UK Civil Nuclear Energy: What Lessons?

In 2008–09, the British Academy, the Science Museum and the Mile End Group of Queen Mary, University of London have jointly sponsored a series of lectures on 'Politics and energy'. On 6 May 2008 at the Science Museum, **Professor Sir Roger Williams** *began the series – listing the lessons to be learned by those planning a nuclear solution to our future energy needs.*

I WAS FLATTERED when asked to give this lecture. An ex-Vice Chancellor who has compounded his academic sin by going on to chair a higher education funding council is usually invited to speak only about higher education. My nuclear credentials are also somewhat long in the tooth: my book analysing Britain's Magnox and AGR nuclear power programmes was published in 1980, and the House of Lords inquiry on research and development in nuclear power, for which I was a specialist adviser, reported as long ago as 1987. The other specialist adviser on that occasion was Sir John Hill, former Atomic Energy Authority chairman, who sadly died in January 2008.

The remarkable thing, after the early decades of hyper-activity, is how relatively little has since happened to nuclear power, at least until the last few years. From the late 1970s to the late 1990s in particular, when new Asian orders began to be placed, the nuclear industry worldwide was in the doldrums. Nuclear power's share of expanding world electricity demand did nevertheless hold up, at around 16–17 per cent. This was because, despite all, there were a few start-ups as well as shutdowns, while growing experience with nuclear stations permitted increases in plant ratings, load factors and projected lives. But in the years of cheap gas and oil, when for most people carbon dioxide was something which they encountered only in fizzy drinks, nuclear power in Britain became almost *passé*, less considered even than coal as we rapidly shrank that industry.

Having begun by acknowledging the venerable character of my credentials, I want as a second initial point to enter a reservation. Although I am in this lecture to draw lessons from the history of nuclear power in Britain, I am a shade sceptical about all such exercises, for the following reason. Attacking Prime Minister Stanley Baldwin, Winston Churchill once asserted that 'History will say the right honourable gentleman was wrong in this matter,' adding after a brief pause, 'I know it will, because I shall write the history.' I recognise, in other words, that mine is simply one view of past events, and that other equally valid views are perfectly possible.

And there is yet a third introductory point I must make. With most topics it is hardly necessary for a speaker to say where exactly he is coming from, what his biases might be. But such an approach will not do here. Rather, I feel that, to be taken seriously, it is incumbent upon me to start by being as honest as possible about my own personal approach to nuclear power.

I did not spend years researching a book and publishing numerous papers about nuclear power because I was technocratic or gung-ho for this new technology. On the contrary, while deeply interested in nuclear power as science, technology and policy, at root I began by sharing the man-in-the-street's worries about it. Frankly, I had been uncomfortable about radiation since discovering casually one day in Oxford's Clarendon Laboratory that, among us physics undergraduates, it was my particular luminous wristwatch which emitted by far the most radiation. Further, in 1964 I initially accepted a junior research position at Culham, from Bas Pease no less, because, in my youthful idealism, I believed there had to be a better route to energy than nuclear fission, and that nuclear fusion was probably it. Fusion, you will recall, was then just forty years away from successful exploitation – as of course it still is.

Actually, romantic that I remain, I still have hopes of fusion: that after all is how the stars shine. But even if in the end fusion does prove a viable energy source on earth, such a development is well outside the current policy timeframe. As well as fusion, my other great speculative hope in the energy field centres on the new, or warm, superconductors, whose commercial introduction could hugely diminish transmission losses and so substantially transform the overall picture by increasing effective supply. This innovation would obviously be of greatest benefit where long distance transmission is required, as for example in bringing electricity from solar arrays in the Sahara to Europe, a scheme which has its advocates even with existing transmission methods. Unfortunately, superconductors of this sort, if not perhaps as distant a prospect as fusion, are still hardly on the immediate horizon.

To complete these somewhat personal observations, I ought finally to admit that, although in the mid 1960s I worked in operational research for the National Coal Board, was in fact safety-trained in the Kent coalfield at a time when there were many hundreds of coalmines, I have never held much of a brief for coal as an energy source either, because I grew up in a South Wales mining village and so knew at first-hand about both pneumoconiosis and the propensity for accidental death underground.

I am then, someone with no great natural love for either nuclear power or coal. It follows that I firmly support careful policy encouragement of all three current energy hopes: enhanced efficiency (including improved heat insulation), decentralised supply, and renewable sources, provided naturally that, in each case, the carbon footprints as well as the economics of all relevant artefacts are correctly treated. For what it is worth, my own greatest hope among the renewables is of tidal power, whether in barrage or free standing form, since this renewable is both predictable and potentially substantial. Really to let my prejudices show, I believe that only for better reasons than I have yet seen should we not proceed with some version of the proposed Severn Barrage.

