of continuous guaranteed supply is powerfully reinforced. Even brief interruptions can now endanger life; longer interruptions can do so on a dismayingly large scale. Accordingly, most electricity supply systems have not just one but a number of power stations. The major exception to this pattern - and it is an important exception - is that of industries which generate their own electricity with on-site facilities. Such industries must make appropriate provision for periods when an on-site station is not operating. However, on a multi-station system, if an individual station must be shut down, other stations on the system can take over and provide the desired supply.

To cope with necessary maintenance, unplanned "outages" (shutdowns) of equipment and other contingencies, an electricity system must have a certain amount of redundancy - extra generating capacity, standby plant of various kinds, alternative routings for transmission, alternative supplies of fuel et cetera. Such redundancy is of course expensive. But without it the system is precariously vulnerable. A large-scale electricity system is a delicate organism, and its stability requires sophisticated control. There must always be an instantaneous match between electricity supplied and electricity used. Sudden increases or decreases in load tend to upset the balance, as do sudden increases or - more often - decreases in generated supply. If a large generating set should suddenly fail, another generating set of equivalent output must be at once - within minutes, if not seconds - connected into the system to take over. A portion of the unused generating capacity is kept ticking over as a "spinning reserve", which can be called upon for swift increments of output if necessary. Otherwise, either by operation of protective devices like "circuit breakers" or by actual damage to components, the result may be progressive breakdown of the entire supply system.

The inability to store electricity, and the commitment to guarantee continuous supply impose stringent constraints on an electricity supply system and on its decision makers. Electricity users switch their loads on and off, turn knobs and dials and alter their collective use continually, not only from moment to moment but throughout the day and throughout the year. Within any 24 hour period the total instantaneous load on the system will vary by a factor of two or more, within a given year the variation may be as much as a factor of five. The operators of the system must therefore arrange for "load-following": varying the collective output of the generating stations to match the instantaneous load on the system. Changing the output is easier for some kinds of station than for others. Hydroelectric and gas turbine stations can be started up and stopped very quickly. Coal- or oil-fired steam turbine stations are less easy to start up and shut down, and their output is less easy to adjust. Nuclear stations are designed to operate ideally at a constant output; repeated variations of temperature, pressure and other operating conditions may significantly shorten the useful life of a nuclear station.

Because of the diurnal and annual variation in the load on the system, some of the system's generating stations will not be required to operate continuously, and some will be required only for a small fraction of an operating year. It has become customary to rank stations according to the roles they play in the generating programme. Those stations whose generating costs are lowest are operated as continuously as possible at their maximum output throughout the year, supplying the "base load" below which electricity use rarely falls. As it happens, stations whose generating costs are low are usually those whose capital cost is high; it is in any case desirable that they operate as close as possible to their maximum output, since capital carrying charges have to be paid whether or not a station is operating. Nuclear stations, whose capital cost per unit output is significantly larger than that of any other type of station, but whose generating costs are low, have to date always been operated as base load stations. (If the proportion of nuclear generating capacity on an electricity supply system increases above the base load, of course, some nuclear stations will have to operate at less than full capacity.) Large modern coal and oil-fired stations also operate mainly as base load stations. Older fossil-fuel stations are brought on stream as the system load increases. The "load factor" of a station is the amount of electricity it produces over a period, compared to the amount it could produce operating throughout the period at maximum capacity.

To meet the brief peak load, which may involve sudden rapid surges as customers all over the system switch on appliances almost simultaneously, stations with swift response are required. For this purpose the ideal design now available is hydroelectric, whose turbines can be spun up to working output in under a minute. A variation on this design is so-called "pumped storage". A pumped storage hydroelectric station is equipped with reversible water turbines. During the slack period of load on the system, electricity from base load stations turns these turbines as pumps, to raise water from a lower reservoir to a higher. Then, when the system load reaches its peak, the water is allowed to flow downhill again, turning the turbines as generators. (Before the peak is reached, a modest downhill flow of water can keep the turbines turning as a "spinning reserve" able to supply power in seconds if necessary.) About two-thirds of the pumping energy can be retrieved as generated electricity. Stations powered by gas turbines also serve to meet peak demand. They burn comparatively expensive fuel, but only for short periods, and their capital costs per unit output are comparatively low.

These various categories of station are brought into service throughout the day and throughout the year as system load requires, according to a so-called "merit order" of increasing marginal cost of operation. Despite the intention to keep an adequate "plant margin" of assorted generating capacity in excess of anticipated load, problems of various kinds - construction delays, difficult maintenance, interruption of fuel supply, labour trouble et cetera - sometimes leave the system unable to meet peak load. At such times the operators resort first to reduction of the operating pressure or "voltage" of the system. If this does not sufficiently reduce the load on the system it may then be necessary to "shed load": to switch off supply to some customers.

Electricity is delivered from power stations to customers in two stages. The power stations are linked together by high pressure - that is, "high voltage" "transmission lines" along which large quantities of "bulk electricity" can be carried with relatively small losses of energy. Transmission lines are strung from tall "pylons" or (at much greater cost) buried in underground trenches. The network of transmission lines is called a "grid". At major load centres electricity is taken from the grid. Its voltage is reduced by "transformers" at "substations" and it is then fed through distribution networks of cables to which customers are connected. Some large users of electricity are connected directly to the grid.

The move from single-station electricity systems to the establishment of a grid has accompanied a fundamental change in the philosophy of electricity supply. In the early days emphasis was laid on the distinctive utility of electricity for specialized applications: for instance lighting, public transport and precision industrial and domestic motive power. It was assumed that the generation of this specialized form of energy was warranted by the advantages that it offered, despite its comparatively high cost. It was acknowledged that to supply one unit of electricity required the burning of, for example, some four times the equivalent amount of coal; three-quarters of the energy of the coal was lost in the process of generation and transmission of electricity. But for the peculiar virtues of electricity the price was one which could be justified.

Since the advent of the grid, however, a new perspective has taken shape. The supply of grid electricity has come to be viewed as a cleaner and more flexible way of distributing to customers the energy of primary fuel, particularly coal. Very large base load coal-fired stations have been built at the mouths of collieries, to burn the coal virtually as soon as it emerges from underground. Electricity has been called "coal by wire". But very little emphasis has been laid on the fact that "coal by wire" involves using three-quarters of the energy of the coal merely to convert and deliver it. Similarly large base load oil-fired stations have likewise been built, in some instances adjoining petroleum refineries, to burn the residual heavy oil from the refineries. But no reference has been made to "oil by wire", perhaps because other convenient ways of distributing oil already exist, none of them involving the loss of three-quarters of the initial energy content. Nor is nuclear electricity referred to as "fission by wire", partly because thus far at least the generation of base load electricity has been almost the only civil application of nuclear energy. Grid electricity seems likely to be for the foreseeable future the only energy supply technology for which nuclear energy can be adapted. Three-quarters of the nuclear heat is of course lost in the process; but it is nevertheless common to refer to nuclear electricity as "primary electricity", by analogy with hydroelectricity in which any losses are inherent in the conversion technology. On the other hand the nuclear industry regularly describes one unit of nuclear electricity as equivalent to four units of coal. The philosophical inconsistency has given rise to a certain amount of controversy. The nuclear industry has thus, for instance, been able to claim to supply 4 per cent of Britain's energy rather than the 1 per cent which it has actually delivered.

As emphasis has shifted from single power stations to the grid, the specialization of stations into different types and purposes has been accompanied by rapid increase in unit size of sets and stations. To build a single set twice as large does not double the amount of material required, or the capital cost; the larger set may also have a fractionally higher efficiency for the conversion of steam energy to electricity. One large set does not require twice as many personnel as two sets half the size. The pursuit of such "economies of scale" - the bigger the cheaper, per unit output - has been a dominant characteristic of electricity supply technology, especially in the last two decades. This governing principle has led to larger sets in larger stations, feeding a more extensive grid at higher voltages. But larger units take longer to build; outages are more troublesome and expensive; and large size tends to mean inflexibility, in planning, in construction and in operation. The alleged economies of scale of recent years may well have been diseconomies. Nevertheless, current plans presume further increase in scale of grid electricity systems and of their unit increments.

For a wide and important range of uses, electricity is much the most suitable form of energy. It does not follow, however, that this electricity is best supplied from a grid fed by base load generating stations. For applications requiring only low quality energy - such as low temperature heat - grid electricity is a roundabout and wasteful route to follow. Despite its virtues, electricity, far from being a "source" of energy, is one of its most extravagant users.

3 The electricity establishment

As Chapter 2 describes, an electricity supply system is a natural monopoly. In the early days of public electricity supply, each power station and its umbilical customers constituted a separate technological unit, with definite but limited mutual dependence. When electricity systems were small in scale and geographical extent, and changes could be carried out within modest time scales, the constraints on decision making were not unlike those of any other commercial enterprise. Gradually, however, the small separate systems grew and merged. Responsibilities became ever more centralized. In the century since public electricity supply was first established, the growth of the system, and of its importance, has drastically altered the context within which decisions must be taken. Over the years the social and economic impact of centralized electricity supply has come to represent an apt paradigm for many of the key choices and decisions now confronting society.

To understand how such a situation has arisen, and to appreciate the problems, options and decisions now under consideration, it is valuable to survey the development of public electricity supply in Britain. The first public supply of electricity anywhere in the world from steam power stations came into service in Britain in 1882 - four systems, at Holborn Viaduct, Brighton, Hastings and Eastbourne. In the same year Parliament passed the Electric Lighting Act 1882, the first legislation anywhere in the world dealing with public electricity supply. Although the Act was intended to lay down the terms by which private entrepreneurs would offer to supply electricity to private customers, it included provisions for local authorities to take over the assets of electricity companies after 21 years. From this time onwards legislation regarding electricity supply in Britain always envisaged public ownership of the supply industry. Even at that early stage it was apparent that the inherently monopolistic nature of electricity supply required a measure of government involvement on behalf of users who could not take their business elsewhere.

At the outset legislation did not, it is true, precisely endorse monopoly supply. However, one of the relevant considerations of the Act of 1882 was the granting of monopoly licences covering defined areas, and determining how to establish boundaries between them. By the late 1880s there were so many competing applications for licences in the London area that a Board of Trade inquiry had to be held. It recommended that a local authority could allow competing companies within its boundaries, but no more than two, and that of these two one should supply "alternating current" and the other "direct current". Boundaries between supply systems continued to present problems, especially when they did not coincide with local authority boundaries.

The first large-scale use of electricity was in any case for street lighting, itself a public service paid for through the rates. Indoor lighting for private premises then became an expanding market for the suppliers. Electric traction for mass transport, industrial motive power, and a burgeoning variety of household appliances added to the growing demand for electricity throughout the 1890s and thenceforth.

In 1898 a Joint Select Committee of both Houses of Parliament under Viscount Cross made a series of sweeping recommendations, eventually to be embodied in the Electric Lighting Act 1909. This Act is still, nearly 70 years later, the leading Act governing public electricity supply in Britain. The Cross committee recommended that powers be granted for compulsory purchase of sites for generating stations, even outside the area of supply; and that supply systems might become much larger in scale and extent, to supply "electricity in bulk". From 1900 onwards Acts of Parliament were passed setting up "Power Companies" which were given "rights in perpetuity to supply electricity to authorized undertakings and for industrial and manufacturing purposes over wide areas, and to give general supplies in parts of the areas not already covered by distribution rights" *(Electricity Supply in Great Britain,* The Electricity Council, 1973).

In 1909 the Electric Lighting Act authorized local authorities and companies also to supply electricity in bulk, and to form joint committees for the purpose. This Act also required that the Board of Trade give consent prior to the erection of generating stations; this proviso, as subsequently amended, is still in effect. The Act further prohibited "unauthorized undertakers" from competing with "statutory undertakers" - those suppliers with areas of supply defined by permits. The natural monopoly structure of the electricity supply system continued to ramify, in an administrative equilibrium between entrepreneurs and government.

In 1918 three high-level committees reported, recommending reorganization of the electricity supply industry into larger geographical units, using larger generating units, administered on a regional basis under the central supervision of a "Board of Electricity Commissioners". In 1919 the first attempt was made to set up such a central authority, the Electricity Commissioners, to carry out regional reorganization. But the Commissioners were handicapped by lack of compulsory powers. After several years of further effort, the Electricity (Supply) Act 1926 brought about the first really effective national coordination of electricity supply. At the end of the year 1925-26 the total installed generating capacity was 3,917 megawatts, supplying 1,655,000 customers.

This Act set up the Central Electricity Board, a public corporation, "to concentrate the generation of electricity in a limited number of 'Selected' stations, and to interconnect these stations, linking up the existing regional system into a national 'Grid', by the erection of a high tension [high voltage] main transmission system". The CEB was to purchase electricity from the "Selected" stations, and sell it to local undertakings for distribution to local customers. In 1935 another Electricity (Supply) Act gave the CEB the power to arrange with owners of "non-selected" stations to operate such stations under CEB direction, to meet peak loads and serve as standby capacity. But in 1936 a committee appointed by the Ministry of Transport, to consider electricity distribution,"recommended legislation to give adequate compulsory power for reorganization based on the absorption by the larger and more efficient undertakings of the smaller and less efficient". They further suggested "that provision should be made in the new schemes to be prepared for the possibility of ultimate public ownership of all undertakings, including those not then subject to purchase by local authorities". In 1938 the CEB established a National Control at Bankside power station in London, to operate the grid as a single interconnected system. From late 1939 onwards it has been operated as a single unit.

In 1943 legislation was passed setting up the North of Scotland Hydro-Electric Board (NoSHEB). Perhaps the most interesting feature of the relevant Act was the so-called "social clause", directing the Board to have regard to the social implications of its activities, and give them due weight alongside the more traditional economic considerations. The social role of electricity supply continued to intensify, but was not given such explicit attention further south.

After World War II, under the new Labour government, Parliament passed the Electricity Act 1947, "nationalizing" - taking into public ownership - all 560 existing electricity undertakings in England, Wales and southern Scotland. Under the aegis of the Ministry of Fuel and Power a new body, the British Electricity Authority, was made responsible for generation and bulk transmission of electricity, and for central coordination and policy. Fourteen Area Boards were made responsible for distribution and retail sale of electricity to customers. However, as the earlier history attests, the 1947 Act was not a drastic shift of responsibility to the public sector, but rather the culmination of a long historical trend. It is at least arguable that the significance of the 1947 Act was not so much "nationalization" as "centralization", of policy and planning, at last accompanied by the necessary power to execute decisions once taken.

The 1947 Act asserted in its opening sentence that the duty of the British Electricity Authority was "to develop and maintain an efficient, coordinated and economical system of electricity supply for all parts of Great Britain except the North of Scotland District". This definition of statutory duty has remained the guiding principle of the electricity supply organizations for three decades. The installed capacity of the system (excluding NoSHEB) at the end of 1947-48 was 11,680 megawatts, supplying 10,801,000 customers.

The Electricity Reorganization (Scotland) Act 1954 set up a separate South of Scotland Electricity Board, under the Secretary of State for Scotland. The British Electricity Authority was renamed the Central Electricity Authority, supplying England and Wales. Three years later the Electricity Act 1957 brought about a further internal reallocation of responsibilities. The increasing size of the system, and the increasing scale of the technology it employed, prompted a more explicit definition of the areas of decision assigned to different constituent bodies of the industry. The 1957 Act created the Central Electricity Generating Board, as it still exists 20 years later. The CEGB was to take over the duty originally laid down in the 1947 Act, now slightly rephrased, "to develop and maintain an efficient coordinated and economical supply of electricity in bulk for all parts of England and Wales". This "bulk" supply was to be transmitted to the 12 Area Boards for distribution to customers. At the end of 1957-58 the CEGB had a total installed capacity of 24,315 megawatts, supplying 14,867,000 customers.

The major innovation of the 1957 Act was the creation of the Electricity Council, whose duty was "to advise the Minister on questions affecting the electricity supply industry", and to cooperate in the overall duty laid down above. In effect the Electricity Council assumed overall responsibility for policy and planning, and for presenting the the industry's case to the government. The Electricity Council was to consist of a Chairman with two deputies, up to three Ministerial appointees, the Chairman and up to two others from the CEGB, and the Chairmen of the Area Boards - a Council in the fullest sense of the term.

The 1947 and 1957 Acts taken together laid down the statutory, administrative and organizational framework within which the electricity supply system in England and Wales has operated for the two ensuing decades. The 1943 and 1954 Acts did the same for Scotland. Subsequent chapters will discuss how this framework has affected essential areas of policy, in particular planning and finance. The growth in economic significance of the electricity supply industry has been accompanied by increasing impact on other sectors of the economy, and indeed on society as a whole. The financial criteria and performance of the industry will be discussed in Chapter 6. The central electricity authorities, especially the CEGB, have become virtual monopoly buyers of large-scale electrical engineering plant within Britain, and also exercise a powerful influence on boiler-making and construction industries; this influence will be examined more closely in Chapters 5 and 7. The electricity supply industry has found itself in a curious symbiosis with the coal industry, a love-hate relationship which remains a source of discord, sometimes bitter. The upsurge in the British gas industry, occasioned by the discovery of offshore natural gas, had led to pointed competition between gas and electricity, which seems likely to intensify; see Chapter 5. The relationship between the electricity and oil industries is less immediate, although some of the largest generating stations in Britain have been built near re-fineries to burn low-grade fuel oil left over from the refining process. Of course the international price of energy - and therefore the economic context of electricity - has been and will continue to be dominated by the world price for petroleum; to that extent the electricity industry must reckon with oil. The nuclear industry, as discussed in the next chapter, relies entirely on the electricity industry as a customer for nuclear engineering and services - an umbilical link which is becoming increasingly strained. The electricity supply industry also involves, directly and indirectly, a considerable number of trades unions, whose members are affected by policy decisions regarding energy in general and electricity in particular. This aspect of the scene will be examined more closely in Chapter 7.

The first annual report of the CEGB, published in 1959, opens with an intriguing statement: "The Board believe that if they are to remain efficient and thereby make the best use of the powers and assets entrusted to them by the nation, they must practise decentralization. At the same time, they must not relinquish an undue measure of their responsibilities for the Board's policies and their execution. In the re-organization they have carried through since the beginning of 1958, they have endeavoured to strike the correct balance between central responsibility and executive freedom of action." It was a striking objective, an attempt to turn back on itself the long-standing trend toward centralization. But it turned out to be at best a holding action; in the field of fundamental policy the trend toward centralization continued, especially as the industry began to find itself increasingly beleaguered. The first annual report exuded good will and eagerness to cooperate. But in succeeding reports the cheerful insouciance and bonhomie gradually faded. The increasing scale of power stations and transmission lines made them very difficult to conceal, and brought mounting opposition from amenity organizations. Two severe winters overtook the system's capacity, and power cuts in January 1963 drew the fury of politicians and public. The industry, plunging into an orgy of orders to augment capacity, overdid it. By mid-1968 it was necessary for the Minister of Power to convene a Committee "to inquire into the causes of delays in commissioning CEGB power stations". The Committee, under Sir Alan Wilson, reported in March 1969, and identified "a greater concentration of responsibility" as one of the ingredients necessary to overcome the problems.

In 1974, after a number of sporadic attempts in earlier years, the government, through the Department of Energy, set up a committee under Lord Plowden, "to examine the structure of the electricity supply industry in England and Wales and to report to the Secretary of State for Energy". These terms of reference, having regard only to structure, were narrow and were so construed. Despite the dramatic changes that had occurred in energy technology, economics and policy since 1957, the overall role of central electricity supply was more or less taken as given. The Plowden Committee reported in January 1976. Its main recommendation was yet further centralization of responsibility: elimination of the Electricity Council and the Area Boards, and tighter top-level control of policy and finances in a single decision-making entity, at the top of a single supply organization. The Plowden recommendations were not received with unanimous enthusiasm. No government action has yet been taken in response to them. But it is widely recognized that the Electricity Acts are overdue for reappraisal and revision. The Plowden recommendations are bound to have a significant influence in such revision.

In June 1976 the CEGB published a Corporate Plan. It "outlines the Board's plans for the short and medium term, together with a background to the activities of the Board in the long term. In addition it includes discussion of many of the choices which need to be made over the next few years". By this time, in the words of the Introduction, the CEGB was "not merely an electricity supply organization. In terms of assets employed it is the 11th largest business concern in the UK and USA together, and 1st within the UK alone. Among electricity utilities in the Western World it controls, operates and owns the largest interconnected system in terms of both load and generating capacity. As the major consumer of primary fuel (roughly 30 per cent of UK) and as a purchaser of specialized technical capital goods of high unit value it has a substantial influence on the national economy. Fluctuations in its investment programme can also affect total pressure on resources in the UK, quite apart from that on the output of specific industries. In addition, it is inevitable that the environmental effects of the Board's operations will make an impact on a discerning public".

However, by this time it was increasingly apparent that the CEGB was caught up in serious difficulties, affecting not only its own future but those of its major suppliers - the boiler-makers, the electrical engineering manufacturers, and the nuclear industry. Some of the difficulties, as shall be discussed in subsequent chapters, are certainly peripheral, misfortune rather than misjudgement. Other difficulties, however, may well be inherent in any industry with the objectives and structures of the British electricity supply industry: its emphasis on grid electricity, supplied by very large base load generating stations, administered by a centralized authority acutely conscious that it will be held responsible for any interruption of supply. Official reaction to the industry's present difficulties seems broadly to press for further advance toward larger scale, longer time scales and tighter centralization. It is far from clear that such measures are either appropriate or feasible. Present problems may be danger signals indicating fundamental flaws in policy. If, as official policy presumes, the problems of the electricity supply industry are to be compounded by multiplying them by those of the nuclear industry, the prospects seem - to say the least - unpropitious.

4 The electric nucleus

In Britain as elsewhere the decision to develop civil nuclear technology was taken by the government. Military nuclear technology, of course, had been developed from 1940 onwards. under conditions of' the profoundest secrecy. This secrecy continued after the end of World War II, when Britain undertook to acquire her own nuclear weapons. Only a handful of people were party to the post-war discussions which set in motion the British nuclear programme. From 1947 onwards reactors were designed at Harwell and Risley, initially to produce weapons-plutonium. In the late 1940s and early 1950s a uranium factory was built at Springfields in Lancashire; a uranium enrichment plant was built at Capenhurst in Cheshire; and plutonium production reactors and a plutonium separation plant were built at Windscale in Cumberland.

Civil applications of nuclear technology took place within the weapons laboratories, and behind the same screen of secrecy. Military expediency dictated the design and construction of Calder Hall, the "world's first nuclear power station", across the river from Windscale. Despite the publicity fanfare which attended its inauguration in October 1956, Calder Hall, and its sister station at Chapelcross over the Scots border, were built at the behest of the military Chiefs of Staff, to augment supplies of weapons-plutonium. The electricity they were to generate was a byproduct. Both Calder Hall and Chapelcross can still be called upon for specifically weapons-related purposes as desired.

The design work, materials research and prototype development not only of reactors themselves but also of their ancillaries were carried out under the auspices of the government nuclear agency. From 1946 to 1954 this was the Division of Atomic Energy Production, Ministry of Supply. The Atomic Energy Act 1954 transformed the administration of the nuclear programme. It created the United Kingdom Atomic Energy Authority, which was given responsibility for all research and development of applied nuclear energy, military and civil. The AEA was - and still is - in some respects a unique arm of the government. It was funded by a separate Vote of Parliament, called for many years the Atomic Energy Vote. In February 1954 the first civil Estimate under this heading was presented, for the sum of £53,675,000. Over the years the annual Vote has slowly increased. It is now called "Industrial Innovation: Nuclear Energy". In 1975-76 the AEA's Estimates anticipated gross cash expenditure of £151,871,000, offset by receipts of £58,444,000, "leaving £93,427,000 to be financed by Parliamentary Grant", as noted in the AEA Annual Report for the year.

The nuclear energy Vote places this form of energy on a footing unlike that of any other in the British economy. Throughout the development of civil nuclear energy in Britain government and industry have been linked in a sometimes uneasy and occasionally precarious symbiosis which is peculiarly characteristic of the civil nuclear field, not only in Britain but worldwide. One consequence of this symbiosis is that nuclear planning has never been governed by normal economic criteria. Government policy directives have always played a definitive role - either overt or covert - in nuclear decisions.

The first British manifestation of this long-running phenomenon was the White Paper, "A Programme of Nuclear Power" (Cmnd. 9389), presented to Parliament in February 1955. The then Central Electricity Authority took no part in the drafting of the document, and were given only a month to comment on it. The White Paper proposed a programme of up to 2,000 megawatts of civil nuclear power stations based on modifications of the Calder Hall "Magnox" design to be constructed through the ensuing decade. After the Suez debacle of October 1956,"in the light of the general fuel situation the need for a greatly expanded nuclear power programme was accepted by Her Majesty's Government" (AEA Third Annual Report, 1956-57). The expanded programme foresaw 5,000 to 6,000 megawatts of nuclear power in operation by the end of 1965. The electricity supply authorities, it is fair to add, were far from enthusiastic about these plans. As the oil supply problem abated and coal supply grew, the cost of the nuclear programme looked less and less attractive. Another White Paper in June 1960 conceded that nuclear electricity would not become competitive with coal- and oil-fired generation as soon as expected. The revised programme, delayed and extended, called for the construction of 5,000 megawatts of nuclear power by 1968.

Almost exactly a year after the inauguration of Calder Hall, on 8 October 1957, one or more fuel rods in the Windscale Number One plutonium production reactor caught fire. The fire went unnoticed for well over a day; by the time it was discovered it was catastrophically out of control. The fire represented a serious hazard not only to workers at the Windscale site, but also to the surrounding countryside. Radioactive iodine and other radioisotopes belched invisibly out of the stack as the fire raged. The stresses on the structure of the reactor were unexpected and severe; the possibility had to be recognized that either the fire, or misjudged attempts to put it out, might lead to breach of the shielding, releasing enormous quantities of lethal radioactivity. However, the fire-fighting efforts had been underway for some 24 hours before even the local Chief Constable was formally notified. It was several days before the full extent of the spread of radioactivity off the Windscale site was publicized, and measures instituted to stop the consumption of contaminated milk and produce.