I am also, however, a comfortable member of the middle classes, who wants his descendents to enjoy at least the same level of affluence and access to energy as he currently does, and wants them to do this on a planet whose temperature is stable. Furthermore, I am someone who can see no reason why all human beings should not aspire to precisely the same advantages as I enjoy, and in a timeframe which is not excessive.

I am making here, of course, what seems presently by far the safest working assumption in respect of global warming, that mankind needs to tackle it with substantially more commitment and urgency than we are as yet demonstrating. I am also moved in passing to observe that since, on only a little more extreme warming projections, the room in London where this lecture is being delivered could itself sooner rather than later be under water, significant defensive steps will eventually be needed outside, as well as within, the energy field.

Unfortunately, many of us, having examined the contemporary dilemma facing Britain and the world, remain unconvinced that energy efficiency, decentralised supply and renewable energy sources between them, however hard they are pressed, can guarantee energy security, at least on the requisite timescale. Energy security here, of course, implies both absolute supply and freedom from political problems in relation to access. Britain in particular faces a somewhat tight energy situation in a relatively short period and, with new energy facilities mostly having long lead times, has correspondingly limited room for manoeuvre. And like it or not, much of a rapidly growing world electricity demand over the next century, above all in China and India, is going to be met either by generation from coal, with carbon capture only if we are very lucky and the requisite technology advances more rapidly than currently seems likely; or else by nuclear power. It is against this domestic and international background that it seems to me both responsible and prudent for the British Government to have made the general provision in respect of nuclear power which it has now done: better even as late as this provision was, than never.

So much by way of preamble, necessary I feel if you are to be in a position properly to judge the credibility of what follows: in the balance of the 30 minutes allowed me, let me turn properly to my topic, the real lessons from the history of British civil nuclear power.

Public acceptance

For nuclear power to have a successful future in Britain a first vital lesson to be drawn from its past in this country is that nuclear policy must be 'owned' by the public to a much greater extent than it ever was in the past. This does not, and realistically could not, mean that everyone must be in favour of nuclear power. It does mean that there is brought about, as a minimum, a broad public acceptance that nuclear power is a rightful part of the way forward. I therefore believe it essential that those who espouse nuclear power take the trouble to ensure that at least this minimum acceptance comes about. Unfortunately, nothing like enough such trouble was taken in respect of the Magnox or Advanced Gas-cooled Reactor (AGR) programmes, or as regards the later introduction of light water reactor technology into Britain. It also needs to be recognised that public inquiries like those at Windscale in 1977–78 and Sizewell in 1982–85 are, at best, tangential to this objective.

One hundred and forty years and two World Wars separated Waterloo and the announcement of the Magnox programme. Nevertheless, British government in 1955 remained permeated by many who would fully have shared the Duke of Wellington's strong disapproval of soldiers cheering, as being too nearly an expression of opinion. Even constructive criticism was unwelcome in the 1950s and 1960s, as I know from direct experience. In my book I described the politics of British nuclear power in its first decades as essentially 'private' to the institutions concerned, the Atomic Energy Authority and British Nuclear Fuels, the electricity generating boards, the construction consortia, the Nuclear Inspectorate and the various associated government departments. Only in the 1970s did the politics of nuclear power become genuinely 'public', to both the dismay and the disadvantage of those who until then had conducted only the 'private' form.

The nuclear industry's worst single failure in regard to public attitudes was undoubtedly its handling of the nuclear waste issue. In respect of the science and technology underlying this problem, the industry was doubtless right in the position which it took: the radioactive waste volumes being generated were perfectly manageable with the ad hoc arrangements in place, and it was best to delay the adoption of any final solution to the nuclear waste

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1908

British physicist and future Nobel Prize winner, Frederick Soddy proposes potential importance of atomic power in lecture at Glasgow University, subsequently published as *The Interpretation of Radium* (John Murray, 1909): 'The energy in a ton of uranium would be sufficient to light London for a year'.

1945

July. Labour Party elected to government.

August. Explosion of two US atomic bombs at Hiroshima and Nagasaki.