The full report on the Windscale fire - the Fleck report, after Sir Alexander Fleck, chairman of the committee of inquiry - has never been published. The Number One reactor was of course a military installation, one of the most secret in Britain. Security regulations could readily be extended to cover the mishap, however irrelevant the information about it might have been to national security. As it happened, the fire led to the permanent shutdown not only of the Number One reactor, which was a write-off, but also of the Number Two reactor next to it; the Number Two reactor might have been susceptible to a similar malfunction, and modification was not feasible. In any case Calder Hall was now in service, with Chapelcross not far behind, and the military appetite for plutonium was beginning to abate. The published truncated summary of the Fleck report in effect attributed the blame for the Windscale fire to an unnamed reactor operator. But it is clear that the design of the reactor, especially of its instrumentation, was severely flawed in some essentials; and plant administration also left something to be desired. The veil of anonymity and elision which was drawn over the episode did not bode well for public access to information about subsequent nuclear developments, civil as well as military.

The aftermath of the Windscale fire included another major consequence: passage of the Nuclear Installations (Licensing and Insurance) Act 1959. The Act, whose wording makes it a masterpiece of legislative obfuscation, embodies several ironies. Although it provided for setting up the Nuclear Installations Inspectorate, it also expressly limited the direct third-party liability of operators of nuclear installations: to only £5 million. (Another £43 million was to be made available by Parliament if required; but operators did not of course have to pay premiums on it. Above the £48 million total no further liability would be recognized.) The deliberations of the Nuclear Inspectorate were to take place on a confidential basis with the licensees, entirely behind closed doors. The public was to be given no access either to the relevant information or to the Inspectorate's comments upon it. The Act also expressly excluded from the jurisdication of the Inspectorate all nuclear installations operated by the AEA - of which the Windscale reactors had been prime examples.

The Nuclear Installation Act was rather intended to cover the civil reactors by then under construction at several locations. In 1962, about a year later than originally expected, the first two civil nuclear power stations in Britain came on stream: Berkeley in Gloucestershire and Bradwell in Essex. The design of the reactors was in each case a development from the Calder Hall Magnox design. However, the Berkeley station was designed and built by the AEI-John Thompson Nuclear Energy Company, while Bradwell was designed and built by The Nuclear Power Plant Company. The Berkeley reactors differed in many respects from the Bradwell reactors; the former, for instance, had cylindrical pressure vessels while the latter had spherical ones. Subsequent Magnox stations differed further.

Eventually the civil Magnox programme in Britain came to include nine stations, each of distinct and unique design, built by five different consortia of industrial firms. The diversity of effort, which might in other contexts have been regarded as a healthy sign of vigour and competition, was in the nuclear context debilitating in the extreme. Orders for stations - all for the CEGB, except one for the South of Scotland Electricity Generating Board (SSEB) - were placed not on the basis of genuine competitive tendering but by a thinly disguised rota, with the government looking over the shoulders of the electricity suppliers. Even so, the drain on the participating firms proved too much for several of them. By the time the ninth and last Magnox station, Wylfa, was ordered, in 1963, the number of consortia had shrunk to three. From that time onward the progressive centralization of nuclear industrial activity has approximated ever more closely the centralization of nuclear decision-making. The results, however, have done little to establish confidence in the policy.

Throughout the 1950s the AEA pursued its programme of design of reactors. Design innovations were fed continually into the work of the civil consortia. On one hand it could be claimed, and was, that these innovations represented reiterated improvement of reactor design. There was, however, also another effect. Nuclear engineering as a discipline was in its infancy. Reactor physics, materials science, control and instrumentation, virtually every contributing field was undergoing a headlong development in the hothouse environment created for the weapons programme. Unfortunately the speed of the research and development in these fields far outdistanced the speed at which large-scale nuclear plant could be built and real operating experience acquired. By the time any given design innovation was actually observable as part of a functioning plant it was likely to be regarded by the designers as already obsolete. Accordingly, each new large-scale nuclear plant was a true prototype, much of its engineering the first of its kind. In retrospect it is a credit to the various designers and consortia that there were not far more major problems.

The Magnox lineage - fuelled by natural uranium metal, cooled by carbon dioxide gas, in a matrix of graphite bricks serving as "moderator" - had inherent limitations. It was expensive to build and thermodynamically inefficient to operate. While the Magnox design underwent its continuing metamorphosis, a more sophisticated gas-graphite design took shape: the advanced gas-cooled reactor or AGR. The AGR was intended to be more compact, to make better use of uranium and to produce higher operating temperatures - making possible conversion of more of the nuclear heat to electricity. The AEA built a small prototype AGR on its site at Windscale; the Windscale AGR came on stream in 1962, shortly after the first civil Magnox reactors.

Two Magnox reactors were sold to overseas customers, the only two nuclear power stations Britain has ever succeeded in exporting. The Latina station was ordered by Italy in late 1957, the Tokai Mura station by Japan in early 1959. Not since then has there been more than a murmur of probability that a British power reactor might find an overseas buyer. The result has been, throughout most of the intervening years, a curious insularity about British nuclear activities. To be sure, this insularity harks back to the US McMahon Act of 1946, which cut off British access to US nuclear information, despite Britain's key role in the war-time atom bomb project. Britain's subsequent determination to go it alone has ever since exerted a powerful influence on British nuclear decision-making, intensifying its centralization and underlining the oddities of civil nuclear economics in Britain.

British nuclear insularity has been accompanied by a disinclination toward detailed public discussion of British nuclear affairs. The habit of secrecy took deep root during the weapons programme. Many senior administrators of the civil nuclear programme were - and are - alumni of the weapons programme, and have never grown accustomed to talking about their work in public. Politicians and civil servants seem largely to have acquired the reciprocal habit of refraining from embarrassing the nuclear administrators with awkward questions - perhaps because inquiries have long been futile. The Official Secrets Act offers a wide umbrella, and is regularly extended now over many aspects of nuclear activities which are in other respects nominally "civil". There are, to be sure, very good reasons for saying little about certain civil nuclear activities, some of which are in any case - like enrichment technology - still "classified". Other aspects are said to be protected for reasons of commercial security. Nevertheless, since civil nuclear affairs still depend to an overwhelming extent on public funds, either directly or - via the generating boards – indirectly, and since nuclear administration is still quintessentially governmental, the public can reasonably claim the right to know a great deal more than has hitherto been forthcoming.

Thus far, however, in the two decades of British civil nuclear development, public access to information about nuclear policy decisions and their foundations has been primarily post hoc. Even after the fact, when the consequences of nuclear decisions are becoming apparent, many relevant details have remained obscure if not completely inaccessible. However, certain groups have succeeded at various times in getting on record valuable background material about the processes and criteria which have determined nuclear decision making.

One of the first really wide-ranging investigations was that carried out by the House of Commons Select Committee on the Nationalized Industries in 1962-63. In a marathon series of hearings into the electricity supply industry, the Committee heard evidence from many of the bodies responsible for electricity and nuclear policy, including the Ministry of Power, the Treasury, the Electricity Council, the CEGB, the Area Boards, the AEA, and interested industries. The evidence makes engrossing reading, especially in the light of hindsight. So do the 84 Appendices, which cover eveything from "The Effect of Interest Rates on Nuclear Generation Costs" to "The Use of Electricity per Industrial Worker" to "Cold Spells in Central England since the 17th Century".

The section of the Committee's Report which dealt with nuclear power provided a capsule survey of the ups and downs of the first nuclear programme. The Committee drew attention to Appendix 39, by the Electricity Council. It disclosed that - as has been mentioned - the Central Electricity Authority had no part in the detailed preparation of the 1955 White Paper announcing the first nuclear programme, and that the CEA was given "only a month or so" in which to comment on the White Paper in draft. "Nevertheless, on the information available they accepted the proposals as a reasonable approach to nuclear energy development in the UK", a telling quotation, especially the phrase "on the information available". The same Appendix pointed out that the CEA would have preferred a smaller programme than the one the government adopted in 1957, which was the largest analysed (and which was later reduced and "extended" - that is, delayed - again by government decision, albeit this time after more consultation with other bodies).

The Committee established that the Ministry of Power had based its nuclear programme at least partly on the fact that it was the smallest that "was consistent with keeping together the skilled manpower of the (three) consortia for the time when nuclear power on a large scale would become economic". Nuclear power, it was made clear, was by no means economic in 1963. "The high hopes entertained in 1955 of the comparative costs of nuclear and conventional power had not been realized", says the Report. The then Chairman of the CEGB, Sir Christopher (later Lord) Hinton, told the Committee that the cost of the history of nuclear power to the CEGB to that stage had been "pretty considerable". A remarkable comment by Sir Christopher - himself, it must be recalled, a former full-time Member of the AEA - is worth noting. The Committee asked (Q. 1025): "But now that you (the CEGB) are really the main client of the AEA it seems fair to suppose that their activity is guided by your requirements?" Sir Christopher, never one to mince words, replied "I think that their activities are guided by what they think our requirements ought to be". Both before and since that time Sir Christopher's comment seems an unanswerable indictment of the determinants which guided British nuclear policy. Curiously enough the next question has been deleted from the published record of evidence.

The AEA's activities included, of course, continuing development work on the Magnox and AGR designs. But it had in addition no fewer than three other reactors under development. The AEA was leading the British contribution to the next phase of the gas-graphite lineage, the Dragon high-temperature reactor, an international project based at the AEA site at Winfrith in Dorset. The Dragon reactor started up in 1964. Winfrith was also preparing a complete departure from other British designs, the steam generating heavy water reactor (SGHWR); in due course a 100 megawatt prototype SGHWR was started up in 1968. But the key to the long-term planning of the AEA was the fast breeder reactor (FBR), fuelled using plutonium and cooled by molten sodium. As early as 1949 this design was seen as essential to the eventual economic validity of nuclear electricity, which might otherwise run afoul of shortage of uranium. The first FBR power station in Britain, the small 14-megawatt Dounreay Fast Reactor, had been built on the north coast of Scotland, as far from centres of population as is plausibly achievable in Britain. It started up in 1959; but difficulties kept it from reaching full power until 1963. On 9 May 1962 Sir Christopher told the Select Committee "I think that progress at Dounreay has been disappointingly slow, and I do not believe that today I can feel any certainty that it will provide an answer at a date that I can forecast." Nevertheless, despite persistent deep-seated CEGB scepticism, the fast reactor continued to assume increasingly central prominence in the AEA view of the nuclear future.

One final observation from the 1963 Select Committee Report must be cited (page 123). "The Ministry[of Power]'s witness [Sir Dennis Proctor, Permanent Secretary] agreed that until nuclear and conventional power become competitive the industry will be bearing the extra cost of nuclear generation because of 'national policy laid down by the government', although he claimed that the industry accept the additional cost now in order to gain the long-term advantage. He readily accepted the Board's figure of £20 million a year [additional cost of generating power by nuclear rather than conventional means] although it had never been specifically discussed with them. In his view the argument as to whether the taxpayer or the electricity consumer should bear the extra cost of the nuclear power programme should proceed from the basis that in 10 or 15 years' time nuclear power stations will be needed, and that just as the present consumers of electricity have benefited from technological advances in the past, so they should bear the cost of present advances. The witness did, however, agree that it was hard for the industry to be saddled with the extra cost of a programme [£360 million extra capital cost for seven nuclear power stations between 1962 and 1968] which is now generally admitted to be too high and which it is doubtful they would have supported if they had been 'perfectly free agents'." Fifteen years on, these words have a strangely familiar ring, a premonitory echo of what is still in 1977 offered as a basis for government civil nuclear policy. Just as electricity customers and power station builders are captive clients of the electricity supply industry, so the electricity supply industry is proving to be a captive client of the nuclear industry and its government mentors.

In April 1964 the government published another White Paper, "The Second Nuclear Power Programme" (Cmnd 2335), which called for 5,000 megawatts of additional nuclear capacity in England and Wales, to be commissioned from 1970 to 1975. The CEGB chronology *Electricity Supply in Great Britain* describes the consequences thus: "The CEGB after a most thorough assessment chose a design based on the Advanced Gas-cooled Reactor developed by the UKAEA." Others involved might have put it differently, especially as regards the "most thorough assessment". Be that as it may, on 25 May 1965 the government announced that the second nuclear power programme would be based on the AGR; and in August 1965 the CEGB placed the order for the first twin-reactor AGR station, to be built next to its Magnox station Dungeness A. The order for Dungeness B was placed with the consortium Atomic

Power Constructions Ltd.; construction started in 1966. Eleven years later Dungeness B is still at least two years short of completion.

In October 1965 the government published a White Paper on "Fuel Policy" (Cmnd 2798), which described how the government proposed to establish such a policy and put it into effect. One of the recommendations of this White Paper was that the electricity industry should continue to give preference to coal over oil and nuclear power. In November 1967 appeared another White Paper on "Fuel Policy" (Cmnd 3438), differing in some key fundamentals - in particular favouring a speedy build-up of nuclear capacity at the expense of coal, harking back to the government decision of 10 years before. By this time the rundown of the coal industry was assumed by official energy planners as inevitable and necessary; the major concern was to reduce if possible the social dislocation such rundown entailed. As can be seen, the central electricity system was perennially beset by quite bewildering shifts of policy, both those arising internally and those imposed from without. The scale of the system, its monopoly character, and the size of the technological increments aggravated the consequences of policy shifts, especially since such consequences were usually still developing while policy was shifting yet again.

Another public attempt to get to grips with nuclear policy was undertaken during 1967, by the newly constituted House of Commons Select Committee on Science and Technology. Choosing for its first inquiry "a subject which was of prime national importance and involved large sums of public money", the Committee decided to investigate the "United Kingdom Nuclear Reactor Programme". Their first Report, with this title (381-XVII), was published in October 1967. It was a revealing one-volume survey of the status of nuclear power in Britain in the mid-1960s. It also embodied themes which have persisted from the outset of civil nuclear activities in Britain. Even the Report's first four recommendations could be regarded as internally contradictory:

1. (a) The consortium system of tendering for nuclear power stations should be phased out as present contracts are completed and the generating Boards should regard themselves as free to place orders for nuclear stations in the same way as they now do for other types of power station.
(b) Any reorganization of the nuclear industry in Britain should have as its aim the more effective concentration of the Atomic Energy Authority's effort on research and development with competitive industrial activity than is now the case.
(c) In present circumstances the best interests of the country would be served by the combination in a single organization or company of the skill and resources of those now separately engaged in the design and construction of nuclear boilers.

2. (a) So much of the Authority's facilities as is presently devoted to research and development of a commercial nature should become part of the new single boiler organization or company.

Precisely how the generating boards, with the end of the "consortium system", "should regard themselves as free to place orders" from a single nuclear boiler organization, or how this could in any sense be construed as "competitive industrial activity", was by no means apparent. On the contrary, it reflected the stubborn ambiguity surrounding the economic status of civil nuclear technology, and the consequent fixation on centralized decision-making, the reluctance to relax the reins too much lest all the various parts of the system get hopelessly out of touch with one another. This advocacy of further centralization became a recurring theme in subsequent hearings on nuclear policy, which was to become a favourite topic for the Select Committee on Science and Technology.

The Select Committee's 1967 Report also advocated establishment of a new British nuclear fuel supply and manufacturing company, and vigorous development of every available design of reactor - the high temperature reactor, water reactors ("the SGHWR and other water reactors showing promising commercial probabilities"), and the fast reactor "with a view not only to its commercial use at home but also to its being offered abroad to meet whatever may be the market requirements overseas". These recommendations are coupled with the confident assertion that nuclear power "is genuinely competitive in relation to other sources of primary energy available to the UK". However, more careful examination of the evidence reveals that this assertion is founded on the estimated cost of electricity from the AGR stations - estimates which were made to three places of decimals, and which, 10 years later, with the AGRs still struggling, look frankly poignant. According to the Committee, nuclear power "is likely to become cheaper as further improvements in the AGR are effected and will be eventually the cheapest of all sources when fast breeder reactors reach the stage of commercial exploitation". Ten years later, the same refrain still echoes in official corridors.

The 1967 Report of the Select Committee indeed reverberates with unabashed enthusiasm for nuclear fission: "a cleaner and more sophisticated way of obtaining the artificial energy on which industrial civilization rests than burning fossil fuels". The Committee clearly found official conviction about the eventual virtues of nuclear power infectious: "Your Committee wish to stress their strong conviction that the production of electric power by the processes of nuclear fission will in the future be seen to have been a great technological revolution which lifted mankind to a higher level of living. Britain must remain in the forefront of this revolution." Worthy though such sentiments may be, they scarcely establish their authors as suitably probing critics of the technology in question - and the Select Committee on Science and Technology is one of the few ostensibly representative bodies which has the power to extract information about nuclear policy from behind the official screen. However, the composition of the Committee has changed with time. Although its instincts in the mid-1970s still broadly favour fission, there are now more often sceptical voices raised, as shall be mentioned later in this chapter.

After several years of AEA design work, the Minister of Technology in February 1966 authorized the AEA to build a prototype fast reactor power station of 250 megawatts output, at the AEA site at Dounreay. Meanwhile work on the small experimental Dounreay Fast Reactor was revealing unexpected problems with materials in the core of a fast reactor, which tended to swell under the influence of the powerful flux of fast neutrons. However, even the Magnox programme, for which the major decisions had all apparently been made, still had some unpleasant surprises in store. By the late 1960s it was becoming evident that specifications for some of the steel components inside the reactors had been inadequately stringent, and that they were experiencing corrosion more severe than anticipated. After prolonged investigation it proved necessary to "derate" all but the smallest of the Magnox reactors - that is, to lower the maximum operating temperature and therefore the electrical output from the stations. Derating varied from one Magnox station to another; but of course, because the capital charges were unaffected, it made Magnox electricity yet more expensive.

A total of five twin-reactor AGR stations were ordered, four by the CEGB and one by the South of Scotland Electricity Board. The AGRs were ordered on the crest of a wave of confidence about rising demand for electricity, and amid a breath-taking leap of size not only in power stations but also in the individual generating sets in the stations. In one headlong rush, orders were placed for a total of 47 sets of 500 megawatts, for the gigantic new coal- and oil-fired base load stations also being ordered, plus 10 sets of 660 megawatts for the AGRs. The boiler makers and turbogenerator manufacturers embarked on a rapid expansion of their facilities and their staff to meet the rush of orders; and for a time all was collective euphoria. But the euphoria was short-lived.

In 1969 Atomic Power Constructions Ltd, beset on all sides by mounting financial, managerial and technical problems at Dungeness B, collapsed, leaving both the partially built station and the entire AGR programme under a cloud. This could be regarded as the moment when the nuclear dream darkened, and became progressively more nightmarish. The Dungeness B disaster exemplifies in an extreme form some key themes which continue to cast doubt on the future of nuclear electricity. Dungeness B was a 20-fold scale-up from the Windscale prototype AGR. For reasons of cost, and in order to win the contract against competition from the other two consortia and against American water reactors, the Dungeness B design tolerances were pared brutally thin. The result was engineering chaos - "watchmaking on a scale of tons", as one engineer ruefully described it.

The problems of scale, and its implications for design, for economics and for timing, are peculiarly intractable in nuclear development, given the speed at which it has taken place. If it had been considered possible to build reactors one at a time, over a period of years, increasing the size and pushing up the performance parameters gradually, the technology might have achieved a convincing maturity, comparable for instance to that of turbo-alternators or conventional fossil-fuel boilers. (Even the latter technologies ran into trouble in the late 1969s, when scale was pushed to new extremes. The Wilson Committee inquiry into "the causes of delays in commissioning new CEGB power stations" - see p.17 - dealt mainly with fossil-fuel stations.) How much such a gradual nuclear programme would have cost, and who would have paid for it, are of course other questions. The designers of the AEA gave Britain a superabundance of alternative concepts for nuclear power reactors. Unfortunately however, the economy has never been able to support all the various alternatives on a cautious approach to full scale, to make possible a genuine comparison of their various virtues and defects. Furthermore, the speed of nuclear development, spurred not by economic urgency but by high-flying imaginations and indulgent accountancy, has never created the conditions for valid evaluation of nuclear innovation in context. Instead the euphoria of the mid-1960s carried the innovators into the harsh constraints of the 1970s, and left a legacy of cost, confusion and antagonism which may take a long time to settle.

The AGR debacle crippled the British nuclear industry so severely that it may never recover. Certainly the after-effects are still visible, not only on the sites of the problem-ridden AGRs; and the bitterness that resulted is still not far below the surface. The first reactors at Hinkley Point B and Hunterston B started up in February 1976, four years behind schedule; Hartlepool and Heysham are now likewise between three and four years behind schedule; and Dungeness B, originally due for start-up in 1970, might start up in 1978 or might not. Neither the AEA nor the CEGB are inclined to accept the blame for the disaster. Even those who were comparatively junior participants still bridle at imputations they consider unjust. Unfortunately for the lessons that might be learned, many significant details relating to the AGR decision remain buried in official files, denied to the public gaze. There is no doubt, however, that when it comes to be written the full history of the AGRs will be both revealing and unnerving. It could scarcely be otherwise, given the magnitude of the misjudgments involved. Professor David Henderson of University College London, in his inaugural lecture, delivered 24 May 1976, estimated the total UK loss, past, present and future, on the AGR programme at some £2,100 million at 1975 prices. However, the ground rules under which nuclear policy operates makes it likely that it will be many years yet before the official veil is lifted enough to allow more than speculation as to the causes of the calamity. When government is as intimately involved in ostensibly commercial decisions as it is in the nuclear field, the long shadow of Whitehall secrecy makes it as hard to learn from experience of policy as it has been to learn from experience of nuclear technology.

However, as seems to be the custom, instead of reappraising policy it was considered more appropriate to reorganize the bodies responsible for executing it. The Atomic Energy Act 1971 split the AEA into three parts. The so-called Trading Fund, which had included the Production Group and the Radiochemical Centre, was reconstituted. The Production Group, which supplied nuclear fuel services, including fuel fabrication, enrichment, reprocessing and radioactive waste management, mainly to the British electricity industry but also to overseas customers, was given a new identity and a new name: British Nuclear Fuels Ltd. BNFL was also given the facilities at Windscale, Calder Hall, Chapelcross, Springfields, Capenhurst and Risley. BNFL was ostensibly to become a separate commercial corporation, independent of the AEA. At first glance this might have suggested a reversal of the trend toward centralization. However, the move toward diversification of the nuclear establishment fell far short of thoroughness. The shares of BNFL were assigned 100 per cent to the AEA, and - at least for the time being, which means ever since - the Chairman of BNFL is also the Chairman of the AEA. Just how much genuine independence BNFL possesses in matters of policy must be a matter of scepticism, especially since senior positions in BNFL are regularly filled by AEA Members or alumni. Partly because of the AEA's role, and partly by virtue of the nature of services offered, especially internationally, by BNFL, the government also continues to exercise an unpredictable but inevitable influence on BNFL affairs. The government also remains intimately involved in BNFL's finances. The status of BNFL as a commercial enterprise therefore remains unclear, especially since it has never paid a dividend to its AEA shareholders.

The 1971 Act also hived off the Radiochemical Centre at Amersham, which was doing an increasingly lucrative business in the manufacture of radioisotopes and radioactive tracer materials for medical and industrial applications. The financial status of the Radiochemical Centre has never given rise to so much ambiguity as has that of BNFL, perhaps because the Radiochemical Centre has never been involved in projects requiring massive capital investment over long time scales. Its field of operations is much more identifiably independent of other major bodies; there is, for instance, no radiochemical equivalent of the electricity generating boards. The Radiochemical Centre is, of course, subject to many of the supervisory bodies which also regulate BNFL, but the quantities of radioactivity dealt with by the Radiochemical Centre are many orders of magnitude less than those dealt with by BNFL. The Radiochemical Centre seems, unlike BNFL, to be largely self-financing; this may be one key reason why it has been essentially free of interference from government policy making. It is worth stressing that the problems of nuclear materials and nuclear energy are - with the exception of nuclear weapons - not inherently different in kind from the problems of other industrial materials. The nuclear problems become serious only because of the scale they assume in the context of nuclear power generation. It is, however, arguable that this difference in scale and interdependence is so large as to be not merely quantitative but qualitative.

The reorganization of nuclear activities also affected the nuclear constructors. In 1970 the government convened a Working Party on the choice of thermal reactor systems, under the chairmanship of Peter Vinter, a senior civil servant at the Department of Trade and Industry. True to form, the Vinter Report was never published, but it apparently paid more attention to industrial reorganization than to its original brief. The Vinter Report was a major target of the Select Committee on Science and Technology, when in mid-1972 it again turned its attention to nuclear power policy. By this time the nuclear power industry was clearly in trouble. The last and largest Magnox station, Wylfa, in Anglesey, with reactors twice the size of those in earlier stations, was found to be suffering from serious design defects, which were going to need expensive and time-consuming corrections and would probably place a permanent limit on the station's performance, well below its design output. The two remaining nuclear construction consortia, The Nuclear Power Group (TNPG) and British Nuclear Design and Construction (BNDC), were struggling. Dungeness B, which had been reluctantly taken under the wing of BNDC, remained a disaster area. The other AGR stations, Hinkley Point B and Hunterston B (TNPG) and Hartlepool and Heysham (BNDC), were already showing signs of unexpected corrosion and other problems, and falling steadily farther behind schedule, as costs escalated. The Prototype Fast Reactor (TNPG) had encountered delays in deliveries and difficulties with its complex 'reactor roof', and was likewise falling steadily behind schedule. Forecasts for electricity demand had by this time proved conspicuously exaggerated. It is true that persistent failure to keep the 500-megawatt generating sets operating had led to power cuts; but in principle the electricity supply system already had capacity well in excess of its "planning margin" of 20 per cent. As the generating problems were ironed out the gap between capacity and demand gaped ever wider.