15 November. Cabinet discusses draft of telegram to be issued that day by US President Harry Truman, British Prime Minister Clement Attlee, and Canadian Prime Minister Mackenzie King, promising utilisation of atomic energy for peaceful and humanitarian ends, and disclosure of 'detailed information concerning the practical industrial application of atomic energy just as soon as effective enforceable safeguards against its use for destructive purposes can be devised. ... It was explained that the present statement was confined to the disclosure to other countries of information possessed by the United States, Great Britain and Canada.' CM (53) 45; National Archives, CAB 128/2

22 November. The Prime Minister, Clement Attlee, reports to Cabinet that talks with Truman mean 'there was no question of any restriction on our liberty to exploit the industrial application of these researches into the use of atomic energy.' CM 55 (45); National Archives CAB 128/2

1946

1 January. Dr John Cockroft establishes the 'Atomic Research and Experimental Establishment' at Harwell on former RAF site, near Oxford.

17 January. 'The Prime Minister informed the Cabinet of a statement which he was proposing to make in the House of Commons on the 22nd January regarding the establishment of an organisation under the Ministry of Supply for the production of fissile material required for the development of the Government's programme for the use of atomic energy. This would make it clear that the Government's object in establishing this production plant was to make available as speedily as possible fissile material in sufficient quantity to enable us to take advantage rapidly of technical developments as they occurred, and to develop our programme for the use of atomic energy as circumstances might require. He would announce at the same time that Marshal of the Royal Air Force Lord Portal of Hungerford had been chosen as head of this production organisation; and that Professor J. D. Cockcroft had been selected for the post of

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Director of the Research and Experimental Establishment at Harwell.' CM 6(46); National Archives CAB 128/5

6 November. Atomic Energy Act gives authority for atomic power to Ministry of Supply.

GLEEP (Graphite Low Energy Experimental Pile) is constructed at Harwell, Europe's first reactor (operated for isotope production at 100 kW, but for most of its life at 3 kW). Went critical 1947.

Construction of BEPO (British Experimental Pile 0) of 6000 kW begins. Used natural uranium, graphite moderator and air coolant. Went critical July 1948.

1947

Beginning of design of Pippa (Pressurised Pile for Producing Power and Plutonium).

1951

October. Conservative Party elected to government.

1952

30 September. Paper by the Paymaster General [Lord Cherwell] presented to Cabinet proposes transfer of atomic energy out of civil service to a nationally owned corporation. 'The exploitation of atomic energy is the most important step taken by man in the mastery of nature since the discovery of fire. In civil life it offers us the prospect of supplementing, during the next few decades, our straitened coal resources. Less than 100 tons of uranium yearly may generate the whole of the nation's electricity. In the military sphere it will soon dwarf all other weapons and perhaps effect changes in international relations as great as those once wrought by gunpowder in the political structure of Europe.' C (52) 317; National Archives CAB 129/55

3 October. Britain conducts successful test of an atomic bomb.

1953

26 January. Minister of Supply [Duncan Sandys] announces British nuclear programme.

White Paper on the 'The Future organisation of the UK atomic energy project' proposes non-departmental Atomic Energy Corporation. Established as the United Kingdom Atomic Energy Authority (UKAEA) in 1954.

March. Government announces first 50 MW reactor based on Pippa design optimised for plutonium production to be built at Calder Hall.

1954

16 December. Lord President of the Council [Lord Salisbury] presents to the Cabinet a memorandum on 'The Trend Report', the

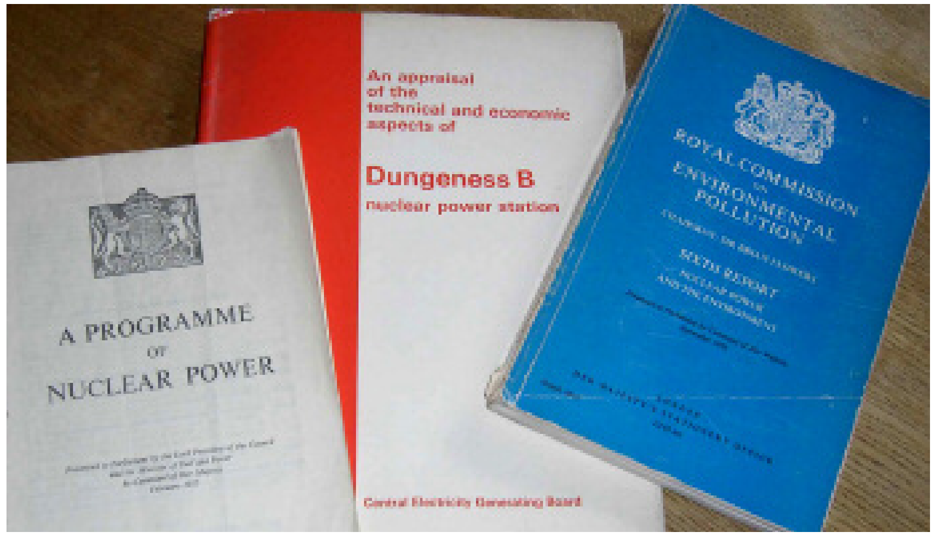

Figure 1. *Key documents: the 1955 White Paper 'A Programme of Nuclear Power'; the 1965 Appraisal of Dungeness B; the 1976 Flowers Report on 'Nuclear Power and the Environment'.*