Accordingly, in August 1972 Arthur Hawkins, the incoming chairman of the CEGB, told the Select Committee that there would be no need to order more than a trifling amount of additional capacity throughout the ensuing decade - at most four base load stations, of which at most one might be nuclear. His evidence offered powerful support for the Committee's reiterated view, echoing their 1967 Report, that even two reactor-building consortia was one too many: that further "rationalization" - centralization - was indicated, and that the country's electricity requirements could support only a single nuclear manufacturing organization. The Committee's opinion was by this time shared by many other influential bodies and commentators. On 8 August 1972 the Rt Hon John Davies, MP, Secretary of State for Trade and Industry, announced in the House of Commons the intention to set up a new single consortium, merging TNPG and BNDC. The National Nuclear Corporation was duly established in March 1973. This body was also to have another key attribute much favoured by some commentators: 50 per cent of its shares were to be held by the British firm of GEC, the General Electric Company (not to be confused with US General Electric, with which it has no links). Another 35 per cent were to be held by other private industry, and 15 per cent by the AEA. GEC were to take over managerial responsibility for the affairs of the NNC. In some quarters this was seen as the essential aspect of the plan; the aggressive managing director of GEC, Sir Arnold Weinstock, had long expressed a wish to take charge of the nuclear construction business and provide it with what he considered the necessary muscle to put it on a stable commercial footing. However, the very first policy proposals advanced under the purview of GEC created a national furore unequalled in the history of civil nuclear affairs in Britain.

On 15 October 1973 Peter Rodgers of *The Guardian* published a front-page story revealing that the CEGB were proposing to abandon the lineage of British nuclear technology in favour of importing light water reactor technology from the US. For some weeks the scope of the CEGB's plan remained a matter for agitated conjecture. The Select Committee on Science and Technology, as always an enthusiastic supporter of British nuclear efforts, convened yet another series of hearings. On 18 December 1973, to the astonishment of many, Arthur Hawkins, Chairman of the CEGB, told the Committee that the CEGB now planned to order some thirty-two 1,300-megawatt Westinghouse pressurized water reactors through the coming decade. Challenged about his evidence only 16 months earlier before the same Committee, Hawkins waved aside all queries. He assured the Committee that he and his colleagues had now had time to study the position, and had ascertained the necessity of the proposed programme of PWRs. In the course of his evidence he also made a variety of disparaging remarks about the existing Magnox reactors, called the AGRs "a catastrophe we must not repeat", and pooh-poohed the SGHWR as "unproven and expensive, already an obsolete technology".

To re-read the Hawkins evidence, only three years later, is to enter a world which is almost surrealist in its casual acceptance of the extraordinary. It is frankly difficult to imagine how a senior executive - supported, it must be said, by his senior colleagues, Sir Arnold Weinstock among them - could even harbour a notion like the PWR proposal, much less defend it with a confidence amounting more than once to simple arrogance. In retrospect it is strange that the episode has been so readily submerged in history, and its protagonist not merely excused but knighted. Only the concerted efforts of an improbable aggregation of critics, including the Select Committee, Friends of the Earth, the Institution of Professional Civil Servants and other trades unions, the South of Scotland Electricity Board, many parts of the British nuclear establishment, a growing number of MPs and peers and - throughout the months of controversy - many well-informed media people, averted an unthinkable economic catastrophe. It is almost impossible to imagine what would now be the situation if the CEGB's wild plan had been given the go-ahead. The international entanglement, the capital commitment, the technological shambles, all in aid of nuclear capacity for which there is now no conceivable need - it would be a salutary exercise for Whitehall to contemplate the future which would now be facing Britain's electric power industry if it had been allowed to follow its instincts - and responsible commercial advice - in 1973-74.

There is an instructive corollary to the LWR episode. What would have happened if the CEGB, instead of deciding abruptly on a programme of 41 gigawatts of American reactors, had elected to order just one? Would the outcry have prevented this? Probably not: it is impossible to guess. What seems, however, likely is that the size of planned programme was determined not by identifiable CEGB requirements but by the minimum programme which would be of commercial interest to GEC as constructors. This emphasis not on the eventual end-user of the product - the electricity customer - but rather on the well-being of the producer and of the producer's upstream suppliers seems to be another recurring theme, deriving from the inflexibility of the system as it has developed, especially in scale and size of unit increments. It is further aggravated by the imposition of bureaucratic rather than economic policy criteria - a desire for order and predictability, which in the context is achievable only by fiat, regardless of economic reality.

In any event, partly because of the change of government in February 1974, and partly because of the barrage of criticism of the CEGB/GEC plan, the plan was rejected by the government - who as usual claimed the final say in the matter. On 10 July 1974 the Rt Hon Eric Varley, MP, Secretary of State for Energy, announced that the government would direct the choice of the SGHWR as the basis for the next nuclear power programme. Furthermore - a point which has been given insufficent emphasis - the government would authorize not 41,000 megawatts, as the CEGB wished, but only 4,000 megawatts - six 660-megawatt units. It was the end of a quite inexplicable spasm in British nuclear policy which demonstrated that governments were not the only source of far-fetched nuclear proposals. It was an episode, however, which must not be forgotten: because it contains some valuable lessons, not all of them yet apparently learned.

Later in 1974 the Rt Hon Tony Benn, MP, took over the portfolio of Secretary of State for Energy. One of his first acts was to arrange for publication of the report given to the government by its Nuclear Power Advisory Board, a nine-member group drawn from the top of the industry. Publication of the NPAB report was the signal for a new approach to nuclear policy, in line with the oft-expressed desire of the new Secretary of State for more openness in government. As an example of the nuclear advice being given the government in confidence the NPAB report was hardly reassuring. The report revealed an irreconcilable split between two factions, one vigorously espousing the cause of the American design, one staunchly defending the British. It was clear that no edict from the government would sway either faction in its conviction.

The government's endorsement of the SGHWR delighted the AEA, as might be expected; it also delighted the South of Scotland Electricity Board, who had championed the SGHWR for some years. In the early 1970s the SSEB had even considered building an SGHWR station at a site near Inverness called Stake Ness. However, in the winter of 1973-74 SSEB attention had moved farther south, and focused on the site cast of Edinburgh called Torness. The SSEB, like the CEGB, had by this time embarked on a policy of applying for power station sites well ahead of any serious plan to build on them, merely to have the sites earmarked for eventual use.

In the given context the idea is understandable; but it does give rise to some difficulties in the planning process. A public inquiry was held into the application for planning permission for a power station at Torness. However, the inquiry was held in late June 1974, three weeks before the government announced its decision on the choice of reactor for Britain. Accordingly, objectors to the SSEB proposal were offered only the vaguest basis on which to proceed. Technical criticism was impossible, since there might have been at least five different reactor types to take into account, with very different technical characteristics. Neither the size of the station nor its timing were mentioned, making it acutely difficult to question the role of the station in SSEB planning. To add to the futility of the inquiry the SSEB Chairman, Francis Tombs, appeared as a witness precisely the day before publication of the SSEB's annual report - which revealed that the SSEB's operating profit of £34 million in 1973-74 had been wiped out by interest charges of £44 million. Such information would have been very useful to the objectors, who might have wished to query the Chairman's views on future investment in generating capacity whose necessity could be doubted. However, the sequence of events gave the objectors no such opportunity. In due course, as expected, the government inquiry officer - the "Reporter" - recommended approval of the application, which was duly given.

After the 10 July 1974 announcement, the SSEB said that they would build their two SGHWRs as a twin-reactor station at Torness; and the CEGB said that they would build their four as a single huge station adjoining the existing Sizewell A Magnox station. The CEGB already had planning permission for Sizewell B, a fruit of its earlier sowing of applications at a number of sites, without more precise specification of intent. The National Nuclear Corporation set up a reactor-building subsidiary, the Nuclear Power Company, and waited for the orders to arrive. But the months passed, and nothing further happened. Behind the scenes the design team from the NPC, the design team from the CEGB and the design team from the SSEB wrestled with the task of scaling up and revamping the Winfrith SGHWR parameters. The Nuclear Installations Inspectorate would have to evaluate the full-scale design in detail, and no reactor could be formally ordered until it had received the NII's blessing. Meanwhile, however, the price of electricity leapt up. To the chagrin of the electricity planners, electricity customers responded by using less. The generating capacity of the CEGB and SSEB systems loomed far beyond that required, even at peak demand. Gradually the realization dawned that even 4,000 megawatts of SGHWRs were likely to be 4,000 too many, for the foreseeable future.

By the summer of 1976, two years after the government's rejection of 41,000 megawatts and approval of 4,000, even the 4,000 looked profoundly unattractive to the generating boards - an investment they could not countenance. The CEGB in the interim sought and received union cooperation to bring forward the closure of 3,533 megawatts of older plant, and the semi-retirement of an additional 2,200 megawatts. By this time the boards were finding their own financial position distinctly uncomfortable, not only because of rocketing bills for fossil fuel but also because of the crushing burden of interest on earlier investment, much of it still not producing any significant positive cash flow. The government found itself surrounded by supplicants. The turbine and boiler manufacturers were facing a desert, devoid of domestic orders from the generating boards for perhaps six years, which might mean the complete collapse of their industries, and would certainly entail sweeping loss of jobs. The Nuclear Power Company had completed its reference design for the SGHWR stations, but there seemed little likelihood of either order being placed. Indeed the design as completed was so expensive that the earlier LWR controversy broke through the surface again.

The Select Committee on Science and Technology, alarmed that its successful recommendation of 1974 seemed to be turning sour, convened in August 1976 yet another series of hearings into the current status of the SGHWR programme. At the first of these the Secretary of State for Energy, Tony Benn, revealed that Sir John Hill, Chairman of the AEA, had written to him on 22 July 1976, declaring that the future domestic market for nuclear power stations no longer warranted introduction of the SGHWR, the AEA's own design. The CEGB appeared to endorse Sir John's view; but the SSEB disputed it, claiming that the reference design was needlessly expensive, being compelled to meet pointlessly stringent safety criteria. However, the SSEB did not seem in any hurry actually to order its SGHWR.

In his letter to Tony Benn Sir John Hill left no doubt about the implications of the situation: "We believe that the country will need a large nuclear programme in due course and we must ensure that there is the industrial capability to install a mixed programme of thermal and fast reactors at that time. It is not reasonable to let our nuclear and power engineering industries collapse in the next few years and attempt to reconstruct them in, say, 1985. We must therefore find a way to keep the power engineering construction industry and the nuclear design industry healthy in the intervening years. We can see no alternative to a vigorous export policy in the short and medium term but acknowledge the difficulty of achieving it. Some minimum domestic ordering programme will also be necessary. Without this there is a real danger of effective collapse of the industry in a few years' time."

The words echo those of the Permanent Secretary to the Ministry of Power in 1963 (see p. 26) - "in ten or fifteen years' time nuclear power stations will be needed". This stubborn conviction about the eventual necessity and economic credibility of nuclear electricity has been the centre-piece of official policy for more than two decades. It is by now, however, beginning to suggest the promise of "nuclear jam tomorrow" - especially when the cost of keeping the nuclear faith is included in the reckoning.

Part of this cost has been that of developing the fast breeder reactor - estimated by Sir John Hill in testimony to the Select Committee, as of Spring 1976, as some £400 million to that time. At 1976 prices the figure might be twice that. The AEA have for some years been urging the government to approve construction of a full-scale fast breeder power station: the so-called CFR-1, for commercial fast reactor, although it is admitted that "commercial" overstates the case considerably. CFR-1 is expected to cost upwards of £600 million. No one can be very precise about estimates except to guess - on the basis of past performance - that any estimate will probably be too small. It seems - to put it mildly - unlikely that public funds to any such value are going to be forthcoming for such a project within the next few years. Accordingly, what the AEA seems to be requesting is a government commitment in principle, to remove the question mark now casting its shadow over the future of the AEA's nuclear plans. From a different viewpoint, of course, any such government commitment will effectively blunt public discussion of the necessity or advisability of building CFR-1; and such public discussion is now very vigorous indeed.

Another major constituent of the fast breeder programme is now likewise subject to vigorous public discussion: the plan by BNFL to construct a 1,000 tonne oxide fuel reprocessing plant at Windscale. Such a plant makes sense only in the context of a decision to utilize the separated plutonium in fresh fuel for fast reactors. The proposed plant is expected to cost upwards of £600 million; part of this cost, say BNFL, will be borne by overseas customers, in the form of advance payment for reprocessing services. However, the future of this plan is now in question. After protracted controversy in 1976, the Secretary of State for the Environment, The Rt Hon Peter Shore, MP, announced on 22 December 1976 that BNFL would be invited to submit a separate application for the oxide plant proposal, and that this application would then be called in for a public inquiry. The application was resubmitted 1 March 1977; the inquiry was scheduled to begin 14 June.

Apart from the costs associated with CFR-1 and the Windscale oxide reprocessing plant - which would sequester resources that might be better applied elsewhere - these plans also focus attention on the fundamental question as to whether plutonium, the raw material for nuclear weapons, should become an article of everyday commerce by the tonne. The AEA appears to have no doubts. But the AEA's blithe confidence is not universal. Indeed it is not even unanimous. Sir Brian Flowers, a part-time Member of the AEA, has found himself increasingly at odds with his colleagues, as a result of his chairmanship of the Royal Commission on Environmental Pollution. The Commission's Sixth Report, *Nuclear Power and the Environment,* published in September 1976, is a landmark study of the status of nuclear electricity as an environmental, economic and social phenomenon. Its findings have received worldwide attention, and greatly enhanced the credibility of some concerns expressed by critics of civil nuclear activities.

The Flowers Report, as it has come to be called, has been variously - and selectively - quoted, both by nuclear advocates and by nuclear critics, since its appearance. Some have called it ambiguous in its findings - not that this is either unexpected or discreditable, in a field as complex as nuclear policy. However, paragraphs 506 and 507 are uncompromising:

"506. Another aspect of the problem is the possible effect of such threats [of nuclear terrorism] on society. The security measures that might become necessary to protect society could seriously affect personal liberties. The need for such measures would be affected by increasing tensions between nations. Indeed, the future risks posed by plutonium constitute a world problem that would not be solved by unilateral action by the UK, though the action we take in response to our assessment of these risks could have a substantial impact on world opinion. We emphasize again that our concern here is not with the position at present, or even in the next decade, but with what it might become within the next fifty years. In speculating on developments on such a time scale no one has a prerogative of vision. It appears to us, however, that the dangers of the creation of plutonium in large quantities in conditions of world unrest are genuine and serious.

"507. For this reason we think it remarkable that none of the official documents we have seen during our study convey any unease on this score. The management and safeguarding of plutonium are regarded as just another problem arising from nuclear development, and as one which can certainly be solved given suitable control arrangements. Nowhere is there any suggestion of apprehension about the possible long-term dangers to the fabric and freedom of our society. Our consideration of these matters, however, has led us to the view that we should not rely for energy supply on a process that produces such a hazardous substance as plutonium unless there is no reasonable alternative."

In one respect above all others the Flowers Report differs from previous official and quasi-official pronouncements on nuclear policy. The Flowers Report points repeatedly and explicitly to the need to revise the policy-making process: to offer the public more access to relevant information, to give more attention to public discussion of nuclear issues, and to position nuclear issues in their wider context. For more than two decades decisions about civil nuclear policy have been taken within an artificial framework, narrowly defined and often difficult to reconcile with economic and social policy overall. The wider context can no longer be ignored. Can civil nuclear interests be coordinated with - even subordinated to - the interests of society as a whole? If not, it is clear that the interests of society will have to be progressively subordinated to those of the civil nuclear establishment.

5 Forecasts and their fulfilment

Like any human enterprise, large-scale supply of electricity involves anticipating the future. However, the characteristics of grid electricity supply impose a number of particular constraints, and make forecasting the future both imperative and difficult. Two key constraints have already been identified: the inability to store electricity, and the commitment to guarantee supply to all users at all times. An electricity supply system is not, of course, a fixed entity. It undergoes continual changes. Components wear out or become obsolete; technological innovation introduces modifications. The system functions, not in a vacuum, but in a social and economic context, with which it continually interacts. In addition, historically, the use of grid electricity has continued to increase, requiring not only maintenance and replacement of system components but expansion of the system overall. However, such changes take time to bring about.

It may take only a matter of days or weeks to connect a new customer to the system. But it now commonly takes ten years to conceive, design, construct and commission a new base load generating station, of whatever kind. Clearly the phasing of changes, to ensure that the system keeps in step with its responsibilities, requires foresight. Electricity planners must work with time scales which may extend over decades. The pattern of research and development carried out at a given time determines the technological options which will be available perhaps 20 years later. For obvious reasons planners with a direct responsibility for modification of the system tend to consider only those technological options which have been "proven", either by the system's own R&D programme or by someone else. Conversely, however, R&D programmes as a rule focus on design concepts which are thought likely to be acceptable to system planners, to fit into the overall philosophy which governs the development of the electricity system. There is therefore an element of the self-fulfilling about the relationship between R&D and eventual technological advance. As will be seen, this element of the self-fulfilling tends to recur repeatedly in the electricity suppliers' view of the future.

Direct modification of the electricity system usually involves a time scale of, say, one year to ten years. Planners must determine the mix of fuels to be used at that later time to generate electricity. They must plan, design, site, construct and commission new power stations, to replace those falling obsolete and to expand the system's capacity to meet anticipated future demands. They must likewise plan the necessary transmission lines, switching and transforming substations and other ancillaries, which may not require such long advance notice as base load power stations but which may nonetheless take a number of years to bring into service. Planners must ensure that the industries which serve the electricity system - materials suppliers, electrical engineering firms, boiler makers et cetera - are aware of the electricity system's plans, and have the production capacity to meet the orders placed by the electricity suppliers. In Britain the CEGB is almost a monopoly buyer of large electricity generating equipment. Its forward planning exerts a powerful and sometimes baneful influence on its manufacturing suppliers, whose business fortunes depend to a precarious extent on the adequacy of electricity system planning, The electricity planners must also, of course, arrange to have satisfactory numbers of appropriately qualified staff available; this too involves difficulties. Financing, tariff policy, and other commercial essentials similarly depend on achieving a defensible viewpoint on the future shape the system must assume to meet its obligations.

The decisions made by electricity planners determine the shape which the industry will have assumed five to ten years hence. However, not until that time has elapsed will it be possible to see whether the decisions were the best that could have been made. The feedback from decision making thus involves a time lag which makes correction of mistakes tricky. In ordinary business, if the business planners commit too many mistakes, and can find no satisfactory rectification of them in good time, the business collapses. However, as regards large-scale electricity supply, no such denouement can be permitted. Not only is the system almost certainly a monopoly, it is also likely to be providing services whose withdrawal will disrupt the entire economy of its customer society, and may well endanger life. Electricity planners are therefore excused the ultimate sanction which might otherwise apply. Society will not - cannot - allow the electricity system to collapse, however out of touch it may become with its social and economic context. In consequence the society may have to adjust to the electricity system, rather than vice versa.

A faulty decision by planners may thus entail a substantial penalty, to be paid not by the electricity system itself but by society. (Chapter 6 will consider a case in point, that of electric night storage heaters.) Even should this not be the case, a faulty decision regarding some part of the electricity system may entail reshaping other parts of the system, and perhaps bending them far out of their optimum shape. A variety of concurrent decisions may in due course, years hence, produce results which are inconsistent and contradictory. It is all too easy to create a system whose structure is grievously distorted, because of the elaborate interdependence of the system. Such distortion is further complicated by the inflexibility of many parts of the system, for example very large base load generating stations, especially nuclear stations. The shape of Britain's electricity system in 1977 has been determined by decisions dating back to the early 1950s - decisions as to research and development, fuel mix, size of units, tariff policies et cetera. It is far from clear that these past decisions have created for Britain the best of all possible systems. But past decisions have an insidious momentum. It is all too easy to let the momentum of past decisions define the limits of the future - even if those limits look very unattractive.

It is conventionally assumed that forecasts of future electricity requirements - "demand", on the assumption that if it is demanded it must be supplied - determine development policy. Before discussing the basis of current forecasting, it is essential to stress that just as forecasts influence policy, so policy influences forecasts. Indeed there is ample reason to believe that in recent years policy has influenced forecasts significantly more than vice versa. Some evidence for this will be adduced later in this chapter.

First, however, it is necessary to identify the sources of electricity forecasts, and the bases on which they are made. In England and Wales three bodies have explicit responsibility to prepare forecasts of future electricity demand: the Area Boards, which retail electricity to customers; the CEGB, which supplies electricity wholesale to the Area Boards; and the Electricity Council, which is responsible for overall planning and liaison between the electricity industry and the government. In Scotland the South of Scotland Electricity Board and the North of Scotland HydroElectric Board collaborate on an overall forecast, with the SSEB, because of its larger size, the dominant partner. The Area Boards, having a relatively immediate contact with the ultimate users, identify trends in domestic, commercial and industrial use of electricity in their areas. They anticipate new loads as a result of new house building, or industrial expansion, about which they are able to acquire comparatively precise advance information, albeit only over a period of, say, three years. Beyond that time their forecasts are more inferential, based on extrapolation of trends in many subcategories of use. The CEGB bases its forecast on a mathematical projection of past trends identified on a national basis, disaggregated differently from those of the Area Boards. The Electricity Council bases its forecasts on long-standing assumptions about the relationship between electricity use and general economic activity.

The Electricity Council receives from the Treasury and other government departments statistical information which is summarized in the "gross domestic product" - the aggregate value of all goods and services produced and supplied to end-users in Britain. A central tenet of electricity planning for decades has been the postulated parallel between the trend in per capita gross domestic product and the trend in per capita primary energy use. If the Treasury identifies and anticipates, say, an exponential growth of 2 per cent per annum in the future gross domestic product, electricity planners then consider it possible to anticipate a similar, perhaps slightly larger, annual percentage increase in per capita use of electricity. Throughout the 1950s and 1960s there was some justification for these ground rules; but recent analyses have largely discredited their future relevance. In any event the Electricity Council draws together the forecasts from the CEGB and the Area Boards, correlates them with its own initial forecast, and derives from the various provisional forecasts its planning forecast, which will guide decision-making. The Electricity Council is required, under the terms of the Electricity Act 1957, to publish each year a forecast for the electricity demand, including simultaneous peak demand, on the system in England and Wales, up to six years hence. This Electricity Council forecast in turn provides the foundation for forward planning, including the ordering of new power stations and their ancillaries.

Unfortunately the track record of the electricity forecasters has not been impressive. In the 1950s the use of electricity expanded very rapidly, taking the planners by surprise. During this period it was customary to allow a "planning margin" of 14 per cent extra generating capacity, over and above the anticipated demand at a given time. The planning margin compensates for the possibility that some system capacity will be out of service at the time of simultaneous peak demand. In Britain this peak occurs in the winter, because of the use of electricity for space heating; if weather conditions are unusually severe the demand may be greater than "normal" for the time of year, and allowance must also be made for this possibility. By the early 1960s, however, the 14 per cent planning margin which had been used in the 1950s was proving insufficient. Technical problems and fierce winter weather pushed the system to its limit in the winter of 1961-62, necessitating voltage reductions. In the following winter, the conditions were yet fiercer; as a result bulk supplies of electricity were cut off 23 times. On 25-26 January 1963 progressive grid breakdown came near to bringing about the total collapse of the CEGB system. The planning margin was thereafter increased, first to 17 per cent and then to 20 per cent above the forecast peak demand. In March 1977 it was raised to a full 28 per cent.

Such a margin is a form of insurance. However, like other forms of insurance it must be paid for. The excess capacity represented by the planning margin involves investment of capital, with concomitant carrying charges. It is of course a commitment inherent in the philosophy of guaranteed supply. It should be noted that "security of supply" of energy, as it refers to grid electricity, is not security of supply merely of fuel, as is the case for imported oil. It is security of supply at the instantaneous points of use of the electricity, involving secure operation of the grid and distribution system as well as of the power stations feeding it. The planning margin is part of the redundancy necessary to provide such security. Redundant transmission and distribution facilities are at least equally necessary and equally costly. In the last analysis the electricity user pays for the insurance which helps to guarantee his supply. He does not, to be sure, have very much say as to whether he considers the margin of insurance coverage adequate or excessive. It is in the nature of grid electricity that all users must pay for the reliability required by the most demanding; storage heaters and operating theatres are indistinguishable loads. In any case, if the margin is inadequate, and leads to power cuts, the public and political outcry is loud and wrathful, as it was in 1963. Accordingly, electricity planners have thenceforth tended to insure themselives against immediate: public wrath, by planning for margins which cushion the system amply against underestimates of demand and unforeseen problems.

Unfortunately, however, the widening excess of capacity resulting from this approach has proved gradually to be just as embarrassing as power cuts, and much more difficult to rectify. The British electricity system now has nearly 50 per cent capacity over and above peak demand - an excess of nearly 30 per cent over the planning margin. Close to 20 per cent more capacity is already under construction and due on stream within five years. To complicate matters further for the electricity suppliers, peak demand has been almost constant for the last five years, instead of increasing exponentially as anticipated.

To add to the discomfiture of the planners, an incisive study published in March 1976 by the Energy Research Group of the Open University - A *critique of the electricity supply industry,* ERG 013 - demonstrated that the planners can be held unambiguously responsible for the present predicament of the industry. It has long been customary for forecasts of the trend in electricity demand to be stated as "such and such per cent per year". Mathematically, a quantity which increases as a fraction of itself - say 3 per cent - over a regular time interval - say a year - is by definition increasing "exponentially". Each successive increase is the same fraction of a quantity which has grown larger in the interval; so each increase is larger than the last. Such exponential growth has been a central tenet of all forms of economic planning in Britain for many years, including electricity planning. Recently there has arisen a question as to whether future exponential growth is either attainable or desirable. However, even the critics of anticipated future exponential growth have generally conceded the accuracy of past descriptions of trends. It has therefore come as a disconcerting surprise to learn that past statistics for key economic indicators do not necessarily support the assertion that historical trends have been exponential. As the

OU Energy Research Group revealed, this criticism applies forcefully to the forecasts by the Electricity Council.

The ERG took the actual data of simultaneous peak demand on the CEGB system from 1960 to 1975. To even out abnormal weather conditions and other anomalies they took a rolling five-year average of the peak demand, and plotted the average on a graph, year by year. Throughout this period, of course, the Electricity Council had been describing the developing trend of peak demand in terms of percentage growth - implying an exponential curve from year to year. But the OU team carried out an almost insultingly simple mathematical exercise on the actual data. They measured the slope of the curve plotted by the rolling average. For a genuine exponential, the slope increases as a fraction of itself, just as the original quantity does. The OU, however, found that the slope they measured, far from thus increasing, remained almost constant throughout the fifteen years from 1960 to 1975, and indeed into the 1970s began slightly to decline. In other words, the simultaneous peak demand was not growing exponentially; at most it was rising along a straight line, and by the 1970s was beginning to level off toward a constant value.