problem as long as possible, so that that solution, when eventually it was selected, could benefit from the most up to date technical knowledge. This position, however, had the disadvantage of leaving nuclear power vulnerable to exactly the criticism made by the Royal Commission on Environmental Pollution in its 1976 report, the famous, or notorious, Flowers Report (Figure 1). This Royal Commission wanted a major commitment to nuclear power 'postponed as long as possible, in the hope that it might be avoided altogether', and in one of its most quoted passages stated that 'it would be irresponsible and morally wrong to commit future generations to the consequences of fission power on a massive scale unless it has been demonstrated beyond reasonable doubt that at least one method exists for the safe isolation of these wastes for the indefinite future.' The nuclear community took this stricture ill, its earlier neglect of this dimension having left it quite unprepared to respond properly to such a charge. But, one might say, all that was thirty years ago and the lessons have long since been learned: perhaps they have, and then again, perhaps they have not. This waste issue needs now to be put to rest in the only way in which that can be done: by saying to the concerned public 'There, in all necessary detail, is the watertight solution which we will apply, and we will move from that solution if and only if at some time in the future we discover an even better solution.'

There are in fact three main aspects to the nuclear waste issue: settling upon a technology, determining a site or sites for final disposal, and ensuring the provision of the necessary finance. With the creation of the Nuclear Liabilities Financing Assurance Board, the government has moved to provide for the third of these aspects. Echoing the Royal Commission of 1976, it would not be unreasonable, a full third of a century after that Commission reported, to argue that, urgent as may be the need for new nuclear stations, none should be approved for construction until the first two aspects have been equally firmly assured.

To meet the public concern about the waste issue, and any other concerns like it, what ideally there would be in the energy field is an institutional source capable of holding the public's trust as ministers, and governments, come and go, a bastion against both the inevitable tide of challenging events and the undercurrent of distrust now all too evident in most things governmental. Here, for example, are just four important points which a really trusted source, but only such a source, might usefully make immediately about nuclear power:

First, we do not create a major new waste problem by building further nuclear stations. We already have that problem, whether one characterises it as major or otherwise, as a result of our nuclear weapons programme and the nuclear power stations we have already built. Another way of presenting the waste problem is to note that new nuclear stations will both produce much less waste than those they replace, and will also generate revenue to help fund whatever approach is judged best for dealing with all the waste, old as well as new.

Second, we do not wholly avoid whatever hazards there still are in contemporary nuclear reactors simply by building no more of them, because France, which currently generates 80 per cent of its electricity from the atom, will certainly persist with nuclear power, many French nuclear sites are located along the Channel coast, and in the event of an accident the prevailing winds are from the west. Nor, it should be recalled, were we untouched by the much more distant disaster at Chernobyl in 1986. What is more, if Britain is to help ensure the highest possible standards of construction and operation in nuclear facilities worldwide, then this is not something we can expect to be able to do from the sidelines.

Third, nuclear weapon proliferation and nuclear power should no longer be bracketed together because, even if all nuclear power development were halted worldwide, the nuclear genii is anyway long out of the bottle and in consequence proliferation has for some years been much more dependent upon political will than it has been upon the availability of technical knowledge. The human race will have escaped lightly if Hiroshima and Nagasaki end up the only instances of nuclear weapons being used in anger, but even if one day these weapons are used again, nuclear power per se will not be to blame. Indeed, one might equally well advance precisely the opposite argument, that a world from which nuclear power has been banned, and which is short of energy, or experiencing uncontrolled global warming, is likely as a result to exhibit a greater propensity for conflict.

Fourth, we have in Britain, and throughout the world, communities which have now lived in proximity to nuclear facilities for, in some cases, more than half a century. This is a fact of considerable social and political significance. Furthermore, while these locations tend naturally to be the first places considered when new nuclear facilities are being proposed, this should not be taken as meaning that such locations constitute an already exhausted set.