The ERG findings infuriated the Electricity Council. The Council addressed an irate letter to the *Electrical Review* decrying everything about the study and concluding by suggesting that the ERG ought to go back to kindergarten. However, the Council had a great deal to be embarrassed about. Whatever the competence of their forecasters and their forecasting techniques, the final published version of their forecasts in recent years had begun visibly to lose touch with reality. In the Council's Annual Report for 1974, they very reasonably declared that the unsettled state of the world energy market after the OPEC price rises of the previous winter made it difficult for the Council to comply with its statutory obligation to publish a forecast for electricity demand six years hence. They would therefore, they said in the report, publish only a provisional forecast: that simultaneous peak demand in England and Wales would grow until 1979-80 at a rate of 6.4 per cent per annum. The same report contained data for peak demand from 1964 to 1974, which revealed that the steepest rate of growth in peak demand at any time in the preceding decade was only 3.5 per cent. At the very least it must be said that here policy was clearly influencing forecast, rather than vice versa. But the policy in question was also, like the forecast, far out of touch with economic reality.

Probably the aspect of policy which has most profoundly influenced forecasting is the endorsement of the concept of economy of scale, with no apparent upper limit, either of system or of unit increments. The original concept of the grid was of course prompted by the urge to interconnect separate power stations and improve their collective load factor - which implied more effective use of capital plant, a basic tenet of economy of scale. Up to a point such an approach is clearly worthwhile - provided other factors are equal, which they assuredly need not be. Up to a point expansion, interconnection and interdependence of a system adds flexibility and reliability; where that point is must now be a matter for conjecture. It is undoubtedly, however, likewise true that beyond that point further expansion and interdependence makes the system not more flexible but less, and imposes a variety of penalties, adversely affecting planning, development and operation of the system. The recent problems of the British electricity suppliers unquestionably arise in considerable part from the present scale of the system.

Central to these problems are those created by the size of individual units which have been progressively regarded as achieving economics of scale. The concept of economy of physical scale of a generating unit rests on certain presumptions. A unit twice as large does not require twice as much material, or cost twice as much. The larger size may enhance certain aspects of the unit's performance, for instance the conversion of heat to electricity - although at present sizes the available improvements must be measured in fractions of percentage points. A unit twice as large does not require twice as many personnel to operate it. Against these advantages must be set some disadvantages. The capital saving associated with the larger scale may be offset by the longer time taken to build the unit, especially if interest rates are in double figures. The reliability of the larger unit must be as good as that of an equivalent group of smaller units - a requirement which goes against the grain of the increasing complexity of larger units. If a larger unit encounters problems in construction, leading to schedule overruns, the carrying charges may wipe out the anticipated capital saving; an early major outage may do likewise. The failure of a larger unit in operation is much more traumatic for the electricity system, and the system must incorporate redundancy sufficient to provide back-up for such large-scale failure - which also incurs further capital costs.

Furthermore, the unit size now considered "economic" means that it now commonly takes 10 years - sometimes more - to order, locate, construct and commission a new base load generating station. But even the electricity authorities concede that it is now impossible to prepare convincing forecasts of electricity demand six years or more hence. Accordingly, it is now necessary to order a new base load station some four years before the planners can ascertain with any conviction that the station will be required. Ordering the station then becomes not an act of foresight but an act of faith, founded on policy. The suppliers must then endeavour to ensure that electricity demand 10 years hence will have increased to the level warranting addition of the new station. The internal objectives of the system planners thus take precedence over the social and economic role of the system. Planning, as conventionally understood in mixed economics, disappears; the technology takes over and reproduces itself according to its own introverted criteria. Any business run on a normal commercial basis which thus defined the terms of its existence would be unlikely to survive. Only by virtue of the essential role of the electricity system can such a travesty of planning long endure.

Unfortunately, those industries which in turn provide the requirements of the electricity system are not so comfortably insulated against the judgment of the marketplace. It may be easy to persuade society that the electricity system cannot be allowed to collapse. It is not so easy to persuade society of the imperative need to sustain the electrical engineering, boiler making and turbine industries which depend for their existence on orders from the electricity suppliers. Questions of resource allocation begin to loom large when there is no immediate threat to light and heat. In 1976 it became clear that the future of the ancillary industries was in jeopardy, through comparatively little fault of their own. Resounding misjudgments by the electricity planners in the 1960s had led to rapid expansion by the ancillary industries, as they responded to the wave of orders for new plants. As the resulting excess of generating capacity began to accumulate, orders dried up, and the ancillary industries faced a debilitating vacuum. Their plight became so pressing that in mid-1976 the government asked the Central Policy Review Staff to carry out an urgent investigation of ways to save the ancillary industries from complete collapse. By late autumn the main details of the CPRS proposals had been copiously leaked to the media. They revealed a poverty of imagination and a hidebound commitment to discredited criteria which if taken at face value cast profound doubt on the competence of the CPRS.

The two major recommendations, eventually formally published in December 1976, called for ordering a huge new coal-fired base load station, Drax B, despite the CEGB's well-founded insistence that the station need not be ordered for several years; and the rapid development of a 1,300 megawatt turbo-alternator set, twice the size of the largest presently in use in Britain. It is frankly difficult to envisage any moves more likely to aggravate the medium-term difficulties of the electricity industry and its suppliers. To order Drax B prematurely would not only impose further superfluous capacity on a system already buckling under the costs of the present excess; it would also make the prospects for the power station constructors by the early 1980s even bleaker than they are now. The utility of a 1,300 megawatt generating set is likewise profoundly questionable on its own terms. The reliability problems created by sets less than half this size have become a perennial headache for the electricity system, and the putative capital savings and improvement in efficiency can be wiped out by a single major outage early in the life of the set - an occurrence which has already been all too frequent with sets of 500 and 660 megawatts.

Coupled with these recommendations for further technological gigantism go recommendations for further centralization: mergers of the two existing turbine manufacturers, GEC and Parsons, and the two existing boiler makers, Clarke Chapman and Babcock and Wilcox. Given that only two huge projects are recommended, this corollary seems inevitable. Whichever firm received the commission to, develop the 1,300 megawatt set, the other would be left in the cold - ditto for Drax B. It remains, however baffling that the CPRS - considered "independent", and therefore presumably able to take into account not only traditional attitudes and options, but also unconventional ones - should propose for an ailing industry an even larger dose of the medicine whose side-effects have created its present pathology.

The CEGB, it should be added, has assumed a lofty lack of interest in the misfortunes it has inflicted on its own suppliers. In June 1976 its "Corporate Plan" (see pp. 17-18) made clear its intention to order no further generating stations until the 1980s, unless the government paid for the extra cost of premature investment. In response to the CPRS proposal the CEGB has relented little from its non-negotiable attitude, declining to countenance the Drax B proposal without government subvention. Consider the position which would by 1977 have arisen had the CEGB been permitted to embark on its proposed programme of 41,000 megawatts of light water nuclear stations (see pp. 34-35). There seems little doubt that the technological, financial and political ramifications in the interim would have left the CEGB in a desperate state, from which even the most heroic and selfless government endeavours might have been hard pressed to rescue it. Viewed in this light the CEGB's disdain for the present sufferings of its suppliers is unbecoming and uncharitable.

In general it is useful to consider two different, and inversely related, concepts of economy of scale: the traditional economy of physical scale, and the more recently recognized economy of time scale. It is becoming steadily more apparent that economies of time scale deserve at least as much emphasis as economics of physical scale. In planning, this implies smaller physical scale, leading to shorter construction times. Smaller physical scale also offers opportunities for technical flexibility; for diversity, for instance of type and geographical location; and for sharing infrastructure, for instance by series orders of components. It would be possible, for instance, to develop an array of urban-sited, coal-fired total energy stations of modest scale, perhaps utilizing fluidized bed combustion, on the sites of CEGB stations now being shut down. Such an initiative from the government would offer the ancillary industries the prospect of a future at once healthier and easier to foresee. The effect of such a programme on skilled employment would likewise be beneficial.

However, it will be objected that such an approach involves a fundamental change in the philosophy of the electricity supply industry. So it does; but so does the present trend to gigantism and centralization. If new generating capacity is to be added on the basis of policy - as would be the case with the recurrent proposals, surfacing again in the CPRS report, for ordering one or two new base load stations every year, to keep the power station builders busy - it will then be necessary to create the users and the uses for the capacity. Policy will then definitively influence forecasts, indeed will define them. It is for instance, long since clear that electricity tariffs have served to promote the use of electricity, as will be discussed in Chapter 6. Advertisements, too, encourage increasing use of electricity, however much dutiful obeisance is paid to the need for conservation and efficiency. Such advertising already betrays a flavour of the schizoid, attempting to convey two inherently irreconcilable messages to bemused customers. Thus far the public-service advertising by the government has remained comparatively coherent, stressing savings rather than use. But if it becomes national policy - on the part of the government as well as that of the electricity suppliers - to expand the system capacity and the role of electricity in the economy, there can be no doubt that the official planners will have to avail themselves of many more means of persuasion.

In essence, such a policy amounts to running the electricity industry for the good of the electricity industry, not for the good of its customers. Dr Walter Murgatroyd, Professor of Thermal Power at Imperial College, London, made a telling comment in his inaugural lecture in 1969. He pointed out that the off-peak tariff was designed to encourage electricity users to time their use of electricity to suit the characteristics of the supply system. Other tariffs, especially industrial, serve the same purpose. The electricity supply industry has always presented itself as a public service, functioning on behalf of its users, responding to their requirements. Unfortunately, however, if the current philosophy of scale and centralization continues to prevail, it seems inevitable that electricity users will have to adapt to the convenience of the system, rather than vice versa. Those electricity users who are also taxpayers will find the development doubly disturbing.

The civil nuclear industry, to be sure, will feel right at home. The historical record makes it clear that the development of civil nuclear technology has always progressed on the basis of government policy, government commitment and government edict, as described in Chapter 4. In the nuclear context policy has always influenced forecasts, not infrequently in direct contradiction of other determinants. It is of course strictly true to say that the Atomic Energy Authority has no explicit responsibility for forecasting energy use patterns, or the role which nuclear systems are to play in them; such responsibility remains with the electricity authorities. However, the AEA has from its inception exerted a powerful influence on the official view of nuclear electricity in forward planning, beginning with the White Paper of 1955 (see p. 20).

The nuclear programme decreed in that White Paper, and the programme modifications and successors which followed, were dictated according to what the AEA considered appropriate. This proved repeatedly to be significantly more conspicuous than the electricity authorities were prepared to welcome (see p. 25). Even at that time doubts were expressed about the possible scale and speed of commercial application of civil nuclear systems within the British electricity sector. But the AEA's research and development activities, encompassing five different types of power reactor, pressed on regardless. No comparable public funding was available for any other category of energy technology. When problems cropped up with commercial nuclear technology, the sufferers were the construction consortia and the electricity suppliers, not the AEA. In that sense the AEA has not had to answer for the consequences of its contribution to forward planning. It has been accordingly a curiously hermetic body, preoccupied with its own concerns, yet wielding considerable - some would say disproportionate - influence in official energy circles. Even today, in 1977, the Energy Technology Support Unit of the Department of Energy is located at the AEA's Harwell research establishment. The former Director of that establishment, Dr Walter Marshall, is simultaneously Deputy Chairman of the AEA, Chief Scientist at the Department of Energy, and Chairman of the Advisory Council on Research and Development for Fuel and Power. It is thus scarcely surprising to find that in the official view of future energy development in Britain nuclear electricity takes pride of place.

In 1974, in evidence to the Royal Commission on Environmental Pollution, the AEA put forward what it called a "reference programme" of nuclear power development in Britain. This reference programme anticipated having in operation in Britain, by the year 2000, 104,000 megawatts of nuclear generating capacity, of which 33,000 megawatts would be fast breeder reactors. By the year 2010 the total capacity would be 193,000 megawatts, including 89,000 megawatts of fast breeder reactors. The total generating capacity in Britain in 1977, fossil-fuelled, nuclear and otherwise, amounts to some 66,000 megawatts. The AEA was thus anticipating that in some 25 years it would not only be possible but desirable to construct nuclear generating capacity equivalent to nearly twice the entire capacity of the existing system - to order it, build it and bring it on stream. The nuclear generating capacity operating and under construction in 1977 amounts to some 11,000 megawatts, depending on the output eventually achieved by the AGRs. The AEA's reference programme thus calls for nearly a 10-fold increase in the installed nuclear capacity, to be completed within 25 years. By 1976 even the AEA was beginning to realize how far out of touch these projections were with economic realities. It was reiterated that this was not a "forecast", merely a "reference programme" - although presumably, since it had been advanced as a basis for policy analysis, it must have been regarded as plausible and achievable. An exchange of letters in *The Times,* between Sir John Hill and Sir Brian Flowers, provided an insight into the differences by this time dividing the Authority members themselves. Sir John insisted, as he likewise insisted in a growing series of articles, that "no responsible person" was advocating a rapid expansion of nuclear generating capacity, and that the AEA reference programme was chosen to convey an extreme upper limit, which should not be taken as the AEA's own proposal. Sir Brian flatly challenged the latter assertion, and declared that the AEA's published reference programme was already significantly smaller than a programme described in early AEA evidence to the Royal Commission.

Nevertheless, Sir John persisted. On 13-14 December 1976 the British Council of Churches held two days of hearings in London into nuclear issues, especially those relating to the fast reactor. Sir John told the hearings yet again that "no responsible person" wanted to build a large number of fast reactors in a hurry; all the AEA wanted was permission to construct one full-scale plant, CFR-1. Then Sir John's colleague, R. L. R. Nicholson of the AEA's planning group, took the stand. He agreed that the 1974 reference programme capacity was unlikely to be achieved by the year 2000. At this a panel member inquired when, in that case, Mr. Nicholson thought it might be possible to have the proposed 33,000 megawatts of fast reactors in service. Mr. Nicholson replied, "Oh, perhaps 2005 or 2010". Sir John and the Director of the Dounreay Establishment, C. W. Blumfield, had earlier told the hearings that they did not anticipate being prepared to order a truly "commercial" fast reactor power station until perhaps three years of operation of CFR-1 - that is, until 1990 or thereabouts. Allowing 10 years from ordering to completion and commissioning, and combining Mr. Nicholson's view with that of Sir John and Mr. Blumfield, such a programme would mean that by the late 1990s there would have to be more than 20 full-scale fast reactor stations under construction simultaneously - not to mention the other "thermal" nuclear stations, which were supposed to be twice as numerous. By any reasonable criterion such a programme is "rapid expansion" of the nuclear programme. Some would call it headlong. Whether finances, industrial capacity, skilled personnel - or even plutonium for fuel - would be available in adequate quantities must be profoundly doubted.

In this connection, it is also important to cite conclusions published in December 1976 by Leslie Grainger, one-time staff member of the AEA at Harwell, now Board Member for Science of the National Coal Board. In "The nuclear issue as seen by a competitor" *(Energy Policy,* December 1976), Grainger took exception to the assertion often made by nuclear proponents, that the fast reactor makes possible a 60-fold increase in the amount of energy which can be extracted from a given amount of uranium. Grainger demonstrated that for plausible assumptions about the rate of expansion of the nuclear electricity system, the time scale to achieve uranium utilization significantly above the thermal rate of about 1 per cent must be measured not only in decades but in centuries. For instance, if the growth rate of the electricity system is above 3.5 per cent per annum, the overall utilization of the energy in uranium can never exceed 5 per cent. Mr Grainger's findings have not thus far received any substantial challenge from nuclear advocates; but the 60-fold increase continues to be claimed in speeches and articles.

In June 1976 the Advisory Council on Research and Development for Fuel and Power (ACORD), under the chairmanship of Dr Walter Marshall (see p. 53), published a report entitled *Energy R&D in the United Kingdom.* Subtitled "A discussion document", it certainly on this score proved a success, provoking a barrage of discussion, much of it very critical. It put forward seven "scenarios", describing possible courses of development of energy use and supply in the UK, under various constraints, in order to identify the programmes of energy research and development which each scenario would entail. The models used to devise these scenarios were not included in the report, making it difficult to establish the bases for the characteristics of each scenario; inevitably, as a result, the seven scenarios chosen for discussion appeared not a little arbitrary, both in their frameworks of constraint and in the deductions drawn therefrom. As far as could be ascertained, the models appeared to embody relationships between energy and economic growth which had been conventionally accepted throughout the two preceding decades of low world energy prices. A telling footnote on Table 2 declared that "structural shifts within the economy are assumed to have only a second-order effect on energy consumption": this although it is clear that a structural shift from energy-intensive goods to less energy-intensive goods and to services is bound to loosen yet further the already less than strict link between per capita primary energy use and per capita GDP. Such criticisms were put forward in profusion, although it is unclear what note will be taken of them by ACORD.

One feature of the seven scenarios selected for display stood out. With the exception of a scenario labelled "Limit On Nuclear", all entailed steady expansion of nuclear electricity. Even the "Low Growth" scenario, otherwise one of the gloomier scenarios, assumed 40,000 to 50,000 megawatts of installed nuclear capacity by the year 2000 - presumably ordered by 1990. Table 2 used the phrase "up to a maximum of 40 to 50" - but the accompanying text called 40 to 50 the lower "extreme" of the planned nuclear capacity over the six scenarios which include nuclear expansion. Table 3 was headed "Contributions of Technologies and their Overall Importance". The entry under "Energy Conservation Technologies", gave the top five-star rating to all three entries, conservation in buildings, industry and transport respectively. However, since the "technologies" are not otherwise specified, the usefulness of this acclaim is questionable. No other main entry got unanimous five-star rating; but "Nuclear Energy" got five stars under "Uranium Supply", "Fuel Processing and Reprocessing", "Thermal Reactors", "Reactors", "Radioactive Waste Management", and "Nuclear Safety"; only "Nuclear Process Heat" had to make do with two stars. Other five-star technologies included "Electricity Generating Plant", "Transmission and Distribution", and "Electricity Utilization Technologies". Among other five-star top priority technologies for research and development, only "Coal Mining Technologies", "Continental Shelf Technologies", "Gas Transmission, Storage and Distribution" and "Gas Utilization Technologies" were unrelated to nuclear electricity.

The report, in stressing the importance of nuclear electricity, also stressed the role of the fast reactor, alluding to the 60-fold increase in uranium utilization it is alleged to offer. (Indeed, it was Leslie Grainger's participation on the Advisory Council that prompted him to prepare the analysis which demolished this claim - see p. 55.) The foreword of the ACORD report asserted that "The dominant aim of the UK's [energy] strategy must be to open technology options". The report also declared that "The particular scenarios adopted in this exercise should not be interpreted as official forecasts". They do, however, give an insight into the policies which are influencing official forecasts. It is becoming increasingly apparent, as the report itself observed, that "The UK simply cannot afford to open all these options entirely at its own expense". As noted earlier, the pattern of research and development carried out at a given time determines the technological options which will be available perhaps 20 years later. All the indications are that today's emphasis on nuclear grid electricity and the fast reactor, far from opening options, is steadily foreclosing them.

6 Money for megawatts

The early development of the British electricity system took place gradually. Individual power stations were small, as were their distribution networks. The time taken to construct them lay well within manageable periods, making it possible to raise the necessary capital on plausible terms. Interest rates were low, and cash flow projections served adequately to establish the financial feasibility of undertakings. Electricity as a commodity was subject to classical market constraints. Although a given supplier had a monopoly of supply, electricity could not really be considered essential. If it appeared too expensive it would not be purchased, and the supplier would go out of business. Prices were stable, inflation was minimal and changes occurred slowly. An electricity supplier could get ready access to finances for investment, to expand his system. Tariffs charged for electricity supplied provided a cash flow which covered current expenses for fuel supplies and staff, and allowed a manageable proportion of new investment to be financed from retained profits. Borrowing the remainder was, for a successful supplier, straightforward.

Gradually increasing government involvement accompanied the steady move toward increasing scale of units, and increasing centralization. Nevertheless, when the Electricity Act 1947 took effect, 560 separate supply undertakings were brought together into the publicly-owned British Electricity Authority. The Act of course made fundamental changes in the financial terms of reference of the electricity supply system. But just the dramatic leap in size of the financial organization was itself the most fundamental change brought about by nationalization, as far as electricity supply itself was concerned. It is, for instance, very much easier for a single very large organization to get access to a single very large block of capital than it is for an equally productive group of small organizations to get access to an equivalent amount of capital divided into small quantities. This factor has proved singularly important.

The Electricity Act 1957 took its lead from the 1947 Act, reiterating that "It shall be the duty of the Generating Board and of each of the Area Boards so to perform their functions as to secure that the revenues of the Board are not less than sufficient to meet the outgoings of the Board properly chargeable to revenue account, taking one year with another" (Electricity Act 1957, Clause 13). In other words, it was not necessary for the Boards to show a profit; but it was necessary for them not to show a loss. A similar financial reponsibility was laid on the Scottish Boards.

In terms of annual gross capital formation, the CEGB is now much the largest organization in Britain. It is a monopoly providing an essential service, as are its sister Boards in Scotland. However the supply Boards meet, or fail to meet, their financial responsibilities, one fact overrides all others. No supply Board can be allowed to go bankrupt. The effect of this constraint on access to finances, whether from central government or otherwise, regardless of resource allocation considerations, cannot be underestimated. It underpins all aspects of the financing of the electricity supply system.

Financial analysis of course plays a key role in planning future development of electricity supply. Anticipated future use of electricity, as discussed in Chapter 5, determines the programme of construction of new plant, to replace the old and to expand the system. It is also necessary to plan the optimum "mix" of generating plant variously fuelled, the optimum scale of unit increments, and so on. All these planning decisions must be positioned within plausible financial terms. Tariffs will affect the level of electricity use. The choice of accounting procedures will affect the anticipated financial performance, and therefore the worth, of proposed investments: allowances for depreciation, for instance, or for the influence of inflation. The choice of future fuel mix, and therefore of new orders for generating plant, will depend on the anticipated prices of various fuels, and how important the fuel price is per unit of electricity generated. The price of coal, for instance, is much more influential than the price of uranium, since a given tonnage of uranium produces much more energy than a given tonnage of coal. On the other hand, the capital cost of a nuclear station per unit output capacity is higher than that of a coal-fired station; so the choice of fuel mix will also depend on the anticipated behaviour of interest rates on capital invested. Financial considerations will also influence the size of unit increments of plant, in pursuit of economies of scale. Questions of anticipated fuel cost and interest rate are specially challenging when fuel costs and interest rates are as volatile as they have become in the 1970s. The decision as to which type of station to build involves a commitment to bear the relevant costs for 30 to 40 years - 10 years of construction followed by the plant's useful life - a period over much of which it is impossible to anticipate such financial details with more than wishful thinking.

Investment in the British electricity supply system is planned, as described in earlier chapters, by the Electricity Council and the CEGB, the South of Scotland Electricity Board and the North of Scotland Hydro-Electric Board, with the predominant role being played by the CEGB. The CEGB, for instance, prepares each year an investment programme, updating that of the previous year, for replacement and addition of facilities. This investment programme is presented via the Electricity Council to the Minister (now the Secretary of State for Energy) for his approval. Under the terms of the 1957 Electricity Act, such approval must be obtained before investment is undertaken. It has of course for more than 10 years been characteristic of major investment that the time taken to fulfil an investment programme is significantly longer than the life of a Parliament, to say nothing of the tenure of a Minister. The fact is largely taken for granted, but it must have an effect on the quality of Ministerial responsibility for major investment decisions.

The capital invested by the CEGB has come partly from its annual operating surpluses, paid into a "Generating Reserve", and partly from borrowing. The Electricity Council is the borrowing agent, the CEGB in turn borrows from the Council (as do the Area Boards). The 1957 Act set an upper limit of £1,400 million on the total amount which could be borrowed by the Electricity Council, on its own behalf and that of the various Boards. By 1976, in successive amendments of the Act, this limit had been raised to its present level of £6,500 million. As of 31 March 1976 the outstanding borrowing totalled £5,223.5 million, of which £3,715.9 million was in the form of loans from the Treasury and £859.9 million in the form of loans from overseas sources. Of the total, £3,369.2 million was borrowed by the CEGB. Since 1961-62 the CEGB has invested annually upwards of £200 million; earlier years were not much less. The percentage of this annual investment provided by internal funds has been mostly between 40 per cent and 50 per cent, although the somewhat smaller annual investment of recent years has pushed the self-financing ratio up to between 60 per cent and 75 per cent. Nevertheless the interest payable on outstanding debt has climbed steadily in the 1970s. In 1972-73 it was £192.3 million; by 1975-76 it was £273.1 million. The increase is due partly to the larger size of the debt, and partly to the steady increase in average interest rate: 6.2 per cent in 1971-72, and 7.7 per cent in 1975-76**.** For the Electricity Council as a whole the interest payable in 1975-76 amounted to £424 million. Overseas loans to the Council are underwritten with a 100 per cent guarantee from the government, as to both principal and interest. During 1975-76 a total of £525 million of new loans were negotiated; the lowest interest rate involved was 12.5 per cent. As older loans are refinanced, the average rate of interest will undergo a further substantial increase. Nevertheless, because, of its size and characteristics the electricity supply system will continue to have access to capital much more easily than any number of small investors. This question of access to capital remains a stubborn asymmetry when comparing a single centralized energy supply system with an equivalent number of smaller decentralized systems - even though the economic performance of the aggregate of smaller systems might offer significantly greater promise.

Much the largest single item on the cost side of the revenue account is expenditure on fuel: £1,465.9 million out of a total expenditure of £2,331.2 million by the CEGB in 1975-76. This cost has leapt upwards since 1973, with coal prices following the lead of oil prices; in 1972-73 the CEGB paid only £595 million for fuel. Unfortunately, the CEGB has only a limited amount of room to manoeuvre among different fuels, according to the availability of generating capacity already in service. At it happens, the current excess of system capacity does allow a shift in the merit order, of different base load plants, according to whether the current price of coal is preferable to that of oil or vice versa. But the added flexibility has been gained at the cost of unnecessary capital charges, and can hardly be considered an advantage. The fuel mix employed by the generating system can be changed only very gradually, and decisions to effect such changes - such as building new generating capacity - must be taken perhaps 10 years before the relevant fuel costs will be applicable. To adopt a policy of diversity of fuels, as the CEGB has attempted to do, implies that there will in due course be enough extra stations of the different kinds to permit switching generation from one fuel to another. This in turn implies redundant capacity, and the consequent carrying charges. As seems so often to be the case, planning of the future distribution of fuel use requires first of all an act of faith: faith, for instance, that 10 years hence nuclear electricity will be cheaper than coal-fired electricity. To be sure, the criterion of eventual "security of supply" is now given considerable weight alongside that of lowest eventual fuel costs. However, the problems which might interfere with supply from different kinds of station are different in kind. It may be considered necessary to allow redundant capacity of each different kind, involving further capital charges. Otherwise the planned diversity may prove illusory.

In any case the electricity supply system is not in practice entirely free to adjust its fuel mix according to its own judgment. Government policy continually intrudes. In earlier chapters the government's role in planning nuclear generating capacity has already been described; the government has likewise regularly indicated its preference for a particular CEGB fuel mix - one, for instance, which burns more coal than the CEGB might choose to burn, if left to itself. The government has also recently made its interest prominent concerning forward ordering of fossil-fired stations, turning down oil-fired base load stations and advocating early ordering of the coal-fired Drax B station. The government, through Ministerial control of the industry's investment programme, can exercise - and indeed has exercised - an ultimately definitive influence on the future fuel mix. Unfortunately from the point of view of the supply industry, the criteria which affect government influence are not necessarily coincident with those applied by the electricity planners. As mentioned earlier, the lead-time before fulfilment of such a decision is usually considerably longer than the tenure of the government participants in the decision. Government influence also affects fuel decisions in the short term - for instance as to the size of coal stockpiles which are to be stored at power station sites. A larger stockpile incurs larger charges for the electricity supplier, although it is of course welcomed by the National Coal Board.

The financial significance of wages and salaries is comparatively minor: a total of £525 million for the entire Electricity Council accounts in 1975-76, out of a current revenue expenditure of £2,849 million. For the CEGB the figures are yet more striking: £70 million out of a current revenue expenditure of £2,331 million, or only 3 per cent. However, as will be discussed further in Chapter 7, industrial unrest can lead to financial consequences which are far out of proportion to the cost which might be incurred as a result of wage increases, a point which is not lost either on management or on unions.

The electricity supply industry draws its income almost entirely from the sale of electricity to customers. The South of Scotland Electricity Board and the North of Scotland Hydro-Electric Board generate the electricity, distribute it wholesale and retail, deliver it to end-users, and receive remittances from customers directly. In England and Wales the CEGB generates the electricity "in bulk", and transmits it to the Area Boards, who buy it from the CEGB at the wholesale "Bulk Supply Tariff", and sell it to customers at a variety of retail tariffs. The structure of electricity tariffs is intricate and evolving. The philosophy which underlies present tariff policy was described by R. W. Orson of the Electricity Council in *Electrical Review,* 20 August 1976: "Electricity tariffs have many purposes to serve: they should give customers the correct cost message, they should be understandable (and this is essential if the first purpose is to be achieved) and they should be regarded as fair in charging different customers for the electricity they use. Over and above these purposes is the requirement that tariffs should bring in the right amount of revenue for the undertaking to continue on a sound financial basis." As Orson goes on to discuss, the implications of these objectives are by no means unambiguous in practice.

Tariff must obviously cover running costs - fuel, maintenance, staff, and other items which fall within a given accounting year. They must also make appropriate provisions for longer-term expenditure - that is, for investment. Orson identifies an intriguing paradox influencing the evaluation of the relevant financial data. He points out the difficulty of calculating the present worth of a power station or distribution line, neither of which is bought and sold on the open market. "The real worth of these assets depends in essence on how much they can earn in the future or, more precisely, the present value of the cash flows the assets are likely to generate in the future. This definition may appear to be circular because it says, in effect, that the real value of the assets depends on the price that can be charged for electricity, while the price that needs to be charged obviously depends on the real value of the assets" - if suitable provision is to be made for depreciation and replacement. Orson continues "However, in an expanding industry, the prices charged must also make it worthwhile to continue to invest, so that, given expansion, there must be a consistent relationship between the cost of new plant and the worth of existing plant." There is in the argument more than a hint of infinite regression: the paradox is not resolved, merely transplanted. It is possible to see in the situation further evidence that the policy underlying the development of the electricity supply industry centres around faith that the industry must be there, because it is there, because it is there. In the short term such faith is sustained by the existence of a vast array of customers dependent on the supply of grid electricity and constrained to accept the edicts of a monopoly supplier. In the long term the faith may require less tautological support.

The ideal electricity customer is one who uses a great deal of electricity at an unvarying rate: for instance the operator of an aluminium smelter. By comparison a domestic user is a difficult customer, whose use of electricity is idiosyncratic, inconvenient and insufficient. The cost of supplying electricity depends on the basic cost of provision of supply, the total amount of electricity used, and the peak demand made by the user. The first category of cost includes connection, metering and administration. 'I'he second category covers the cost of fuel used to generate the electricity delivered, and repairs and maintenance. The third category, the cost related to peak demand, is in theory the additional cost incurred by adding the necessary generating facilities to meet the particular peak demand. In practice, costs attributed to this category are almost invariably subject to multiple counting, since only the last switch thrown "on" actually necessitates bringing on stream the last increment of generating capacity. Only major loads truly qualify for charges related to peak demand, and then only with qualifications.

Electricity tariffs are designed to recover the costs of supplying electricity; this philosophical basis of tariff structure has been cited repeatedly by industry spokesmen in recent years. There is nothing sacrosanct about the principle; nonetheless it has a certain hard-edged consistency about it. A corollary of the principle is, however inevitable. Large industrial users are easier to supply than small domestic users. This is not the fault of the electricity supplier; it is inherent in the shape of the enterprise. But it means in practice that, if the supplier is to recover the costs of supplying electricity from those to whom it is supplied, the small domestic user will pay perhaps twice as much per unit of peak electricity as will the industrial user. Some well-behaved industrial loads will be charged still less. (The Anglesey and Invergordon aluminium smelters have long-term contracts, drafted in expectation of cheap AGR electricity, which compel the CEGB and SSEB respectively to supply electricity at a small fraction of actual 1977 generating cost.)

The supply industry does not like to hear such a tariff described as "promotional". It likewise dislikes suggestions that small users are in any way subsidizing larger users. But small users must be forgiven for resenting the industry's obvious preference for large users. A domestic user of electricity makes a commitment each time he or she invests in an appliance. In absolute terms the investment may not be large, but it will represent a significant portion of the family budget. The domestic user is then a captive client of the electricity supply for the useful life of the appliance. The charge which will be made for the necessary electricity is of course set unilaterally by the supplier, and may - will - increase during the lifetime of the appliance. The only sanction open to the user is to reduce the use of the appliance, which strictly increases the capital cost of each period of use.

The most notorious recent demonstration of the implications arose in the early 1970s A vigorous campaign of promotion by the electricity industry in the 1960s persuaded hundred of thousands of people to invest in "night storage heaters". A night storage heater is an array of firebricks enclosing a heating element; the element operates during off-peak hours, and the heat retained in the bricks is then gradually released throughout the following day. The system is inflexible and inefficient, at its hottest in the middle of the night; but it is a simple system to install, and its capital cost is moderate. However, the main attraction which convinced buyers was the industry's emphasis on using low-priced off-peak electricity - electricity which, it was claimed, cost only half as much as the daytime electricity. Unfortunately, the industry's promotion proved entirely too successful. It gradually became apparent that the surge of load which occurred when the night storage heaters switched on was requiring the operation of generating plant well down the merit order: that the night storage heaters were using electricity which cost the suppliers considerably more to supply than the customers were paying. The suppliers' response was predictable and understandable. They proposed an increase in the off-peak tariff. However, the increase they proposed boosted the off-peak tariff to well over half the peak tariff, and customers all over the country were enraged. The customers pointed to the industry's promotional commitment to "half-price" electricity; and many MPs took up the cry. The supply industry, under stern pressure from the government, retreated from its position - but did not abandon it completely. In return for an agreement to postpone the increase of the off-peak tariff the industry received government agreement that the increase would nevertheless in due course - some two years later - come into effect. Night storage heaters have no moving parts; they do not wear out. But the market in second-hand storage heaters has been glutted, as disillusioned domestic users have disconnected their white meter white elephants. In the last analysis domestic electricity users are captive clients of the suppliers. If the suppliers get it wrong, the domestic users have to bear the consequences.

Industrial users are not, in theory, as vulnerable as small domestic users. An estimated 16 per cent of the electricity generating capacity of Britain belongs to private concerns - everything from small generators to large standby plant to full-scale privately-owned power stations. However, the public electricity supply industry has long had an evangelical approach to the supply of grid electricity. Concerns which rely on their own private generation are viewed as wandering from the path of righteousness. For many years the annual reports of the public electricity suppliers referred with fervent missionary zeal to "so-and-so many megawatts won from private generation". To be sure, the public supply industry has always used more than sermons to bring the errant into the fold. If a potential customer for grid electricity generates any of his own electricity, the tariff which will apply for grid supply is "negotiable" - and unpublished. A concern generating its own electricity is likely, for instance, to want a connection to the grid, to supply grid electricity when the private generating plant is shut down for maintenance or such. To obtain such a grid connection the concern is likely to be asked to pay a charge which some would call penal. The grid operators insist that the charge is reasonable, because there must be grid supply generating plant available if and when the customer decides not to use his own plant. However, this argument implies that the customer is adding his load to the system peak; it rings hollow when applied to the entire range of customers requesting grid backup for private generation. Nor will the grid accept privately-generated electricity in reciprocal exchange for electricity supplied from the grid. The grid will pay only a nominal amount for private electricity, far below what it charges for grid-supplied units. To an outsider, the grid operators appear to be exerting all possible pressure to persuade such customers to abandon their own generation and submit themselves to the hegemony of the grid.

A tariff structure designed to recover from each customer the cost of his supply, as costed by the supplier, is in no sense implicit in the nature of grid electricity. It is on the contrary a policy decision on the part of the supplier. When tariffs are defended by reference to the principle, the defence is no more than a restatement of policy in slightly more philosophical terms. Whether intentionally, or otherwise, the tariff policy thus adopted favours those customers whose requirements are closest to the preferred operating characteristics of the electricity system. A small user is in no position to challenge the tariff in any way. A large user is offered Hobson's choice: pay the charge imposed by the electricity supplier, or accept the entire responsibility for private electricity supply unsupported by grid backup. Tariffs thus give the electricity supply industry considerable leverage over the way in which customers use the industry's product.

However, the electricity supply industry does not have a free hand with the setting of tariffs. There is no specific reference in either the 1947 or the 1957 Electricity Acts to the role of government in tariff policy, but such a role certainly exists and has recently been much exercised. The Prices and Incomes Board of the Heath government in the early 1970s imposed controls on many prices which would otherwise have increased, including electricity tariffs. Similar controls were further exercised under the prices and incomes policy of the Wilson government. The government policy of price restraint was much resented by the electricity supply industry, faced as it was with a dramatic leap in fuel costs and an insidious increase in interest charges. In fact the electricity supply industry was more fortunate than many other industries subject to government price restraint: in 1973/74 and 1974/75 the government made direct grants to the industry to reimburse it for the losses incurred under price restraint. Nevertheless, in his Foreword to the Electricity Council Annual Report for 1974/75, Sir Peter Menzies, chairman of the Council, insisted: "Throughout the year we maintained, with some force I may say, our view that, against a background of escalating costs, price restraint would make huge losses inevitable". Industry spokesmen decried the increase in fuel costs which had made the generation of electricity so much more costly. The implication was invariably that the combination of increased fuel costs and government price restraint had been responsible for the loss of £258 million incurred by the industry in England and Wales in 1974-75. However, an examination of the statistics in the Annual Report reveals that during the 12 months the cost of generation had undergone an increase of £561 million - but that during the same 12 months the revenue from sales of electricity had increased by £651 million. Clearly the increased fuel cost had been adequately covered by permitted tariff increases during the period. What had not been adequately covered was £386 million of interest charges. Fuel cost increases and price restraint were imposed on the electricity industry from outside, whereas the interest charges were a consequence of the industry's own capital investment decisions in earlier years. It is unsurprising that the industry preferred to attribute the losses to the effects of external factors, rather than to those arising internally. But such attribution is one-sided and tendentious.

Be that as it may, the industry in England and Wales in the event received financial support from the government - compensation of £176 million in 1973/74 and £56.5 million in 1974/75 for the consequences of price restraint. In this way the public paid for its electricity both directly and indirectly, through electricity bills and through taxes. Such a roundabout financial route of course obscures any relevant economic signals conveyed by prices - a point made vehemently by the Electricity Council in its Annual Reports. Nevertheless the electricity supply industry was in no way reluctant to accept the compensation.

The nuclear industry for its part has accepted - indeed subsisted on - government financing from the inception of civil nuclear activities. As noted in Chapter 4 the net total financing estimated for the first financial year of the newly established AEA was £53,675,000 - in 1954 pounds. This to be sure included weapons-related expenses, a factor which has continued to complicate analysis of the economic status of civil nuclear enterprise. By 1958-59 the estimate passed the £100 million mark. Actual appropriations were usually in line with, or slightly above, the estimates. The government grant for 1961-62 showed a drop to £78 million, reflecting the completion of the major production plants associated with the military programme. Some £49 million of this grant was explicitly spent on the civil research and development programme.

By 1965 the AEA's trading activities, mainly in services to the electricity supply industry, had reached some £30 million per annum, and were set up as a separate Vote. The Atomic Energy Vote had by this time fallen to just over £29 million; it was coupled with the Atomic Energy (Trading Services) Vote, which was given a financial basis "more nearly resembling those of other industries, both public and private", and a token Vote of £1,000. By this time the total assets of the AEA stood at a balance sheet value of £460 million, down from a high of £578 million in 1962, mainly as a result of downward revision of the value of fissile material. By this time arrangements had been completed for the defence departments to pay regular contributions to defray the cost of the AEA's weapons-related facilities. In 1966/67, for instance, the total non-trading expenditure was £79 million; the Ministry of Aviation however paid the AEA nearly £27 million, the largest single receipt among those bringing the net total expenditure down.

By 1970, as described in Chapter 4, the nuclear establishment was undergoing major reorganization. In 1970-71, the last year of the AEA's overall responsibility for nuclear affairs, the gross expenditure was some £96 million, receipts were £58 million, and the Parliamentary Grant covering the difference was £38 million. Some £58.5 million was spent on research and development, £41.9 million of it on the programme of reactor research and development, including £26.3 million on fast reactors.

Hiving off of British Nuclear Fuels Ltd and The Radiochemical Centre Ltd did not diminish the financial commitments of the AEA: on the contrary. In its first year divorced from its former Trading Services its gross expenditure was over £96 million. Receipts of some £51 million left £45 million to be financed by direct Parliamentary

Grant. Expenditure on civil research and development amounted to £63 million, £47 million of it on the reactor programme. In succeeding years the sums have increased, partly as a result of inflation. In 1975-76 the gross expenditure was £143 million. Receipts covered £55 million, leaving £88 million to be financed by Parliament, Nuclear research and development entailed a net expenditure of £96 million, £49 million of it on the fast reactor.

The most recent government White Paper on public expenditure (Cmmd 6721, February 1977) estimates that nuclear research and development will involve a net outlay of £127 million in 1977/78. In the following four years the outlay, after expenditure cuts, will still amount to over £80 million per year. This expenditure, under the heading of "Industrial Innovation", is by far the largest single allocation of support for research and development, exceeding by more than 30 per cent even the second largest, which is the blanket heading of "General Industrial Research and Development".

As discussed in earlier chapters, the pattern of research and development largely determines which technological options will in due course become available for commercial application. There can be no doubt that government commitment to nuclear energy has involved a support for nuclear research and development which has been little short of single-minded; all the indications are that this single-mindedness is to continue. However, support for R&D is by no means the only financial obligation undertaken by the government on behalf of civil nuclear technology. The Nuclear Installations (Licensing and Insurance) Act of 1959, as amended in 1965 and 1969, provides explicit government backing for third party liability which might arise as a consequence of a nuclear accident. Whatever the justification for such a procedure it inevitably distorts the comparative actuarial evaluation of nuclear energy technology, in favour of nuclear as against other energy technologies. A similar preference is shown by government backing for major nuclear investment activities.

Certain government involvements remain either obscure or unresolved. The basis for the export financing of the Latina and Tokai Mura Magnox stations, in Italy and Japan, is at this date unclear; but the original purchase of each station involved the lifetime supply of fresh fuel and of reprocessing and waste management services, the recent cost of which has little relation to the costs anticipated at the time the overseas sales were agreed. Again, the financial entanglements consequent on the bankruptcy of Atomic Power Constructions Ltd, and the in-fighting over Dungeness B remains unresolved, and may yet entail substantial government subvention.

The capital structure of British Nuclear Fuels Ltd involves certain ambiguities. At 31 March 1976 the fixed assets of BNFL included £16.7 million in freehold land and buildings, £62.4 million in plant, and £33.1 million in assets under construction. At the vesting date of 1 April 1971, when BNFL emerged from its AEA antecedents, it inherited the facilities at Windscale, Capenhurst, Calder Hall, Chapelcross and Springfields: five very large industrial installations. The BNFL Annual Report for 1975/76 includes the following Notes on Fixed Assets: "The figures of cost and accumulated depreciation shown above include the cost attributed to and depreciation provided on the civil proportion of the fixed assets transferred to the Company on 1 April 1971 under the provisions of the Atomic Energy Authority Act 1971. Assets originally provided for Defence purposes, and which the Company may in certain circumstances be required to use for such purposes, had no value attributed to them on their transfer to the Company." Which of the assets at the above five installations were "originally provided for Defence purposes", and do not appear on the books, is entirely unclear. The distinction is in any case bound to be at least somewhat arbitrary, since all five installations were "originally provided for Defence purposes". This in turn makes the published financial performance of BNFL likewise ambiguous. For instance, the Calder Hall and Chapelcross generating stations produced electricity to the value of £14.7 million in 1975/76; but their plutonium production is still earmarked for weapons use. In any event, as the Public Accounts Committee of the House of Commons noted in 1976, BNFL has not since its establishment paid a dividend to its one shareholder, the AEA; by retaining its profits it is in effect receiving an interest-free loan from the AEA.

However, BNFL is now embarking on an investment programme which includes £245 million for improvement of facilities for reprocessing Magnox (metal) fuel; £300 million for centrifuge enrichment facilities; £40 million for industrial-scale prototype vitrification facilities for high-level radioactive waste; and - provided a number of barriers are overcome - upwards of £600 million for construction of a new oxide fuel reprocessing plant. Investment in the Magnox reprocessing plant and the vitrification facilities is dictated not by commercial interest but by technical problems, for which other solutions would be still more costly. The existing Magnox reprocessing plant at Windscale has encountered mounting difficulties of contamination and maintenance. Magnox fuel, which is discharged into water-filled cooling ponds at eight of the nine commercial nuclear stations, cannot long remain under water; the Magnox cladding deteriorates. (Only Wylfa has gas-cooled storage facilities, which do not cause deterioration.) In practice Magnox fuel remaining under water for a year or more becomes progressively more difficult to handle. BNFL have been grappling since 1974 with problems in Magnox reprocessing which seem to be increasingly serious; it is not easy to learn details from BNFL, as even industry correspondents have lamented. Under other circumstances an investment of £245 million could not be taken lightly; but there seems no doubt that costs of at least this order must now be borne if the current problems are not to become unmanageable. Work on the radioactive waste management technique of vitrification is likewise not commercial but necessary, in light of the existing inventory of some 800 cubic metres of liquid high-level radioactive waste, both military and civil, currently stored at Windscale, for which some credible long-term management programme must be devised.

Controversy now surrounds the BNFL plans to construct a new oxide fuel reprocessing plant. Not the least controversial are the financial arrangements involved. When BNFL was established in 1971, it joined in partnership with French and West German firms to form United Reprocessors GmbH, a joint marketing organization which had all the hallmarks of a cartel. The formation of UniRep had been prompted by the expectation that there would be far more reprocessing capacity available than the market would require. UniRep was intended to serve as a means of dividing up the available work without price-cutting competition between Britain, France and West Germany. The precise details of the UniRep link have never been published, nor have the arrangements for market-sharing. However, the anticipated excess of reprocessing capacity failed to materialize. BNFL's oxide "Head-End Plant" at Windscale suffered a radioactive leak in September 1973 that contaminated 35 workers and led to the protracted shut-down of the plant for rebuilding; it is not expected back in service until 1978. Cogema of France encountered persistent problems with its new oxide plant at Cap la Hague. KEWA of West Germany ran afoul of financial difficulties, as the private chemical firms involved grew reluctant to put up the capital sum required to build their proposed plant, and could not persuade West German electricity suppliers to advance the money. Accordingly, as of the mid-1970s there is no commercial oxide fuel reprocessing capacity in operation anywhere in the world.

One response, in the US, has been to question whether this is in fact an economically sensible undertaking at all - whether it might not be better just to store oxide fuel unreprocessed. Another, however, has been to plan the construction of large new oxide reprocessing facilities, with BNFL taking the lead. From late 1974 onwards BNFL began planning to add new plant, described at first as having a capacity to handle 2,000 tonnes of fuel annually, then as involving two 1,000-tonne plants, then after public contradictions between senior BNFL executives in the spring of 1976 as involving not two but just one 1,000-tonne plant. In June 1976 BNFL submitted to Cumbria County Council an application for planning permission for this plant. From 1974 onwards the anticipated cost of the plant varied by more than a factor of two, presumably in part because of the uncertainty as to its size and capacity; the lowest figure attributed to BNFL was £100 million, the highest some £900 million. Meanwhile negotiations were proceeding with a consortium of nine Japanese electricity suppliers, who were compelled by Japanese law to arrange to dispose of their spent fuel as a condition of being allowed to operate their nuclear stations. In 1975 the deal was said to involve 4,000 tonnes of Japanese fuel, to be reprocessed by BNFL for a contract price of £400 million, of which the Japanese would advance £150 million for BNFL to use as capital to construct the new plant.

When the proposed Japanese contract came to public attention in Britain in October 1975 concern was expressed that Britain was to become the repository for radioactive waste from foreign countries, and a storm blew up. Comparatively little attention was paid to the implication that BNFL would be expected to return to Japan any plutonium recovered from reprocessed fuel - some 40 tonnes of it from the quantity of fuel involved. The consequent controversy was still unresolved in April 1977; the public inquiry into the BNFL proposal was to commence in mid-June 1977. But the financial context remains obscure, ambiguous and inconsistent. The Nuclear Industry (Finance) Act 1977 (see Chapter 8 for further details) provided up to £1,000 million of government backing for BNFL's plans, in circumstances which are more than somewhat mysterious. Presumably there will also have to be agreements, on the level of treaty between British and foreign governments, concerning the eventual destination of high-level radioactive waste, and - more importantly - of recovered plutonium. BNFL insist that the enterprise will be of enormous financial benefit to Britain. Nothing in the record of oxide fuel reprocessing lends any support whatever to the assertion. But BNFL's word appears to be good enough for the British government.

As described in earlier chapters, plans for construction of new power reactors in Britain involve the steam generating heavy water reactor and the fast reactor. In the case of the SGHWRs, little is likely to happen while the question of reactor type is rehashed yet again. Until this question is resolved the CEGB need make no further pronouncement. It will, however, be interesting to see whether the CEGB does indeed place an order for its Sizewell B station with any alacrity once the position is clarified. Judging by its reluctance to place an early order for the second stage of its Drax coal-fired station, it is unlikely to show any eagerness to embark on further capital-intensive addition of generating capacity without some form of government intervention. The intervention may have to take the form of compensation for premature investment, as the CEGB has already requested in the case of Drax B. As for the plans for a demonstration "commercial" fast reactor, CFR-1, there seems no doubt that the entire financial package will have to be provided by the government. There will, to be sure, be repayment clauses included, relating to the sale of the electricity eventually generated; but few expect that such sales will come close to covering the total cost of the plant.

In this connection it is ironic to note the recent reiterated insistence by the CEGB and the SSEB that "nuclear electricity is now the cheapest in Britain". Virtually all the commercial nuclear electricity in Britain is produced by the Magnox stations, all of which were capitalized at least 14 years ago. Capital carrying charges make up over 80 per cent of the cost of a unit of nuclear electricity. In December 1972 the Department of Trade and Industry submitted a memorandum to the Select Committee on Science and Technology, entitled "Comparative Costs of Electricity Generation". The memorandum, which appears in the Minutes of Evidence, Appendices and Index to the Committee's 1973 report *Nuclear Power Policy* provides some telling figures. In 1971 the average cost per unit of electricity sent out from the seven CEGB Magnox stations then operational was 0.43p; the cost per unit from eight coal-fired stations of comparable age was 0.41p; and for three oilfired stations was 0.39p. When the accounting basis was revised to constant currency (January 1972 prices), capital charges were based on an annuity rather than straight-line depreciation, and common load factor of 75 per cent was assumed, the following Table resulted:

GENERATING COSTS (IN PENCE PER UNIT) AT 1.1.72
MONEY VALUES

	8% interest rate	10% interest rate
Magnox	0.56 to 0.94	0.64 to 1.07
Coal	0.37 to 0.62	0.39 to 0.65
Oil	0.40 to 0.43	0.42 to 0.46

The memorandum goes on to state: "With these adjustments, the nuclear stations appear the most expensive in 1972, but care is needed in the interpretation of Table 2 as it tends to conceal the effect of advances in technology. The higher end of the range for Magnox generating costs reflects the cost of the earlier and highly capital intensive stations, whereas the lower end of the cost range reflects the generating costs of the more recent stations which took advantage of factors such as improved steam conditions and increased size. Magnox type stations have not been ordered since 1964 and the choice for future stations would be made between more advanced types." The one "more recent" Magnox station not included was Wylfa; by taking advantage of increased size Wylfa managed to be over five years late in attaining more than a modest fraction of its design output. As recently as 1975 it produced only 16 per cent of the electricity it could have produced operating as intended throughout the year. It is hardly necessary to refer to the record of the still "more advanced"

AGRs, although as usual the memorandum goes on to adduce excellent - albeit hypothetical - generating costs for Heysham, which in 1977 is still at least two years short of first start-up.