More points like these four could, and should, be made, but let me now turn back to other lessons from the British nuclear story.

Healthy scepticism

Hardly less important than a real public ownership of nuclear power policy is for policy makers to resolve to be completely honest with themselves, and also adequately sceptical about all claims made by whatever agency. Once again, it was not so in the past. The worst single example here was the announcement in May 1965 that, in a nominally fair competition, the British AGR had decisively beaten off the challenge offered to it by American light water reactor technology. Politics being what it is, it was perhaps forgivable for the minister responsible to claim publicly that this was ‘the greatest breakthrough of all time’. And it was also understandable that, conscious of their responsibility as a shop window for British technology, the electricity authorities had the outline of their comparative reactor appraisal translated into six languages. But those close to the decision had no business fooling themselves as to the imperfect integrity of the assessment process which they had gone through, with its highly dubious, and as it turned out in some instances plain wrong, assumptions. I have quoted the Duke of Wellington once already in this lecture. Let me do so again. It seems that a Mr Jones, secretary of the Royal Academy, was occasionally mistaken for the Duke but that on one occasion it happened the other way round, a minor civil servant in Pall Mall raising his hat to the Duke and saying ‘Mr Jones, I believe’, to which the great man immediately replied ‘Sir, if you will believe that, you will believe anything.’ So certainly it was with the AGR decision of 1965: if you believed that you really were capable of believing anything. Inevitably too, the self-delusion behind this decision had to be paid for, the Dungeness B station, the initial prize which the AGR’s controversial win had secured, taking 20 years to complete.

Though this was the worst single example of British wishful thinking, it was regrettably far from unique. In the same category must be included the persistence with all-purpose

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report of an interdepartmental committee, chaired by Burke Trend, on ‘the production of power from nuclear energy’. The generation of electricity by nuclear methods can now be accepted as technically feasible and has a good chance of proving, within the next 10 years, competitive with electricity generated by conventional methods. C 54 (395); National Archives CAB 129/72

21 December. Lord President of the Council [Lord Salisbury] brings plan for civil nuclear programme to Cabinet. Asks for £50 million for two power stations to be completed by 1960. The Chancellor of the Exchequer [R.A. Butler] ‘said that the successful development of atomic power for civil purposes was of crucial importance to the future of the national economy’, and welcomes proposal. The Cabinet agreed. CC 90 (54); National Archives CAB 128/27.

1955

4 February. The Lord President of the Council [Lord Salisbury] presents to the Cabinet the draft white paper ‘A Programme of Nuclear Power’. Proposes 4 commercial stations on Calder Hall pattern, followed by 4 more Advanced Gas-cooled Reactors (1963-64), followed by 4 liquid-cooled reactors. ‘Nuclear energy is the energy of the future. … Our civilization is based on power. Improved living standards both in advanced industrial countries like our own and in the vast underdeveloped countries overseas can only come about through the increased use of power. The rate of increase required is so great that it will tax the existing resources of energy to the utmost. Whatever the immediate uncertainties, nuclear energy will in time be capable of producing power economically. Moreover it provides a source of energy potentially much greater than any that exist now. The coming of nuclear power therefore marks the beginning of a new era. … The stakes are high but the final reward will be immeasurable. We must keep ourselves in the forefront of the development of nuclear power so that we can play our proper part in harnessing this new form of energy for the benefit of mankind’. C 55 (31); National Archives CAB 129/73.

1956

July-November. Suez crisis and British/French takeover of Suez Canal. Oil crisis.

17 October. Queen opens Calder Hall, proclaimed as the world’s first civil nuclear power station.

1957

Advanced Gas-cooled Reactor prototype design approved.

28 February. Cabinet approves trebling of nuclear power programme: ‘the unit cost of electricity from the earliest nuclear power

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station might prove to be slightly higher than that from conventional stations; but technical development, which might be expected to be rapid, should succeed in eliminating this excess cost.' CC 14 (57); National Archives CAB 128/31

1 August. Following a recommendation that the government borrow from the International Bank for Reconstruction and Development [part of the World Bank] to fund nuclear power, the Minister of Power [Lord Mills] tells Cabinet 'a decision to borrow from abroad on behalf of our nuclear power programme, which had become a symbol of our industrial leadership in the post-war period, would be a considerable shock to public opinion.' C.C. 60(57); National Archives CAB 128/31

October. Fire at Windscale Pile, next to Calder Hall.