Furthermore, since the Magnox stations were capitalized, inflation has drastically lowered the value of the pound. As a result, an investment made in pre-1964 pounds is by now very good value in straightforward numerical terms. On the other hand, if the accounting were done on the basis of the 1977 replacement value of the stations, very different figures would emerge. In other words, the current comparative cheapness of nuclear electricity from the old Magnox stations gives no indication whatever as to the probable economic status of nuclear electricity generated by stations ordered and capitalized in 1977 or later. To argue that the cheapness of the one implies the cheapness of the other is indefensible. It is merely another promise of nuclear jam tomorrow.

If, however, it is decided to order new base load stations regularly, come what may (see p. 52), anyone can thenceforth promise anything. Financial analysis, like other aspects of planning, will become irrelevant. If promises about the financial performance of investment are not fulfilled, it will be far too late to do anything about it. The time-scale of the investment programme will be too long to allow any useful feedback. Decisions will be taken centrally and on faith; the momentum they generate will guarantee that the arrangement becomes self-perpetuating. It will become self-perpetuating, that is, so long as the rest of the economy and the society can stand it. However, the capital requirements of the electricity supply sector under such a regime, and the ancillary demands on overall resource allocation, may not be indefinitely supportable. Indeed it seems likely that they will lead to progressive dislocation and deformation of the rest of the economy, with consequent worsening of unemployment. The longer such a state of affairs prevails, the more intractable it seems likely to become. If, in due course, the financial requirements of the electricity supply sector can no longer be provided, the community will face a daunting dilemma. Bankruptcy of the electricity supply industry will by that time translate directly into bankruptcy of the entire economy. The community may find that it cannot afford to support the electricity system, and simultaneously cannot afford not to. The prospect must not be lightly dismissed.

7. Saving labour with electricity

All processes which take place involve the conversion of energy from one form to another, with a net reduction in its quality. Almost all the energy involved is solar energy. It reaches the earth as high quality sunlight, and powers the circulation of the atmosphere, the winds and the waves, and the growth of green plants on land and in the sea. Virtually all the solar energy that reaches the earth is eventually - much cooler, much lower quality - re-radiated back into space. But in the process the earth is maintained at a temperature which makes possible life as we know it.

However, the energy which concerns policy makers is energy which is bought and sold. This energy is in fact a trifling fraction of the total amount of energy involved in terrestrial processes - but it has a disproportionate influence on human life and society. Such energy has always included the energy converted and applied by animal and human tissues. Here as always it is important to distinguish between low quality human energy and high quality human energy: between drudgery and craftsmanship. It has become customary to use the term "labour-intensive" to describe an economic activity in which people play a major part. But the term blurs an important distinction. Some economic activities are undoubtedly "labour-intensive" and no more. But others - many others - are "skill-intensive": they require not just human muscles, but human brains.

The Industrial Revolution was fuelled by coal and powered by steam. The steam engine made it possible to convert the stored, concentrated solar energy in coal into mechanical motion to drive pumps, locomotives and other machines, offering a dramatic multiplication in the energy it was possible for human beings to apply and control. Unfortunately, for many people, the Industrial Revolution simply substituted a new kind of drudgery for the old. Brutal working hours and working conditions subordinated people to machines. The ensuing two centuries have seen much improvement in working hours and working conditions - although there is still plenty of room for further improvement. But in many industrial contexts, it is still clear that people are subordinate to machines. Ideally, there is an obvious optimum relationship between people and machines, reinforcing human skill with the precise amplification of energy which machines make possible. Such reinforcement can increase dramatically the "productivity" of a worker: the amount of useful output per unit of working time. "Productivity" thus defined has become a byword for desirable improvement in the rate of industrial activity. However, in many contexts such "productivity" in essence is equivalent to the substitution of capital and energy for people: that is, to loss of jobs. An increase in the rate of production from a human worker may entail progressively less efficient utilization of capital and energy. A complete analysis of "productivity" should include consideration of the "productivity" not only of people but also of the plant and power they use. Most present-day industrial practice seems far from any plausible optimum. Large industries, with a high ratio of plant to people, tend to be inflexible in response to changing markets and economic circumstances. Such industries produce what their production systems are designed to produce - not necessarily what the community needs. Shopfloor workers become machine minders; personal involvement in the productive process becomes negligible; responsibilities become so subdivided that they evaporate. Such job fragmentation and lack of involvement are further aggravated by the sheer size of a firm in which lines of communication are long, tortuous, and impersonal. In such circumstances industrial relations become a minefield. The pursuit of economies of scale and of ever increasing worker productivity also, paradoxically, makes the industrial system increasingly vulnerable to manifestations of worker discontent. Recent evidence indicates that lost time due to strikes increases with the size of factories. Yet economies of scale and increased worker productivity persist as central to the policy objectives of industry and government.

The electricity supply industry is the most capital-intensive industrial sector in the British economy. As at 31 March 1976 the net assets employed by the Electricity Council and its Boards in England and Wales amounted to £5,991 million. The number of employees totalled 166,826. On average, therefore, the industry employed £35,912 worth of assets per employee. The Central Electricity Generating Board itself is yet more capital-intensive. At 31 March 1976 it was employing 63,212 people and net assets of £3,697 million - £58,485 per employee. The jobs were distributed as follows:

	Council + Boards		CEGB	
	1976	(1967)	1976	(1967)
Managerial and Higher Executive	1,697	(1,810)	795	(796)
Technical and Scientific	26,430	(25,612)	15,049	(13,695)
Executive, Clerical, Accountancy, Sales, etc.	46,619	(47,668)	8,121	(8,512)
Industrial	86,658	(141,927)	37,246	(53,915)
Technical Trainees and Apprentices	5,422	(11,503)	2,001	(3,217)

Comparison with the figures for 1967 is revealing. In the decade 1967-76 total employment in the electricity industry in England and Wales dropped from 228,520 to 166,826, a decrease of 27 per cent. In the CEGB total employment dropped from 80,189 to 63,212, a decrease of 21 per cent. During the same decade the number of units of electricity sold to customers in England and Wales increased from 141,478 million to 189,438 million, an increase of 34 per cent. The increase in worker productivity is striking - especially with respect to industrial workers, the sector which showed the most pronounced drop in job levels during the decade. In the entire industry in England and Wales, Council plus Boards, 55,269 industrial jobs disappeared; in the CEGB alone the lost industrial jobs totalled 16,669. The single factor most responsible for this trend has been the increasing size of individual power stations and generating units. Present policy intentions will continue to reinforce this trend. A similar trend is evident in Scotland. The total number of employees of the SSEB dropped from 16,498 in 1967 to 13,941 in 1976, while the net fixed assets per employee increased from £20,269 to £48,001.

In 1975/76 the CEGB system included 79 fossil-fired steam turbine stations with sets of 60 megawatts or larger (plus 59 smaller and older stations, many of which did not operate during the year). The total number of "generation employees" at conventional steam stations was 34,445. Averaged over the 138 stations this gives an average of 250 such employees - not including supervising staff, administrative and clerical employees, apprentices and trainees, canteen employees and some other small groups - per station. If the same total number of employees is averaged over the largest 79 stations the number per station is 436. The actual number per station will be of this order, or - for the largest base load stations - slightly higher. Some 17 per cent of the total were technical staff; 45 per cent were workmen on operations and 39 per cent were workmen on maintenance. For the eight CEGB nuclear stations the total number of generation employees was 3,660, an average of 458 per station. Some 25 per cent were technical staff; 43 per cent were workmen on operation; and 32 per cent were workmen on maintenance. In the decade 1967-76 the number of generation employees on conventional steam plants per megawatt sent out dropped from 1.42 to 0.65; on nuclear plant, from 1.21 to 1.05. The total number of generation employees on conventional steam plant dropped from 47,542 to 34,455, although the "average declared net capability" - useful system capacity - increased from 33,565 megawatts to 52,933 megawatts. The total number of generation employees on nuclear plant increased from 2,980 to 3,660 - 23 per cent - while the useful system capacity increased from 2,459 megawatts to 3,462 megawatts - 41 per cent.

Other things being equal, the jobs of staff operating a power station are available throughout the operating life of the station - conventionally 25 years for a fossil-fired station and 20 years for a nuclear station. The last 15 years, however, have seen a structural shift in the type of jobs associated with the electricity supply industry. The operation of the generating plant on the system requires fewer and fewer people - of whom a significantly larger proportion must have advanced technical skills. On the other hand, the construction of a new power station, in particular a base load station, requires a large number of people for a comparatively short time. Fewer people are involved in the construction of a single large base load station than would be required for the construction of an equivalent capacity made up of smaller stations. But the single large station will require the presence on site of upwards of 2,000 people during the construction phase, although some will be required only for months or weeks. A report by the County Planning Officer of Gwynedd, "The Impact of a Power Station on Gwynedd", dated September 1976, suggests that the labour force for construction of a nuclear power station might include the following:

Civil Trades		Engineering Trades	
Labourers	500	Reactor installation	500+
Carpenters	200	Turbine installation	100
Steel erectors	200	Pipework	200
Painters	50	Electrical engineers	300
Drivers. bricklayers, etc.	50		

In addition there will be 400 to 500 staff. The construction of the Trawsfynydd and Wylfa nuclear power stations indicated that the workforce on site will increase from 1,000 or so at the outset to a peak of some 2,500 during the third and fourth year of construction, and then tail off fairly rapidly - depending, of course, on how well the work proceeds. Similar data for the AGR stations would extend over some years further. Nevertheless the work is by most criteria short-term, although not sufficiently short-term to make commuting any distance worthwhile for most of those involved.

Large base load stations, especially nuclear stations, must be located on sites which conform to a number of stringent criteria. Cooling requirements in particular usually dictate that a station be sited in an area of low population density; similar constraints apply with relation to the safety criteria for siting of nuclear stations. In Britain this in practice means that a substantial percentage of the construction workforce must be brought into the locality where the station is to be sited. It has often been claimed that the construction of a large power station confers economic benefit on the local community, and mitigates unemployment. But the Gwynedd report has this to say: "The effects of large scale construction schemes on unemployment are difficult to isolate. It is a fact, that while all the large scale construction schemes were going on in the County, unemployment only dropped by a small amount and that only in the initial stages of the schemes. In 1966, when some 2,600 workers were employed on the Wylfa scheme, the number of unemployed in Anglesey was 282 less than in 1963. A similar pattern was evident at Trawsfynydd." Furthermore: "The completion of large scale construction schemes in the County has often been followed by a rapid rise in unemployment. This is due to the difficulty of finding new employment at the end of the construction period, unless there is a new large scale construction scheme to move onto within the area. The situation is much worse in a period of economic depression since it is difficult to create new jobs for local workers, and migrant workers tend to stay in the area, adding to the number of unemployed. The pattern of events is well illustrated by the recent employment history in Gwynedd. After the Trawsfynydd station was completed, there was a shift of workers to the Wylfa. scheme which was already under way. While Wylfa was still under construction, work on the aluminium smelter at Holyhead got under way and in 1970 there were in excess of 3,000 workers employed on the two schemes. When work finished on these projects the unemployment rate in Anglesey was higher than it had ever been, with a large number of construction workers unemployed."

Similar considerations affect those employed in the ancillary industries like boiler making and turbogenerator manufacture. A single order for a single large unit can only be allotted to one plant; when it is completed the large workforce involved in its construction must obtain another order or be laid off. The official response to this dilemma is to encourage new construction schemes and new orders as fast as necessary to maintain employment. But there is a fundamental inconsistency in such an approach. If a base load generating station, say, is intended to last for upwards of 20 years, and if it takes no more than 10 years to build one, then simply keeping the construction workforce occupied implies unending growth of the system generating capacity. Sooner or latcr - and the time may not be far away - the resource demands of this approach will become insupportable. Whatever its other virtues or defects, it seems untenable as an approach to employment policy.

The shift of employment from long-term operation of facilities to short-term construction of them has been accompanied by other significant effects. Industrial relations on construction sites for large projects are different in many respects from those applying to the operation of existing plants. A construction site involves many contractors and subcontractors, giving rise to tensions and blurring of responsibilities, described in some detail in the Wilson report (see pp. 16-17). The rapid shift of employment structure on site aggravates these problems. It is self-evident that when completion of a job is to be followed by consequent unemployment, the job may not be completed with any alacrity. Ironically enough a converse effect manifests itself on the management side. If senior project managers know that they must see a project through to its completion, when its duration may be as long as a decade, their morale may suffer at the thought of promotions long delayed and other professional advancement impeded. Such has certainly been the case on base load station construction projects since the mid-1960s in Britain, of which Dungeness B is only the most notorious. Low management morale exacerbates the problems arising from industrial relations. The longer a project is expected to last the more likely it is to suffer further delays.

The shift of employment patterns within the electricity supply industry has a corollary - perhaps a mirror image - in the community, particularly in a community into which a large power station construction project is introduced. While it may not provide the sort of jobs which significantly alleviate local unemployment, it may on the other hand attract away from local community jobs a sizeable percentage of the local skilled and semi-skilled labour force. This would be a disturbance under any circumstances, although workers cannot be faulted for favouring jobs paying better wages if such should be the case. However, the disturbance is doubled because of the short-term nature of the jobs introduced. It is certainly true that a large number of new wage packets will also be fed into the local economy; but the bonanza will be short-lived, and the after-effects of its withdrawal have been in some cases pronounced and disruptive.

Much stress has been laid recently on the need to build more power stations for the purpose not only of "creating jobs" within the power station construction industry, but also to ensure electricity supply for the jobs in other industries. In general this argument does not stand up to close examination. In the first place it is by no means clear that increased electricity supply to industry will necessarily lead to more employment; there is good reason to suspect that the converse may be true, given the continuing emphasis on "worker productivity". In the second place, as usual, insufficient attention is given to alternative patterns of resource allocation which may be considered. It may, for instance, be more appropriate for an industry to provide the energy for its workforce by on-site generation of heat and power together - which would incidentally also involve employing generating staff on the site, as well as entailing the construction and installation (on a short time scale) of the necessary generating plant. If a large number of industries were to move gradually over to such a regimen the effect both on the generating-plant construction industry and on the actual industrial employment would be a beneficial smoothing out of the cycles both of ordering and of employment, as well as involving more long-term employment on the operating side. However, as Chapter 6 has indicated, even getting access to the capital for such an investment may constitute too much of an obstacle for industrial management. Instead the centralized planning of centralized supply remains the official policy, accompanied by confident pronouncements about the employment benefits it is alleged to convey. To many ears the pronouncements ring increasingly hollow.

For the workers at 48 small urban-sited generating stations on the CEGB system the move to a system centred on large base load stations has meant finding new jobs. Some 4,000 industrial workers and another 1,000 non-industrial workers lost their jobs when the small old stations were closed in October 1976 and March 1977, further reducing the staffing levels already described. Some of the displaced workers are being reassigned by the CEGB. According to the 1975-76 Annual Report "The Board has introduced measures to readjust manning levels which include permanent redeployment within its organization, temporary arrangements to transport employees to available work, financial assistance for compulsory transfer and offers of voluntary severance terms. Assurances have been given that there will be no compulsory redundancies for 12 months after the closure dates." Be that as it may - and no indication is given as to how many of the 5,000 fall into the different categories - the sudden displacement of something like 10 per cent of the industrial work force of the CEGB is a reminder that planning decisions involving capital and plant may take decades to bring to fruition, but that similar decisions involving personnel may be brought about with breath-taking swiftness. According to the criteria of centralized planning, when an inflexible system cannot be easily adjusted, people have to adjust to it. It is in this context particularly that the unfortunate consequences of ineffectual planning, described in Chapter 5, strike home. The top management and politicians responsible for the ill-advised over-ordering of the mid-1960s have retired, have been promoted or otherwise elevated, or are no longer alive. But the effects of their decisions are still working their way through the system: through the CEGB itself, and through the ancillary industries. It would be deeply unfair to suggest that the management of the electricity supply industry is in any way inhumane or insensitive; but the reality of the situation means that inevitably it is easier to hire and fire staff than it is to add or subtract power stations. When the electricity supply system gets into economic difficulties, it is easier to cut the wages bill than it is to reduce interest charges. The fact that the reduction of the wages bill is likely to be only a minor improvement of the system's balance sheet is little consolation to those whose wages have vanished in the adjustment.

There is of course one very serious constraint facing the management of the electricity supply system when they desire to take advantage of the comparative flexibility of staffing levels: the trades unions. Ironically, however, the centralization of management has been paralleled by the centralization of union leadership. As a result senior trades union leaders can exert only limited discipline over actions taken by workers on the shop floor. Lines of communication on the union side are comparable in length to those on the management side, and may be subject to similar inadequacies. When dissatisfaction arises on the shop floor, there is an asymmetry in the response available to the union leadership. If the leadership is prepared to endorse the dissatisfaction, the leaders can continue to lead. If, however, the leadership does not consider shop floor dissatisfaction to be soundly based, the leaders may not be able to persuade the shop floor workers to accept this conclusion. At such a stage the initiative passes from the union leaders to the shop floor. There is no shortage of examples of shop floor intransigence; whether well-founded or ill-founded, it can disrupt an entire industry, even if the actual instigators are very few in number. If "worker productivity" eliminates human jobs in favour of machines, those few workers who remain tending the machines can also produce impressive "unproductivity", using the same leverage. It is ironic and unfortunate that a small dispute can produce effects detrimental first of all to the earning capacity of other workers whose jobs become impossible as a result of industrial leverage applied by their fellow workers. In very few industries can such dramatic leverage be applied as in the electricity supply industry. Here again, the inability to store electricity and the commitment to guarantee its supply encounter an inherent challenge. After the coal miners' strike in early 1974, a spokesman for the electric power engineers was reported as remarking "The miners brought this country to its knees in eight weeks. We could do it in eight minutes." He was, of course, entirely correct. His remark underlines the potential for polarization created by increasing reliance on a highly centralized, essential yet vulnerable system like grid electricity. The polarization, and its possible consequences, take on a still more sinister aspect when the grid electricity is supplied by nuclear energy.

8 Power to the powerful

Virtually since its discovery nuclear energy has been a polarizing influence. Even as a natural phenomenon it sets its initiates apart from the laity. To be sure, many forms of specialized understanding might have this property; but very few have brought with them the power - both physical and metaphorical - which has proved a characteristic of nuclear energy. Not everyone could consider it a mark of special status to be, say, a mining engineer or a metallurgist; but to be a nuclear physicist has always had an undeniable cachet. As a discipline nuclear physics is certainly no more esoteric than, say, cosmology or geophysics. But, unlike the latter two, nuclear physics gave the first generation of nuclear physicists an unparalleled influence on key policy making not merely about their esoteric branch of science but about the conduct of domestic and foreign policy in the most powerful countries in the world. Even the policy makers were divided: into those briefed directly by the nuclear elite, and those who had to receive their briefing at second or farther remove. To the general public, awed by the terrible potential unleashed at Hiroshima and Nagasaki, the very word "atomic" acquired a mystic power. Anything "atomic", or subsequently "nuclear", was ipso facto the twentieth century equivalent of magic: not to be understood by mere mortals, but to be wondered at and dreaded.

The Manhattan Project, and subsequently the nuclear weapons programmes not only in the US but also in the UK, the USSR, and France, and weapons-related research in Canada, took place behind a curtain of secrecy more impenetrable than any hitherto. This secrecy, more than anything inherently esoteric about nuclear phenomena, reinforced the polarization between the nuclear insiders and the rest of society. Not only were nuclear phenomena difficult to understand - they were declared to be too powerful a mystery for the public to see. The public, still gaping at the spectacle of the mushroom clouds, and the hideous devastation of the Japanese cities, accepted that matters nuclear were not a fit subject for the everyday citizen. Even elected representatives and civil servants were inclined to accept with little question that nuclear policy was a province requiring extraordinary talents, and to allow themselves to be directed accordingly, by those with access to the nuclear inner sanctum. The official history of Britain's nuclear weapons programme, *Independence and Deterrence,* by Professor Margaret Gowing, recounts how the British nuclear effort took shape effectively unnoticed by all but a handful of policy makers, on the basis of guidelines which were more implicit than explicit - even though the undertaking involved expenditure of some £100 million of public funds, at late-1940s prices.

The British weapons programme indeed was initiated as a consequence of the US McMahon Act, the Atomic Energy Act 1946, which tried to preserve US nuclear supremacy by excluding the UK and Canada - allies during the Manhattan Project - from any further access to US nuclear information. Nuclear energy even, at that embryonic stage was exhibiting its polarizing "inner sanctum" effect. Policy wrangles arising from this psychology thwarted the brief postwar effort to internationalize nuclear energy. Instead those countries with a foot in the door to the inner sanctum determined to make their own entry, at whatever cost in financial and political terms. To be a "nuclear power" was the acme of international prestige. Thirty years later it is still so regarded, if no longer unanimously. However, even those nations which insist that they have no interest in acquiring nuclear weapons nevertheless desire the prestige of nuclear capability, expressed in civil nuclear technology. Their enthusiasm is undertandable. They have been listening for two decades to the euphoric pronouncements of civil nuclear advocates, *ex cathedra* from the nuclear inner sanctum. They too wish to embrace the faith. The nuclear missionaries, for their part, are out in the field yet again, delighted to find a new generation of potential converts.

In the nuclear industrial countries like Britain the "inner sanctum" effect has had a profound influence on nuclear policy-making, not only concerning weapons but also concerning civil applications. As described in Chapter 4, the British civil nuclear programme arose within the weapons programme. The habit of secrecy, instilled from the inception of the weapons programme, carried over into civil nuclear activities. Employees of the Atomic Energy Authority have always been subject to the Official Secrets Act, even when occupied exclusively on civil work. Senior administrators, many of whom have been with the AEA since before it was so designated, have never become accustomed to discussing their work freely in public, even with politicians and civil servants, to say nothing of the media and the lay citizenry. Partly as a result the media, which in the 1950s were prone to take a "gee whiz" attitude to matters nuclear, are now as likely to overreact unfavourably. In the absence of a long-running public dialogue on civil nuclear affairs, nuclear policy makers have grown used to taking major decisions with little fanfare and little public interest. The recent upsurge of attention has struck them as a surprise, and by no means a welcome one. They have failed to appreciate that other major sectors of the economy - the coal industry, the railways, chemicals, aerospace, agriculture, and so on - have always been subject to public discussion, criticism of policy, political comment, all the mechanisms by which the social consensus evolves in an industrial democracy. The world of the nuclear policy-makers has by contrast been almost hermetic, generating a minimum of feedback from the world outside, and unreceptive to such feedback in any case.

The consequent dilemma was described succinctly by the Rt Hon Tony Benn, MP, Secretary of State for Energy. on 13 December 1976. Addressing public hearings organized by the British Council of Churches into the proposed commercial fast reactor (CFR-1), Mr Benn had this to say: "There is another set of factors to which reference has been made in public debate: I would describe them as domestic political factors arising out of two considerations. One is the problem of security and the risk of terrorism and the second arises from what happens when you have policies so complex that the democratic process finds it hard to come to terms with the choices that have to be made. Certainly as a Minister with these responsibilities now on and off since 1966 when I first became Minister of Technology, I have always found nuclear policy the most difficult: because Ministers are not experts, they are not scientists, they are not engineers, they are not qualified to assess in any way the technical decisions that had to be made. And yet, whether you look at it in terms of the environment or safety or energy policy, or the massive public expenditure involved in all the projects of this scale, it is essential that nuclear policy should be preserved within the democratic framework of control and not sub-contracted off to those whose only claim to reaching decisions might rest upon their technical qualifications. I think it would be very frightening indeed if we were to say that our fuel policy required us to adopt a technique of production like nuclear power which in its turn required the decisions to be taken from the process of Government answerable to Parliament and the public, and put into the hands of those whose special qualifications for deciding them would rest upon their technical knowledge."

Mr Benn might well have added that decisions so made could not avoid being influenced by the specific interests of those technically knowledgeable. Highly specialized technical knowledge like that possessed by nuclear engineering experts is acquired partly by a necessary narrowing of focus. Even without yielding to conscious self-interest such an expert is bound to place particular value on his specialized knowledge and its technical manifestations. He cannot be expected to make dispassionate judgements as to the allocation of resources and time as between his specialist area and others perhaps at least as worthwhile. Yet precisely such judgements are now crucial, in energy policy as elsewhere. If, in the words of the Secretary of State, "the democratic process finds it hard to come to terms with the choices that have to be made", the consequences may be profoundly disturbing.