1958

Concentration on four types of reactor: Steam Generating Heavy Water Reactor (SGHWR), Advanced Gas-cooled Reactor (AGR), Fast Breeder Reactor (FBR), High Temperature gas-cooled Reactor (HTR).

nuclear construction consortia to build the stations, no less than five having initially been encouraged to form. This was wishful thinking because the competition to which the consortia gave rise, when not outright spurious, tended to produce expensive diversity rather than efficient design replication. The consortia system also led to a 'Buggins' turn' principle which, when it failed, caused much political embarrassment, notably over the second reactor at the Wylfa station, and then that affair's knock-on effect at Dungeness B. Competition is well worth the having, but only when it is genuine, and in the context of high technology, competition's scope will often be quite limited. This again is something to remember for the future.

Some would also describe as wishful thinking the long British persistence with gas-cooled reactors, but there is a more important lesson of contemporary relevance which this persistence illustrates. It is well understood that Britain felt pushed into gas-cooled, graphite-moderated, natural uranium reactors by the circumstances which the country faced in the late 1940s. Plutonium was urgently needed for the weapons programme; the United States had abruptly ended war-time atomic co-operation; enriched uranium was not readily available as fuel, nor was heavy water as moderator; and light water reactors, being then thought less safe, were judged to need remote sites, a difficult problem for a small country like the UK. But despite these reactors initially being off-limits, the underlying attractions of water cooled reactors did not go unrecognised in Britain, and the 1955 White Paper which announced Britain's first nuclear power programme (Figure 1) in fact looked to the last four stations of that programme possibly being liquid cooled, with the liquid likely being water. What then changed was that as the first programme got underway, the potential of gas-graphite reactors began to look much better, so that by the time that first programme was effectively quadrupled, in 1957, it had been decided to standardise on these gas-graphite reactors. Even so, as the increased availability of enriched uranium began to make enriched, as opposed to natural, uranium a more feasible fuel, a switch might have been made to water cooling for a second nuclear programme. By then, however, the Atomic Energy Authority was well along with research on an enriched uranium gas-graphite reactor, the Advanced Gas-cooled Reactor, and after the 1965 Appraisal, which was undertaken to compare the AGR against light water reactor designs specifically for the Dungeness B site (Figure 1), it was of course the AGR which was used for Britain's second nuclear power programme (Figure 2).

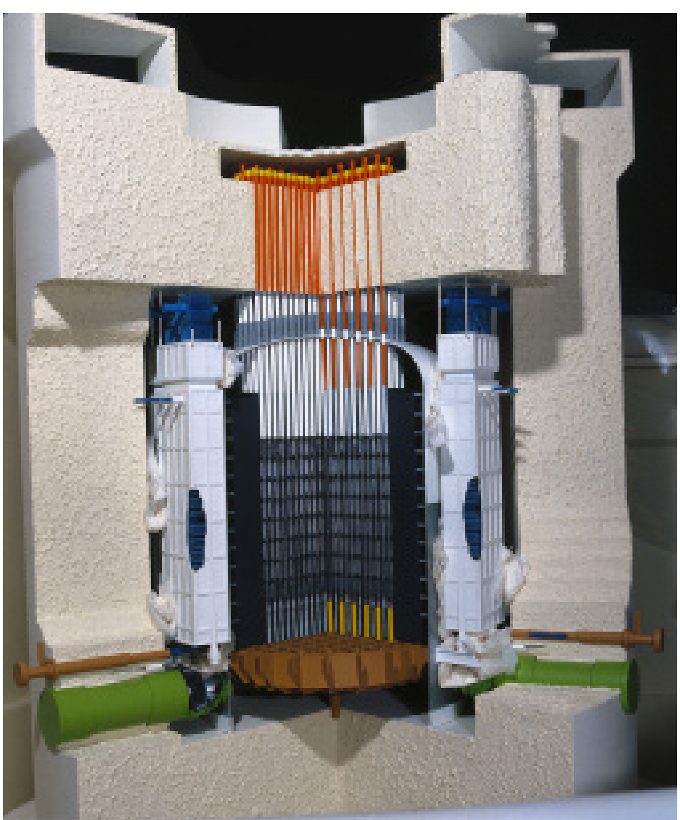

Figure 2. *An engineering model of an Advanced Gas-cooled Reactor, at Heysham II. Photo: Science Museum/SSPL.*

Instructively, France, like Britain, also began with gas-graphite reactors, but switched much sooner, and far more decisively, to light water ones. Sizewell B, completed in 1995 (Figure 3), remains Britain's only light water reactor station, and as things currently stand, when the last AGR closes in 2023, Sizewell B will then be the only nuclear station still operating in Britain, supplying some 3–4 per cent of total UK electricity demand.