In Britain the excess capacity of the electricity supply system and the fall-off in growth of electricity use, combined with the disarray of the nuclear industry, produced a *de facto* pause in electronuclear activity. The timing of the pause coincided with a belated upsurge of public interest in aspects of British nuclear electricity policy: plans for a third programme of nuclear power stations, plans to expand oxide fuel reprocessing at Windscale, and plans to build the CFR-1 fast reactor demonstration plant. In late 1975, and on a number of occasions thereafter, the Secretary of State for Energy, recognizing the opportunity afforded by the policy pause, called for a "public debate" on the various aspects of nuclear electricity policy. Whether as a result of his exhortation, or otherwise, 1976 saw an unparalleled intensification of interest in nuclear issues in Britain, on the part of the general public, the media and Parliament. But the "public debate" had and continues to have a slightly artificial flavour. Civil nuclear policy in Britain has roughly a 20-year head start on public opinion; no force-fed "public debate" can in a short time make up the deficit in sophisticated consensus. When due allowance is made for the over-rapid progress and economic forcefeeding of the civil nuclear programme itself, it is hardly surprising that there remains a deep gulf between contemporary practical nuclear policy and the public, "debate" or no "debate". The public must be forgiven if it does not drop everything and rally to the podium newly offered it. As for the nuclear establishment, it too finds the "public debate" unsatisfactory, if for a slightly different reason, as Sir John Hill, Chairman of the AEA, explained in *The Observer* (1 August 1976): "1 see as one of the major problems of nuclear power the concern of the honest straightforward citizen genuinely confused by the 'balanced' debate on nuclear power. Half the argument is for nuclear power and half against. How would the debate now deal with the argument about the flat or the round earth hypothesis - would there still be two contestants for each point of view and an 'independent' chairman holding the balance? I would ask that those whose professional lives have been devoted to the study of the real problems of nuclear power should also be accepted as friends of the earth who believe that the fast reactor will save future generations from the worst consequences of our present policy of squandering the earth's resources." For some twenty years there was no problem like that postulated by Sir John, of a "balanced" debate on nuclear power. "Those whose professional lives have been devoted to the study of the real problems of nuclear power" had almost exclusive access to the ears of Whitehall. Indeed, despite the year of "public debate" which has now passed, all the signs are that the nuclear professionals still control the inside track to the decision-making process as it affects nuclear policy. As described in Chapter 6, the government introduced in February 1977 the Nuclear Industry (Finance) Bill, earmarking £1,000 million of public funds for the support of British Nuclear Fuels Ltd. The background briefing on the Bill, while including copious quantities of basic information, made no attempt to offer any specific reason for committing the government to guarantee advance payments from overseas customers for reprocessing services. Indeed the only actual example given - "e.g. if the plant were not built" - was patently irrelevant: in such a case the advance payment would still be in the form of liquid assets in the hands of BNFL, and could be returned to an overseas customer forthwith. No government involvement would be necessary. Be that as it may, the Nuclear Industry (Finance) Bill received the Royal Assent in early April. The inference must be that, as usual, nuclear interests have persuaded the appropriate civil service and government representatives to arrange yet another 10-digit subvention for the industry, with no more than minimal explanation of its purpose. So long as such episodes continue to occur the relevance of any "public debate" to practical policy making must remain a matter for profound scepticism.

On the contrary, it must be assumed that in nuclear matters the policy makers continue to bow to the guidance of the technical elite. The "inner sanctum" effect continues to prevail. If nuclear electricity is to assume an ever greater significance in British energy supply, the stage will be set for the insidious establishment of an electronuclear technical oligarchy, exercising a fundamental influence on planning, finance and employment. There is every likelihood that this influence will in due course be all-pervading, not only in energy use and supply but throughout the whole of society. A society in which nuclear electricity is the dominant form of energy supply will be shaped by criteria arising from the nature and character of nuclear electricity. Many such criteria can already be easily identified, as they have come into play during the two decades of Britain's involvement in civil nuclear affairs.

Energy research and development in Britain has been and is still dominated by electronuclear interests. Government funding for nuclear research has been mentioned in earlier Chapters; to it must be added further expenditure on R&D related to grid electricity, invariably the second largest item in the annual budget after nuclear research itself. As indicated in Chapter 5, policy on R&D funding and priorities casts a shadow forward at least 20 years, exerting a profound influence on the technological mix which will be available for practical applications. Convictions as to the comparative relevance of different technologies are apt to be self-fulfilling, at least in a negative sense. If a technology is perceived as unpromising, it will not be given any opportunity to overcome such a negative evaluation. On the other hand, the track record indicates that no influence has so nurtured the role of nuclear electricity as the simple devout conviction that one day it will vindicate its supporters. Since these supporters have been in a position to press their conviction, to the continuing disadvantage of alternative claimants, the present prominence of nuclear electricity in planning is scarcely unexpected. Furthermore the present power of the nuclear supporters in the decision-making process guarantees that the future mix of technologies will develop in a pattern favouring nuclear electricity. One characteristic of the nuclear inner sanctum effect is that it tends to be self-perpetuating.

Grid electricity is the only presently accepted way to distribute nuclear energy. There is thus a broad community of interest between nuclear and electric interests, despite some fraternal friction. Both nuclear and electric planners have come to accept the desirability of traditional economies of scale, and of centralization, both in planning and in technology. Both work within time scales of a decade or more even for immediate decisions. But the nature of grid electricity as a commodity - impossible to store, supplied by a monopoly and guaranteed available at all times - imposes severe constraints. "Security of supply" of grid electricity refers not to the supply of fuel, or of facilities, but to the supply of electricity at the user's power points and switches. The consequent philosophy of planning by nuclear electricity suppliers diverges steadily from "planning" as commonly understood in a mixed economy: that is, anticipating future developments and attempting to harmonize economic activities with them. Instead, electricity supply planning begins increasingly to resemble the planning-by-edict which takes place in centrally planned economics such as those of eastern Europe. As was discussed earlier, the nature of grid electricity as an essential commodity removes the ultimate sanction of bankruptcy in the event of unfulfilled plans. Public participation in planning is at least an inconvenience; public opposition to particular plans - say for the siting of a new power station - may become such an inconvenience that it may have to be administratively overruled. A recent study supports this view, and underlines its worrying implications.

Nuclear Prospects: A comment on the Individual, the State and Nuclear Power, by Michael Flood and Robin Grove-White, was published jointly by Friends of the Earth, the Council for the Protection of Rural England, and the National Council for Civil Liberties, in October 1976. It was a plausible and disturbing analysis.

For the purpose of their commentary Flood and Grove-White accepted the "reference programme" presented by the AEA in 1974 in evidence to the Royal Commission on Environmental Pollution study *Nuclear Power and the Environment.* As originally proposed by the AEA this "reference programme" would have entailed having in operation 104,000 megawatts of nuclear capacity including 33,000 megawatts of fast breeder reactor power stations by the year 2000 (see pp. 54-55). However, Flood and Grove-White pointed out that the precise timing of such a programme would not fundamentally affect the considerations to which they were directing their attention. Indeed they might well have added that much of the second half of their analysis, "Consents for sites" (for power stations and other facilities) did not in the main require that the sites in question be nuclear. Such expansion of grid electricity, however fuelled, would still serve to give rise to many of the problems they identified. No brief paraphrase can do justice to the meticulous critique put forward by Flood and Grove-White. Before summarizing the main course of their argument it is essential to emphasize that they offer exhaustive documentary references, of impeccable authority, to support their views. Their introductory comment declares: "This paper deals with some future social and political implications of nuclear power in Britain. It is a very speculative paper." Speculative or not, it is founded on the historical record. Its findings cannot be ignored.

Reference will be made later in this chapter to Part 1 of *Nuclear Prospects* "Security and nuclear democracy". Part 2 deals with planning for new electricity generating capacity, public response to the planning, and official reaction to public response. Part 2 is called "Consents for sites". For some years the electricity supply industry has endeavoured to maintain a "pool" of approved sites upon which new power stations can be constructed when the electricity suppliers so desire. However, the last CEGB application for outline planning permission for a new site (as distinct from an extension of an existing site) was in 1971, at Connah's Quay, Flintshire. (As it happened, the application was rejected.) Flood and Grove-White point out that until recently any opposition to such an application would have arisen primarily from local people directly affected by the application; and their opposition would be based explicitly on this direct local effect, especially in that they would suffer the disturbance while electricity users elsewhere would draw the benefit. However, in recent years the establishment of national pressure groups with an interest in national energy policy overall has created a new context for any such planning application henceforth.

Thus far only two applications for new generating sites have been heard since the advent of national pressure groups involved in energy policy. The first was from the CEGB, for the Dinorwic pumped storage station in north Wales, in 1973-74, and the second from the South of Scotland Electricity Board, for the Torness nuclear station east of Edinburgh, in 1974. (Dinorwic did not involve a public inquiry.) The involvement of national pressure groups in these applications underlined an aspect which is likely to become increasingly unsatisfactory. The Secretary of State for Energy is directly responsible for granting planning approval for a new power station site in England or Wales; he also appoints the principal Inspector at a public inquiry. As a result, in the words of Flood and Grove-White: "At individual power station or power line inquiries, the Secretary of State for Energy will increasingly be simultaneously in the position of defendant, judge and jury. While he is not the promoter of individual nuclear power stations in formal terms (that being the CEGB's function), it will be *his* nuclear policy which will lead directly to individual applications for consent, objections to which will be heard by Inspectors appointed by *him,* at inquiries organized by *him,* leading ultimately to decisions taken by *him.* Objectors will probably come to see this situation as inequitable." Indeed, Flood and Grove-White need not have referred only to the Secretary of State's nuclear policy, or to nuclear stations; the same comments apply to energy policy overall, and to all stations however fuelled. As regards local considerations, the Secretary of State for Scotland has responsibility for such planning inquiries in Scotland, but the national policy context will require him to pay very close attention to his Ministerial colleague at the Department of Energy.

The conflict of interest thus implied has a serious corollary. It may mean, as was the case in the Torness inquiry, that objectors can offer no challenge to the "need" for the proposed site. A government witness at a local planning inquiry cannot be cross-examined on matters of national policy. The consequent frustration of objectors has already led to bitter confrontation in another area of planning, that concerning motorways. There is every likelihood that similar frustration may produce similar results in the field of energy policy, especially that affecting electronuclear proposals. Flood and Grove-White quote the Torness Inspector's Report: "The nuclear safety aspect could only be considered at the inquiry in assessing its particular application to Torness and the surrounding area. Witnesses from the Nuclear Installations Inspectorate and the Industrial Pollution Inspectorate spoke to the application of Government policy on safety to the site." Flood and Grove-White observe "This passage will have a familiar ring to students of motorway inquiries, who will know that Inspectors for such inquiries are under Departmental instructions to permit discussion of the *application* of traffic forecasts to the particular scheme in question, but not to allow challenge to the merits of the forecasts themselves." The track record of electronuclear forecasters would be similarly immune to challenge. Moreover, even more than in the case of motorway proposals "it is in the nature of a *national* system of electricity generation and distribution that the elements of the system are interdependent . . . even if challenge to the need for a single project were allowed . . . the effectiveness of such a challenge might be quickly frustrated by the project's relationship to other elements in the [electrical] system."

Flood and Grove-White then point out that, "Denied the opportunity to challenge official thinking on crucial questions at public inquiries, nuclear power objectors would be told instead to rely on Parliament for scrutiny of the range of issues deemed (at inquiries) to be matters of 'policy'. Ministers would justify restrictions on the scope of public inquiries by asserting that, constitutionally, scrutiny of 'policy' issues is Parliament's function." But they add "It appears to us unlikely that objectors at public inquiries . . . would find this argument persuasive unless they were convinced of the true effectiveness of parliamentary scrutiny on these 'policy' matters." Flood and Grove-White comment that, even in a Select Committee, "a full appreciation of the esoteric techniques and methodologies employed by electricity planners and engineers might well prove difficult for MPs to sustain"; that Parliament may not have adequate independent advice; that Departmental secrecy may increase (see pp. 32-33, concerning the unpublished Vinter report); that knowledgeable experts may be disinclined to offer criticism, lest it reflect on their professional standing - recalling that some professional skills are subject to virtual monopoly of employment opportunity; and that the extended application of the Official Secrets Acts could further hamper access to information about nuclear industry activities. The syndrome is already evident; if nuclear electricity is to assume the prominence proposed by present policy, there seems no way to avoid policy making behind the scenes, influenced definitively by the interested technical elite. Even a Select Committee is impotent, when faced by an obdurate government. Flood and Grove-White conclude "Failure of this kind would be reflected almost certainly in a more general incapacity of Parliament as a whole to react effectively and on an informed basis against the executive's implementation of its programme. The accountability of Ministers to Parliament in these circumstances might be widely seen to be no more than an empty fiction." This being so, "neither administrative ... nor parliamentary . . . mechanisms for reflecting public discontents may prove adequate to the tasks put upon them by the nuclear programme . . . Public expectations of real influence on planning decisions, bred by the rhetoric of public participation, could thus be thwarted. Should this happen, the possibility of serious civil disobedience might arise."

The recent history of electronuclear affairs in Britain has thus far been free of significant confrontation between the authorities and the public. Indeed civil nuclear affairs in Britain have thus far entirely avoided such confrontation, although the Campaign for Nuclear Disarmament, and subsequently the Committee of 100, were involved in a number of major challenges to the British nuclear weapons programme, with marches, demonstrations and public obstruction. However, in other countries there has been since 1974 a growing number of head-on collisions between nuclear protestors and the authorities, in France, West Germany, the US and elsewhere. Some of the resulting clashes have been violent. In Britain the government's motorway programme has encountered openly disruptive tactics by objectors frustrated at the government's refusal to countenance challenge to policy through orthodox channels. It is by no means far-fetched to suggest that future proposals for new electronuclear facilities may meet similar aggressive opposition. Flood and Grove-White comment bleakly "Direct action involving the possibility of physical intervention in electricity supply facilities and disruption of statutory processes could thus present a government committed to an expanding nuclear programme with acute difficulties. The range of possible official responses to this situation is very great. It could embrace every kind of device or campaign for influencing public opinion, from the subtly persuasive to the obviously coercive. Government has at its command a wide range of resources for achieving these ends. We have chosen not to speculate about them."

There is, accordingly, good reason to believe that plans for electronuclear developments will not be open to effective democratic scrutiny, although they may elicit other less desirable public reaction. If plans are to be implemented, they must be paid for. As earlier chapters have described, the type, speed and scale of electronuclear plans which have been undertaken in Britain in the last two decades have entailed sweeping government involvement, on the financial level as elsewhere. It is clear from the record that the public has had little genuine opportunity to influence the course of electronuclear financing. Even at the most obvious point - that of tariffs, and the resulting electricity bills - prices have risen as decreed by the government at the request of the industry. During the period when prices were restrained, the effective difference in the pattern of payment meant only that money from the public was channelled via taxes to the industry, rather than via tariffs.

An individual small consumer had, and has, no option but to pay up, or be deprived of electricity supply. He may, of course, decide to switch from one type of energy supply to another - from electricity to gas for heating or cooking, for instance. However, to do so will involve losing his capital investment in appliances. In any case, on the time scale of current long-term official planning, there will come a time when such a switch will no longer be possible: when gas is no longer being supplied, in line with current official declarations as to its availability. The official view of future energy supply implies that, within the lifetime of many present-day Britons, the only form of energy supply which will be delivered to the great majority of premises will be electricity. At such a time the customer's preference will be Hobson's choice; and his already minuscule leverage on the tariff he pays for electricity will vanish. Larger users will to be sure still have alternatives - with a comparably larger penalty for switching capital from one system to another, say from electricity to direct combustion of coal. But the large user who still desires to be connected to the grid will not have the option of on-site generation of his own electricity, except by paying the unpublished tariff decreed by the grid operator (see p. 66).

In recent years the rise in electricity tariffs has presented many low-income users with a brutal dilemma: whether to spend their limited resources on food or energy, to run up electricity bills they have no hope of paying, or to switch off heating they can ill manage without. In 1976 more than 200,000 electricity customers had their supply cut off for failure to pay. Some old age pensioners undoubtedly died as a result of their fear of using even one-bar electric fires, for fear of the cost; many thousands certainly suffered from hypothermia. To combat the trend a number of socially-oriented pressure groups united under the banner of the Right To Fuel campaign, to call for a ban on electricity disconnections, in view of the genuine hazard they represent to those disconnected. An acrimonious debate ensued, with the electricity industry asserting that it saw no reason why reliable and financially responsible customers should have to bear extra costs on behalf of the rest. The Right To Fuel campaign asked that court proceedings be required before any customer be disconnected; the industry responded by alleging that the cost would add 10 per cent to present electricity bills. The issue remains unresolved; but the industry clearly has the controlling position. Without explicit legislative action there is unlikely to be any fundamental change, especially any change which adds further to the rapid increase in the delivered cost of electricity; and this implication makes any such legislative action unlikely. A further complication is that present policy allows a decision to disconnect to be made locally, with no significant high-level supervision; the opportunities thus offered for bureaucratic pettiness are considerable, and may grow more so. The government has recognized the problem which present-day energy costs represent to low-income users; in early 1977 some £25 million was made available to provide grants to assist in payment of electricity bills for those whose circumstances meet the conditions. Even here, however, there is an element of the ad hoc, with no coherent long-term policy in evidence. The grants are to be made available for the payment only of electricity bills, not of gas bills or - perhaps even more sensible - bills for improved insulation of draughty and unsatisfactory dwellings; and they apply only to the first quarter of 1977. All the indications are that the severe sanction of disconnection of supply will remain to reinforce the industry's inevitably increasing tariffs. The resentment and frustration of electricity users are not likely to diminish.

The user of grid electricity, it is clear, has very little opportunity to control the money he pays directly for the electricity he uses. He has even less opportunity to control the money he pays indirectly, via taxes. The problem of Parliamentary scrutiny identified by Flood and Grove-White in respect of planning (see p.93-94) applies with similar force to considerations of public financing of electronuclear activities. Nominally, to be sure, the investment plans of the electricity supply industry require the approval of the Minister, as do those of the AEA and BNFL. In practice, however, Ministerial decisions relating to such investment - and to government subventions, guarantees, and other financial support - escape significant challenge from the Commons. The annual increment of public money for the AEA, which now appears in the Civil Estimates under the heading of "Industrial Innovation: Nuclear Energy", a uniquely privileged energy technology, is swept through annually without comment, although it now entails allocating nearly £100 million per annum as a direct grant not subject to repayment.

On 8 February 1977, the Secretary of State for Energy brought before the House the Nuclear Industry (Finance) Bill, which proposed to earmark up to £500 million of government funds to guarantee loans from private finance to BNFL for its current expansion plans - plus another £500 million to guarantee advance payments by customers for fuel cycle services from BNFL. Through two Commons debates and three sittings of the Standing Committee on the Bill the Minister of State, Alex Eadie MP, simply ignored a wide range of substantive particular queries raised by MPs from all sides of the House. He declared repeatedly that he had answered this query or that, citing earlier speeches: but a dispassionate reading of the cited passage revealed in each case not the slightest attempt to offer anything but benign reassurance that the government know best and that all was well. Unfortunately the official Opposition were inclined not to pursue the matter, accepting the government's reassurance, in a way that would have been extraordinary if a similar sum had been proposed for, say, British Leyland. The nuclear inner sanctum effect prevailed. If, in due course, as seems entirely possible, the government is called upon to make good on guarantees thus offered, it may be expected that the public will remain, as hitherto, in the dark.

In the coming months the government may in succession decide to devote further public funds to electronuclear plans: early ordering of the Drax B coal-fired base load station, of the Sizewell B and Torness nuclear stations, and of the CFR-1 fast reactor station. It must be doubted whether Parliamentary scrutiny will play any role in the decisions, except of a cosmetic nature. The inability of the public to influence, directly or indirectly, the support given to electronuclear plans means that resources are allocated by default and by definition, to further the development of a system whose type and scale are by no means obviously optimum in the overall economic or social context. As the electronuclear system becomes the dominant mode of energy supply, so will it be less and less susceptible to public control or query. Whether this will be generally accepted by the public must remain a matter for speculation.

It is, indeed, not easy to see at once where control of electronuclear activities may come to lie. The conventional assumption is that control will lie with the government Minister, with his civil servants, or with the senior administrators of the electricity supply system itself. However, as discussed in earlier chapters, much of the necessary decision making is now taking on the character of an act of faith; and the faithful cannot claim to exercise control over the outcome of such an act. Decisions taken in the near future will impose constraints which will remain in effect for decades hence. The time scale and interdependence of the electricity supply sector make it increasingly difficult to identify any effective human control mechanisms whatever, on long-term fundamentals. The system is already showing signs of becoming self-propagating.

On a day-to-day basis, however, it is abundantly clear where the control of the electricity supply system lies. It lies with those who are closest to the switches. The plant operators, the grid controllers and their colleagues are the link between the electricity supply system and the society it supplies. All the other staff of the electricity system - the administrators, the planners, even the Board chairmen - are ancillary appendages of the handful of highly skilled personnel who actually run the equipment. Without them the system is useless. It may be recalled that at the time of the last showdown over political "power-sharing" in Northern Ireland, the Protestant Workers' Council called what amounted to a general strike. Among the workers who responded were the engineers from the Northern Ireland electricity system. In the resulting confusion, one call was frequently heard: for the army to go in to operate the power stations. But knowledgeable people pointed to the futility of any such attempt. In the first place the skills required to operate the stations and the rest of the system were far too specialized and the system far too complex for less than qualified staff to tackle the job. In the second place, any overt move on the part of the army might be greeted by swift, definitive and irreparable sabotage by those who knew precisely where the system was most vulnerable. In the overthrow of the "power-sharing executive" in Northern Ireland, control of the electricity supply system played a significant part; and the control lay in the hands of the system operators.

Such being the case, the system administrators must obviously exert such control as they can over those to whom such responsibility - and such power - is to be given.

American nuclear engineer Gregory Minor, who resigned from US General Electric because of concern about the implications of civil nuclear energy, has pointed out a curious aspect of the problem. According to Minor, a number of pivotal jobs - such as that of reactor operator - should not be filled by personnel of high intelligence. A reactor operator spends an entire shift watching charts and dials which ideally show no change of interest or importance. Unless the operator is prepared to accept the consequent boredom he is likely to be unsuited for the job. However, should a chart or dial reveal - possibly quite suddenly - a fault, the operator will be expected to respond swiftly and capably. The inconsistency of the requirements for such positions is only now becoming apparent. It also casts a vaguely disquieting light on the psychological context of those with immediate control of the electricity system. This psychological context is reinforced by the antiseptic remoteness of the control centre itself, in which even a major malfunction will manifest itself only at the end of a long sequence of intervening communication links. A worker on an assembly line may also find the work boring; but at least he will be surrounded by activity. The control room of a base load power station in normal operation is industrially akin to sensory deprivation. There is undoubtedly too much stimulation in many industrial jobs; but in some key jobs in the electricity supply industry there may be too little.

Be that as it may, the jobs are indeed key jobs: so much so that - especially if the future dominance of the electricity supply is fulfilled - electricity system operating staff cannot be allowed to strike. That, however, may be easier to decree than to enforce, as the strike in Northern Ireland demonstrated (see pp. 98-9). Although the operating staff of an individual base load power station may number in the low hundreds - and although only a handful of these may be essential to the actual control of the station - the unions representing the staff of the electricity supply industry are, like most others, very large indeed, with many strata of union bureaucracy between the union leaders and the shop floor. It is well known that many of the most troublesome industrial relations problems in recent years have arisen through unofficial action by shop-floor workers whose grievances even their own union leaders have been unable to settle. Trades union leadership cannot prevent shop-floor industrial unrest; they may find themselves as unwilling, as unpopular and as devoid of control as management. On 25 January 1977 thirty-two changing-room workers at Windscale went on unofficial strike for increased hazard allowances. BNFL management sent home the rest of the workforce who could not then enter the radioactive areas of the plant; when it became apparent that the rest of the staff were not to be paid some 3,000 men walked out. Protracted negotiations between management, union officials and the shop-floor representatives failed to break the deadlock. The strike lasted into March. By this time the workers were picketing the gate of the plant. On 7 March the pickets refused admittance to a lorry carrying a load of liquid nitrogen required to maintain an inert atmosphere in a plutonium store. On 10 March they repeated the refusal. Secretary of State for Energy Tony Benn made a flying visit to the plant, as concern began to mount about the safety implications of the strike action. According to reports, he received a stormy reception from the strikers, but warned them that, if necessary, troops would be brought in to get the essential safety supplies into the plant. At that point the strike collapsed; the workers accepted a token offer from the management and returned to work. However, the strike demonstrated the vulnerability of the system. The Calder Hall reactors had to be shut down as soon as the full-scale strike occurred, cutting off their supply of electricity to the grid.

Throughout its duration the strike remained unofficial, but it was no less intractable for that, indeed it was probably more so. The local nature of the strike meant that its effect on electricity supplies was minimal; and the type of action taken meant that the government threat to bring in troops could have been carried out effectively if necessary - although it may be doubted that troops could have taken the necessary safety measures without difficulty. However, if - as the strikers requested - the strike had been made national, and had involved power station workers all over the country, the government would have been faced with a much more challenging problem. It might have presented an immediate and desperate threat not merely to the safety of a single industrial installation but to the entire electricity supply. If the electricity supply system continues to become ever more essential, such an eventuality will be only a matter of time. It is by no means clear how the government of the day will cope with it. Calling in the army will only exacerbate the problem.

Control of the electricity supply system thus presents inherent difficulties, because of the nature of the system and of the role it plays. Because it is impossible to store electricity, and because of the commitment to guarantee supply, control of the system is precariously vulnerable; the social context aggravates this vulnerability. Interruption of normal operation of the electricity supply system can have effects which are both nationwide and virtually instantaneous, and may be lethally disruptive. Those who administer and manage the system cannot claim effective control even over the actual operators of the system, much less those outside the system who might, for whatever reason, interfere with its operation. The system administrators must therefore strive to foresee and forestall any disruption, whether internal or external. In Britain, industrial relations within the electricity industry, and social circumstances surrounding it, have not thus far occasioned any acute tensions of the kind which might lead to actual disruption of electricity supplies on a large scale. There has, to be sure, been brief and selective industrial action by electrical power engineers - notably an overtime ban in 1973 - cutting off supplies to some customers. There have also been small-scale acts of violence involving the destruction of power pylons and other facilities in Scotland and Wales. But such incidents have been isolated and infrequent, briefly inconvenient rather than disastrous. There is little evidence that the administrators of the electricity supply system in Britain have hitherto taken any more precautions against wilful disruption than might be expected in any large industrial undertaking - nor indeed any evidence of need for such precautions. This happy state of affairs may be indefinitely prolonged. On the other hand it may not.