The international mainstream

Whatever the wishful thinking about the virtues of gas-graphite in this two decade saga, the really significant consequence was that Britain's choice of gas-graphite cut it off from the international mainstream. By

Figure 3. *An engineering model of the Pressurised Water Reactor at Sizewell B. Photo: Science Museum/SSPL.*

'international mainstream' here, of course, one really means 'American', because it was above all the American commitment to water reactors which made them the world standard. The result is that today two-thirds of world capacity is based on the Pressurised Water Reactor, with another quarter based on the other water reactor version, the Boiling Water Reactor. This is not to imply that had the Americans opted instead for gas-graphite, then gas-graphite would have become the world standard, because the deeper point is that, with greater freedom of choice than Britain initially enjoyed, it was for water reactors that the Americans decided. Intriguingly, according to Lord Hinton, outstandingly the initial architect of British nuclear power (Figure 4), there was at the beginning an informal understanding with the Canadians that, if their heavy water reactors proved better than Britain's gas-graphite ones, then Britain would switch to them, and if the reverse happened, then the Canadians would make the switch. In sharp contrast, as regards US light water reactor technology, there was always in Britain towards it something of the 'not invented here' syndrome.

These early years were indeed what Lorna Arnold has called Britain's 'era of illusion'. They underline that international isolation must definitely be avoided in any nuclear future. Circumstances happily have much diminished this particular risk, almost now to the point where it could be described as negligible.

A stable commercial future

With mention of Britain's first and second nuclear programmes we encounter other unhappy features of the country's nuclear story, its rigidity and 'lumpiness'. The basic cause of these features was that this was a tale written, and rather badly written, by government. The core lesson is that if nuclear power is to be part of UK energy supply over the next half century and beyond, then nuclear construction wants to be much more commercial than political, with companies taking commensurate responsibility. A new beginning after the long interval will obviously impose extra costs and create its own problems – as regards regulation as well as construction. In sharp contrast to the 1950s, adequately qualified manpower in particular is likely this time to be initially in

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1959

HTR becomes international Dragon project.

White paper 'Control of Radioactive Wastes'. Leads to the 'Radioactive Substances Act' of 1960, which establishes national control of discharge of radioactive waste.

1960

2 June. Minister of Power [Richard Wood] told the Cabinet that 'the original ten-year programme announced in 1955 for the development of civil nuclear power had been accelerated in 1957, with the object of providing 5,000-6,000 megawatts in commission by the end of 1966. There had since been changes in the fuel position, and it was now estimated that conventional fuel supplies would be adequate for ten to fifteen years, even if no nuclear power stations were ordered in the next few years. The capital costs of nuclear generation had been higher than had been expected, but the cost of generating nuclear power was now falling faster than the cost of generating electricity from conventional fuels. A nuclear power programme on the 1957 scale was therefore no longer necessary, but it was essential to find out as soon as possible how to build a fully competitive nuclear power station and to provide for an industry which would in due course be capable of expanding at the necessary rate. It was proposed to spread the nuclear power programme over a longer period, by proceeding at the present rate of ordering which was roughly one station a year. This would provide 3,800 megawatts by the end of 1966, and 5,000 megawatts in 1968. It would fully maintain the rate of technological

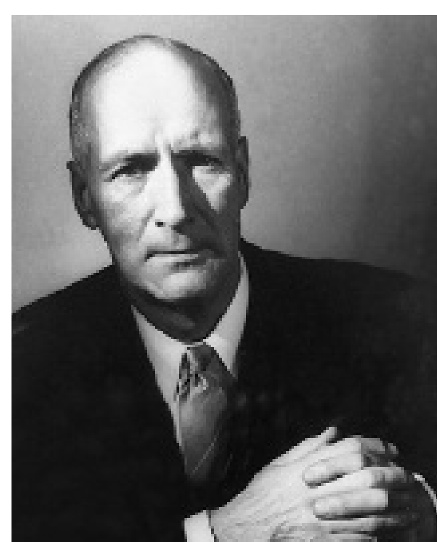

Figure 4. *Christopher Hinton (1901–1983). Photo: The Institution of Mechanical Engineers.*

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development, and would be sufficient to keep three industrial consortia employed.' CC 34(60); National Archives CAB 128/34

1963

US companies claim cost breakthrough in light water reactors.