In any event, whatever the attitude of the rest of the electricity sector, the nuclear establishment has always accorded security a special pre-eminence in its activities. Initially, of course, the security in question was the handmaiden of military secrecy related to national defence. But long after the inception of the civil nuclear programme the security provisions still apply, and are being strengthened. Even in Britain, albeit gradually, civil nuclear administrators are coming to accept the possibility of sabotage of nuclear facilities, or of the theft and misuse of fissile material, particularly plutonium. The Flowers report (see Chapter 4) devoted an entire chapter to the subject, Chapter VII, "Security and the Safeguarding of Plutonium". It is a sombre survey, underlining the credibility of concern, not only regarding the various categories of threats which might be posed, but also regarding the social and political effects of official responses to such threats. The Chapter concludes:

"335. We are confident that the security hazards associated with the present level of nuclear development in the UK are now fully appreciated by the Government and the authorities concerned, and that the security measures now in force or planned are adequate for present circumstances. We have no doubt that these measures will be periodically reviewed, and if necessary strengthened, in the light of nuclear and other developments that would affect assessment of the risks. However, a flexible response to security risks in the light of events is one thing; it is quite another to question whether the hazards of nuclear development in the future could become so great that adequate security could not be ensured, or alternatively whether the implications of the security measures needed could become unacceptable to society. We cannot see that the present system by which decisions are reached on nuclear development allows us to address ourselves to such questions.

"336. The issues we have discussed in this Chapter - the risk of sabotage against nuclear installations, the risk of plutonium diversion and its use in terrorist action or threats against society, and the extent of the security measures that might become necessary to provide adequate safeguards - are by their nature very difficult to assess. The significance that they might assume in the future can only be a matter of opinion, depending on speculative judgements about likely developments in society, and to some degree in the world at large, which no one can make with certainty. Nevertheless, these issues are real and important and of a kind which, in our view, require wide appreciation and discussion. Public debate will not resolve them but it may form a climate of opinion which would assist Government in assessing the weight that should be given to these matters in decisions on nuclear development. Though serious risks from such development probably lie well into the future, judgement about their possible severity and acceptability could react on decisions that need to be taken now."

Part 1 of *Nuclear Prospects* by Flood and Grove-White (see pp. 91-95) is entitled "Security and nuclear democracy". Although the study was undertaken some months before publication of the Flowers report, Flood and Grove-White, in what they called "a spirit of high conjecture", carried out precisely the sort of "speculative judgements about likely developments in society" to which the Flowers report alluded. In their introduction they acknowledge that "there is a real and troubling conflict between the priorities of public knowledge and nuclear security. The conflict is clear from the very fact that we raise the issue at this early stage in our speculations. Happily, however, in its important recent report on *Nuclear Power and the Environment*, the Royal Commission on Environmental Pollution has faced the problem - and has urged that discussion should proceed. We agree with this judgement. It would be far the unhappiest and most distinctive feature of nuclear power if its successful development were held to involve hazards so great that a democracy could be prohibited from talking about them."

Flood and Grove-White's "reference year programme" of installed nuclear generating capacity is derived from figures presented by the AEA and the Department of Energy, and postulates a year in which 66 gigawatts of fast breeder capacity and 62.5 gigawatts of thermal reactor capacity are in service in Britain - which might arise, on official projections, by about the year 2005. The programme would entail utilizing plutonium-uranium fuel containing some 86 tonnes of plutonium, plus an equivalent additional amount elsewhere in the fuel cycle during the year. There would be some 100 nuclear reactors in service, at 30 or 40 different sites around the country; there would be four or five shipments a day of plutonium fuel from fuel fabrication plants like that at Windscale to the various power station sites. Plutonium fuel would be moving regularly from the control of the fabricators, BNFL, to the control of the electricity supply industry. "Major problems of security would then be presented by the steady growth in the numbers of individuals with access to plutonium, in a pure or mixed form, the increased possibilities for sabotage of nuclear reactors, and the steadily more complex and centralized nature of the country's energy supply system."

In Appendix III Flood and Grove-White discuss "Credible terrorist threats arising from nuclear power", in particular the theft and malicious use of plutonium and the sabotage of nuclear installations. By reference to authoritative sources they make it undeniably clear that the implications of nuclear terrorism are real and appalling. In their view "The catastrophic consequences that could follow from the passing of plutonium into the wrong hands, or from sabotage of a fast breeder reactor, require that such possibilities should be treated as matters of the gravest national importance. This means it is the Security Service, MI5, that would prescribe and supervise the safeguards to be employed" - and "In its actions, and more particularly in its *policies*, the Service appears to be subject to no formal fetters", Parliamentary or otherwise. "It would not be surprising if the clandestine nature of the Service's conduct and its lack of direct accountability were already obscuring our view of what plutonium and fast breeder safeguards might entail."

The security services - MI5, the Special Branch, and the security officials of the various public agencies involved - already take seriously the threat of nuclear malevolence. There is a strict security embargo on information about movements of plutonium fuel between Windscale and Dounreay. All professional staff at AEA establishments and at Windscale are "positively vetted": subjected to rigorous security investigation of their personal lives and political associations. The application of the Official Secrets Acts 1911 and 1920 to civil nuclear activities means that "the passing by employees to outsiders of even the most trivial information about activities within the various plants may be subject to penal sanctions". "The Authority also has its own Special Constabulary to guard installations (including BNFL's fuel processing facilities) and movements of specified nuclear materials such as plutonium. Uniquely amongst private police forces this Constabulary has powers to carry arms of all descriptions at all times, to engage in 'hot pursuit' of thieves or attempted thieves of nuclear materials and to arrest on suspicion." Flood and Grove-White comment "Thus the known blanket of security practice with regard to Britain's present modest plutonium and FBR (fast breeder reactor) activities is already extensive. It may reasonably be taken to reflect a sober appraisal of the types and levels of risk now seen to exist in these activities."

Flood and Grove-White then extrapolate to their "reference year" They suggest that the plutonium traffic then occurring would entail enjoining under the Official Secrets Acts tens of thousands of employees of the electricity supply system, and subjecting them to vetting as stringent as that currently required for the AEA and BNFL. "For the first time in the UK, the 'political associations' and 'character defects' of many thousands of non-government employees would become objects of routine security service investigation," with no redress for those deemed unsuited. Even "an employee's attitude to nuclear power itself could become an object of interest". Similar rigorous screening might even be extended to power station construction staff and other service industries. "Finally, it is likely the CEGB would need a substantial armed constabulary, comparable to the AEA's Special Constabulary, to guard the growing quantities of special nuclear materials and sensitive nuclear installations under its jurisdiction," with profound constitutional implications.

The security net would not, however, stop there. "The risks of nuclear malevolence make it imperative that the security services should be aware continually of individuals or groups likely to conspire in such acts." Surveillance and infiltration, not only of politically active radical groups but of other types of political association may ensue: "it is likely that (plutonium) use (will) create pressures for infiltration into civic, political, environmental and professional groups to a far greater extent than previously encountered and with a greater impact on speech and associational rights" *(The Impact of Intensified Nuclear Safeguards on Civil Liberties,* report of a conference at Stanford Law School, quoted by Flood and Grove-White).

Simple opposition to further development of nuclear power may soon be justification for security surveillance in Britain; such opposition is already seen by at least one British trade union and a number of influential European bodies to represent "politically motivated" intention to "undermine society". Even traditional local opposition to power station siting may provoke the suspicion of the security services, especially if - as must be considered possible - such opposition gives rise to civil disobedience. Surveillance may include telephone tapping, opening of mail and telegrams, and the use of informers; none of these methods is subject to effective legal constraint under British law. Security requirements may entail further official pressure on news media, and further constriction of the flow of information - even information with no security implications - about civil nuclear activities, further impeding Parliamentary and public scrutiny.

The clearest recent signpost along the road to the plutonium economy was the passage of the Atomic Energy Authority (Special Constables) Act 1976. By its passage, say Flood and Grove-White, "Parliament accepted security measures which are seriously at odds with Parliamentary control of nuclear power. But in the circumstances, we argue, Parliament may have had little choice. For the brutal message of the Atomic Energy Authority (Special Constables) Act seems to be that plutonium security is not simply more important than democratic controls. It may actually be *incompatible* with those controls."

The Act established for the first time a third armed force in a grey area between the armed forces and the regular police (whose access to firearms is restricted by statute). "Despite the Special Constabulary's broad powers and the almost total public ignorance of its structure and code of conduct, the line of its accountability to Parliament is extremely thin" - as Flood and Grove-White document with finality. They deduce that Ministerial reluctance to exercise direct control might be because "greater Ministerial powers over the Constabulary would actually *inhibit* the effective guarding of special nuclear materials and installations" - that "the Government may have been advised by the security services *not* to give powers to a Minister, precisely in order to avoid the possibility of answerability for the Constabulary's actions". "If this reading of the Special Constables Act's passage is correct, civil nuclear power has already presented Britain with a frightening dilemma. Effective security of nuclear materials demands Parliamentary (and hence public) ignorance. But public ignorance on matters of this importance is totally incompatible with an appraisal of the full implications of a growing nuclear commitment."

Pre-emptive security measures, no matter how stringent, cannot in the last analysis guarantee to prevent the theft of a significant quantity of plutonium - which might be 6 to 8 kilograms out of the annual traffic of over 100 tonnes. Since materials accounting cannot be made more precise than about 1 per cent, it will be impossible to know that no plutonium has been stolen; any threat based on implied theft is credible. If a theft were to occur, Flood and Grove-White point out that recovery of the stolen material would take precedence over all procedural niceties; the threat of a terrorist nuclear device would be of overriding concern. "The power to undertake very general house to house searches might be needed. Speed of recovery could be of the utmost national importance, as malevolent use of plutonium could give rise to a disaster many times greater than has hitherto resulted from terrorist action." Present law grants no police powers of general search. If they are thought necessary, "powers of general search would have to be granted by Parliament in *anticipation* of any such emergency. In the passage of a Bill through Parliament, the public would thus be made aware of the purposes for which the powers were required. This would mean in turn that actual recourse to the powers, should this prove necessary, would be profoundly alarming to public opinion. It might well be known that plutonium had been stolen - and that this could recur. Such alarm could give rise to great public pressure for more stringent and so potentially more repressive measures of surveillance and pre-emption, to prevent a repetition. The consequences for civil liberties, and even for political dissent in general, could be extensive". Granted such powers, the authorities might feel called upon to use them in other non-nuclear crises. "In this way, the possibility of a plutonium crisis, even if it never took place, could seriously change the relationship between individual citizens and authority."

In sum, there is reason to fear that increasing reliance on centralized electricity supply, powered by fast breeder reactors and fuelled by plutonium, will seriously erode the trust which is the basis of government with the consent of the governed. The vulnerability of the essential energy supply seems likely to require official measures unpleasantly suggestive of the totalitarian. In a country with the historic libertarian tradition of Britain such measures are unlikely to be universally accepted without dissent. The consequent social polarization and tension could create precisely the conditions most likely to provoke the confrontation to which the energy system would be most vulnerable. To say the least the prospect does not appear to be one of durable social stability. It is rather of a social system subject to steadily mounting stresses within, and vulnerable to catastrophic disruption: a fissile society.

9 Nuclear electricity: future imperative?

Some nuclear advocates in Britain have lately begun to call any and all criticism of their activities and proposals "emotional" - and therefore by implication ill-informed, irrational, unbalanced, unworthy of reasoned discussion. It may be assumed that the preceding chapters will be similarly stigmatized. Despite the apparent intention of those who thus use the term, there is nothing necessarily pejorative about being "emotional"; some prospects entirely warrant a response with a leavening of emotion. Indeed, emotion is the lifeblood of the political process. Nevertheless, those same nuclear advocates who chide critics for being "emotional" have themselves taken to using remarkably "emotive" language. Sir John Hill, Chairman of the AEA, in the *Morning Star* for 8 February 1977, summed up his attitude thus: "But without nuclear power how will we be able to meet the energy deficit which is certain to arise in about 15 years' time and which will affect transport, industry, heating and lighting and the: standard of living to which we are used, and which for many is still not high enough?" The tenor of argument advanced is that we must decide rapidly whether to opt for fast breeder reactors or for freezing in the dark - certainly by any criterion an "emotional" argument, and one which begs more questions than it answers.

According to nuclear advocates a steady expansion of nuclear electricity is effectively inevitable, the only credible option for future energy supply. If this were indeed the case, the corollaries, however unattractive, would be likewise inevitable. The only reasonable course for the general public would be, metaphorically, to relax and enjoy it. Planning would have to adapt to the nuclear electric influence: centralization, increasing scale of system and units, planning by faith and edict, and above all subtly pervasive secrecy. Patterns of energy use would have to adjust to the characteristics of the supply. Transport, for instance, would have to be progressively electrified - perhaps on its own terms a desirable development, but one which would be undertaken willy-nilly, desirable or not. The capital requirements of electronuclear investment would have to be found, almost inevitably by diverting resources from other sectors, probably including general industrial investment. There would be a fundamental structural shift in patterns of employment associated with energy supply and use, from long-term stable operating jobs to short-term transient construction jobs, and from skill-intensive jobs to unambiguously labour-intensive jobs. Substitution of capital and energy for people would proceed, under the banner of "productivity", bringing with it industrial inflexibility and diminishing creative responsibility and initiative. In the event of irretrievable mistakes on the part of planners and administrators the first to suffer would be the workpeople; the size of undertakings and the time scale of plans would make gradual realignment of management objectives and acquisition of new skills difficult and "uneconomic". The nature of the planning process would make it less and less accessible to the public; but the vulnerability of the essential electronuclear system would impose on the authorities the need to foresee and forestall any manifestation of public discontent. For the people of Britain the putative inevitability of the electronuclear option, far from avoiding "drastic changes in lifestyle", would bring them in its train.

One further dimension must be added - in many ways the most important and urgent of all. The focus of attention hitherto has been confined to the electronuclear option as it has taken shape and influence within Britain. But the international dimension of the nuclear syndrome has now overtaken the national. In Britain as elsewhere the struggles of the civil nuclear industry have been translated into a compulsive drive to export civil nuclear services and technology to virtually all takers. Britain is at present involved in construction of the first two nuclear power stations in Iran, and is tendering for the first nuclear station to be ordered by Kuwait. BNFL has contracted to supply enriched uranium to a number of overseas customers; and overseas customers are expected to advance the capital for construction of a proposed new nuclear fuel reprocessing plant at Windscale (see p. 39). In return for overseas payments BNFL is likely to be expected to return to overseas customers - among them Japan, Sweden, Switzerland and Spain - the plutonium recovered from reprocessed fuel. Senior experts, particularly those in the US, are now acutely concerned at the implications of such activities. On 1 November 1976 Dr Victor Gilinsky, one of the five Commissioners of the US Nuclear Regulatory Commission, told an audience at the Massachusetts Institute of Technology: "International action to control [the dangers of the proliferation of nuclear weapons] associated with the civilian nuclear fuel cycle depends critically on understanding of two facts: first, that nuclear weapons can be manufactured from reactor-grade plutonium; and second, that for any nation that has done its homework, separated plutonium - in either metallic or oxide form - can be suddenly appropriated from its storage place and inserted in warheads within days. A recent IAEA (International Atomic Energy Agency) document acknowledges this latter point. It concludes the safeguards system must be able to function on the same time scale. The Agency does not appear, however, to have seen the vital implication of these facts, which is that separated plutonium is not safeguardable by any means now available to us - we cannot count on warning in time to head off an illicit weapons effort."

All the indications are that the senior administrators of the British nuclear establishment have failed to come to grips with this crucial realization. Just as they insist that domestic plutonium utilization will pose no insuperable problems, so they similarly insist that the international implications will be amenable to control. Present projections suggest that by the year 1990 there will be enough plutonium produced in Third World countries alone to manufacture 10 atom bombs per day. The title of a 1976 report to the US Arms Control and Disarmament Agency asks if the nations of the world may be "Moving Toward Life In A Nuclear-Armed Crowd?". In itself it is a frightening prospect. More frightening still is the evidence that many British nuclear administrators do not take the prospect seriously. Their determination to advance the cause of the "peaceful atom" may be a fatal stumbling-block in the way of those trying to prevent a worldwide build-up of nuclear weapons.

Nevertheless, if the electronuclear option in Britain and elsewhere is inevitable, so are all its accompanying attributes - including its original obverse, nuclear weapons. There is, however, an alternative interpretation of the state of affairs. It seems abundantly clear that no one would ever have attempted to establish a civil nuclear industry on a normal commercial economic basis. The capital commitment would have been too astronomical, the lead-times too long, the technology too complex and interdependent. Only the existence of the military nuclear weapons programmes made civil nuclear development possible. Indeed it seems clear that nuclear weapons likewise provided the psychological - "emotional" - impetus behind the civil programme. Many of those involved desperately desired to demonstrate that their work on nuclear fission would ultimately be a boon, not a bane to mankind. It was an entirely understandable and laudable desire, and - given the existence of the facilities and the skills - eminently worth pursuit. However, two decades later it must surely be time to pause for reassessment. On the basis of the historical record, and despite extraordinary support from public funds, nuclear electricity as an energy supply technology has proved inordinately complex, difficult, expensive, vulnerable and risky. To suggest, as do nuclear advocates, that only the electronuclear option remains is surely a counsel of desperation. It might with at least equal justice be argued that the government's obsessive support for the electronuclear option since the mid-1950s has been misguided and diversionary, and that the time has come to redirect British energy policy onto a more rational pathway.

There is, to be sure, a common public impression that, "if only it were safe", nuclear electricity would be the ideal form of energy supply. The record, however, demonstrates that even if it were unquestionably free from any hazard whatever, nuclear electricity would be no bargain. Only the stubborn determination of government, influenced behind the scenes by the advice of weapons-programme alumni, has kept the British civil nuclear programme from collapsing long since under its own burden of inconsistencies. Just as it could not have been launched on normal commercial terms, so it has never had to meet normal commercial economic criteria, and shows no sign of being capable of doing so in the future: witness the historical and present position regarding funding for research and development, uranium exploration and mining, enrichment, nuclear power station construction, reprocessing, radioactive waste management, insurance, regulatory supervision, and export activities, among others. Only regular transfusions of public money, eight or nine digits at a time, have kept the nuclear invalid from expiring of terminal futility. As a result a staggering amount not only of money but also of effort and time has been squandered, resources which might have been devoted with greater advantage to any number of other energy-related activities in the past twenty years. Despite the cumulative setbacks, the momentum of commitment nevertheless remains and prevails. Public accountability and control, always rudimentary hitherto, seems likely to become steadily more tenuous. The question now is not "whether Britain can survive without nuclear power", but whether Britain can get out of the nuclear cul-de-sac with as little further expense and embarrassment as possible.

It must be emphasized that the civil nuclear fiasco has not been the fault of those in the industry. The great majority of those engaged in civil nuclear affairs have done so in good faith and with dedication, in the genuine conviction that their work would benefit the community. Indeed it must be added that nuclear industry staff have been as susceptible as the general public to the combined effect of enthusiastic propaganda plus secrecy. The true state of affairs must be as much a surprise to them as it is to the public.

It must likewise be emphasized that, whatever its drawbacks and problems, the British civil nuclear industry exists; no precipitate public disillusion will make it go away. The Magnox nuclear power stations seem likely to have some years of useful service in them yet; the AGRs, barring further trouble, can be expected to play a significant role in base load generation until the turn of the century. Both series of stations will require the manufacture of fuel for their lifetimes; the AGRs will also require enrichment services. Unless some alternative means of spent fuel storage is installed - gas-cooled storage like that at Wylfa, for instance - Magnox fuel will require reprocessing. Oxide fuel from the AGRs need not be reprocessed, unless it is established that long-term radioactive waste managemerit requires reprocessing, and unless some credible programme for handling - and safeguarding - of the separated plutonium has been devised. But spent AGR fuel will have to be stored, presumably in water-filled cooling ponds, in the interim, with appropriate supervision. Staff now employed in the existing facilities are likely to be required for the rest of their working lives. Simply unravelling the legacy of problems will probably take a generation.

The civil nuclear industry, in Britain as elsewhere, is an artificial creation of government, nurtured in a bureaucratic hot-house in the hope that one day it could be transplanted into the real world. That hope seems increasingly vain - unless the real world is to change drastically to suit nuclear electricity. If it is not, the day cannot be long postponed when it will be necessary to decide in principle to phase out electronuclear activities, in favour of more sustainable alternatives. The sooner such a decision is taken, the less painful will be its consequences - and the easier it will be to re-orient planning, finance and employment into healthier directions. Without such a decision, the momentum of central commitment will carry the day. The future will be electric.

Postscript

Civil nuclear advocates have lately begun to insist that Britain must keep "the nuclear option" open, while likewise insisting that nuclear electricity, plutonium fuel and the fast breeder reactor are "inevitable". There is no such thing as an inevitable option. An option can be pursued, or it can be forgone in favour of others more promising. The official position in Britain as elsewhere is to set up nuclear electricity as the paradigm among energy options against which "alternatives" must be measured: "if not nuclear electricity, what else is there?" This is special pleading at its most egregious. It makes as much sense to ask the alternative to burning five-pound notes. The alternative, first of all, is not to.

Nuclear electricity in Britain this year reaches its twenty-first birthday. Far from welcoming the key to the door it remains patently incapable of surviving on its own, without massive and perpetual assistance. If the British government had not been so obsessively determined to bring into being a civil nuclear industry, shielding it for two decades from the chill wind of everyday economics, the resources, skills and time thereby sequestered would have been freed for application in any number of more rational directions. In 1977 the alternative to expanding Britain's civil nuclear industry is not to expand it. Simply removing the burden of the electronuclear commitment will provide a welcome stimulus to constructive thought and action about energy.

It is, after all, less than four years since OPEC changed the ground rules; and there is already an abundance of constructive thought and action taking place in Britain - albeit with very little government support. Organizations like the International Institute for Environment and Development, the Science Policy Research Unit at the University of Sussex, the Energy Research Group at the Open University, the publishers of the present study, and many others are contributing to a ferment of innovative analysis and policy formulation, shaking off the outworn habits of the wasteful decades, looking anew at how energy is actually used, and devising the most elegant and efficient ways to supply the appropriate kinds of energy. Centres of excellence in creative energy technology are springing up everywhere: Cardiff University's Solar Energy Unit; the wave power team at Edinburgh University and Loughborough Polytechnic, and their colleagues following other approaches; Reading University's wind energy specialists; and like-minded engineers and technologists in many other disciplines, at many other institutions. The Building Research Establishment is investigating and publicizing the numerous possibilities for improving the thermal performance of buildings, both those already standing and those now coming off the drawing boards. Interest groups like the District Heating Association and the International Solar Energy Society UK Section, and professional bodies like the Institute of Fuel, the Institution of Electrical Engineers, the Institution of Civil Engineers, and the Institution of Mechanical Engineers are devoting active attention to the wide range of opportunities now coming to light.

Local councils all over Britain are carrying out projects and evaluations of up-graded insulation standards, solar installations, heat pumps, energy stores and total-energy systems, not only in existing and new housing but also in public buildings such as schools and administrative blocks. Industries from the smallest to the largest are demonstrating that they can achieve dramatic improvements in the efficiency of their energy use - and the Department of Energy is advertising their achievements. Trades unions are beginning to recognize that it is in the interests of their members to encourage a trend away from capital-intensive, inflexible industry toward skill-intensive production and products - witness the Corporate Plan prepared by the Lucas Aerospace Combine Shop Stewards Committee, with its imaginative chapter on small-scale diverse energy technologies. The Department of Energy's own Energy Technology Support Unit is at last offering tentative endorsement to solar energy and combined heat-and-power, and inviting discussion of progressively more innovative programmes of research and development.

The Parliamentary Select Committee on Science and Technology in 1975 published a report on energy conservation which made many substantive and valuable recommendations; its report on alternative sources of energy is expected later this year. Members of both Houses of Parliament regularly raise questions of fundamental importance to energy policy in debate and in Parliamentary Questions. Many well-informed and articulate journalists carry the issues to the public at large. The Department of Energy itself, while still espousing the narrowly electronuclear view of the energy future, has lately begun to show signs of growing enlightenment.

Britain's energy scene is nothing if not energetic. Imagine how much more so it would be if a significant fraction of present electronuclear funding were progressively made more widely available for research and development and investment: in energy conservation technologies, advanced coal extraction and utilization technologies, cogeneration of heat and electricity, heat pumps, solar water and space heating, low temperature long-term energy storage - energy technologies which already exist and need only a modicum of official recognition and support to become increasingly valuable contributors to a sensible energy mix. Other technologies are waiting in the wings. The opportunities for long-term skilled jobs and for a newly vigorous energy export industry are there for the taking.

Civil nuclear advocates tend to see critics as "anti-nuclear", and to see such criticism in a narrow frame of reference defined by nuclear electricity. Some nuclear advocates go so far as to suggest that nuclear critics are in some sense "against progress", hostile to technology *per se,* neo-Luddites. It is understandable that those within the nuclear industry should see nuclear issues as "yes-no": "yes, do this nuclear thing" or "no, do not do this nuclear thing". But nuclear issues, like all other issues in human affairs, are "either-or": "either do this nuclear thing or do something else instead". Nuclear diehards who now insist that theirs is the only possible path to pursue are preaching an indefensible doctrine of fatalism. Humanity deserves better.

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Abbreviations

ACORD	Advisory Council on Research and Development for Fuel and Power
AEA	(UK) Atomic Energy Authority
AEI	Associated Electrical Industries Ltd
AGR	Advanced gas-cooled reactor
BNDC	British Nuclear Design and Construction
BNFL	British Nuclear Fuels Ltd
CEA	Central Electricity Authority
CEB	Central Electricity Board
CEGB	Central Electricity Generating Board
CFR	Commercial fast reactor
CPRS	Central Policy Review Staff
ERG	(Open University) Energy Research Group
FBR	Fast breeder reactor
GDP	Gross domestic product
GEC	General Electric Company Ltd
IAEA	International Atomic Energy Agency
LWR	Light water reactor
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NoSHEB	North of Scotland Hydro-Electric Board
NPAB	Nuclear Power Advisory Board
OPEC	Organization of Petroleum Exporting Countries
OU	Open University
PWR	Pressurized water reactor
R&D	Research and development
SGRWR	Steam generating heavy water reactor
SSEB	South of Scotland Electricity Board
TNPC	The Nuclear Power Company Ltd
TNPC	The Nuclear Power Group
UNIREP	United Reprocessors GmbH

Conversions

1 megawatt=l million watts
1 gigawatt =1,000 megawatt
1 tonne=2,204.6 lb