1964

10 April. Minute by the Chancellor of the Exchequer [Jim Callaghan] to the Prime Minister: 'The Nuclear Power Programme'. 'The Economic Policy Committee was troubled by the possibility that an announcement that we were willing to contemplate reactors of American design would kill the prospects of our own nuclear power industry and involve us in writing off the very substantial sums of money which have been devoted to nuclear power research in the past. They took the point that if, at this stage, no nuclear system was competitive with the latest conventional power stations the choice should lie between a British nuclear system, even if this were more expensive than an American alternative, and conventional power.' Supports draft white paper which said that the Central Electricity Generating Board would 'issue an enquiry for tenders for an Advanced Gas-Cooled Reactor station' but also be ready to consider tenders 'for water-moderated reactor systems *of proved design*'. The decision for the first choice of the next generation of reactor systems would be deferred. CP (64) 86; CAB 129/117

October. Labour Party elected to Government.

1965

May. The AGR developed by the Atomic Energy Authority chosen as the basis for the second generation of British nuclear power stations. An AGR to be built at Dungeness B.

11 October. Minister of Power [Fred Lee] circulates to Cabinet draft white paper entitled 'Fuel policy'. 'Although the earlier expectations about the economics of nuclear power have proved premature, there has been a steady fall in the capital costs of successive stations in the first nuclear power programme, and the tender (an Advanced Gas-cooled Reactor - A.G.R.) recently accepted for the second nuclear station at Dungeness (1,200 MW) suggests that it should give cheaper base-load electricity than future coal-fired stations on the present price of power station coal… The programme will be based on the Advanced Gas-cooled Reactor developed by the Atomic Energy Authority, but at this stage the possibility of another reactor type making a contribution is not excluded. It is estimated that on these assumptions, and with further developments in nuclear technology and expected increases in the size of stations, a total of 8,000 MW might be in commission under the second nuclear power programme by 1975.' C (65) 130. National Archives CAB 129/122

short supply. Nonetheless, the clear aim should be to achieve in due course a steady state, with the nuclear component of energy supply, and thus nuclear construction, changing only gradually thereafter. One would not normally prefer soap opera to drama but the record makes clear that in the nuclear case, the soap opera of business is much to be preferred to the drama of politics.

This leads on to the economics of the various forms of electricity generation. It is natural to ask that competing energy sources be compared on the same basis. Regrettably, it is difficult to ensure genuine comparability, complications arising in respect of subsidies, operating assumptions and a wide range of externalities. It is also legitimate for governments to take a broader view, for instance putting their own valuation on security of supply, or deliberately choosing to set an international example, or insisting upon a mixture of energy sources rather than allowing economics alone to determine policy. What were not in evidence in the past were efforts to make the economic and political dimensions absolutely explicit. This again should be rectified in the future. Specifically, these dimensions must include rigorous consideration of all carbon footprints, and in the nuclear case, the financial implications of full decommissioning and waste disposal as well. Only with all the economic and political assumptions made completely transparent will it be possible to have confidence in UK energy policy and its evolving options.

Safety

If the lessons I have so far suggested from Britain's nuclear past all seem rather negative, there were also positive features which fully deserve re-emphasis in any nuclear renaissance. Outstanding among them is the country's nuclear safety record. To see this in context we should begin with the international picture. From the start, nuclear engineers have had to live with the discipline that, unlike most other technologies, theirs is not one which dare rely on the principle of learning mainly from its mistakes. With civil reactors the resulting safety figures are now highly impressive: in 12,000 reactor years of operation in over 30 countries there has been only one commercial reactor accident where the consequences were not effectively contained within the reactor itself: including naval operation would double this figure. That one accident, Chernobyl in 1986, was though, as we all know, devastating, with 47 immediate deaths and around 10 child deaths so far from thyroid cancer, plus an unknowable number of additional cancers to date and to be expected over coming decades, and these right across Europe. As is also well known, this accident occurred with a reactor type which would not have been licensed in the West, and which in addition was at the time being operated improperly. Both Chernobyl and the world's second worst nuclear accident, at a reprocessing facility in 1957, took place in the Soviet Union, a country where the safety culture was especially poor. After these Soviet accidents the next two in order of gravity have been Windscale in the UK in 1957, and Three Mile Island in the US in 1979. Windscale involved a primitive air-vented, and thus uncontained, military reactor, there were no immediate deaths but there was a significant radiation release, though fortunately less than a thousandth that at Chernobyl. At Three Mile Island there were again no immediate deaths and in this instance only a relatively minor and short-term radiation release. Still smaller radiation releases occurred at reactors in the US in 1961, Switzerland in 1969 and France in 1980.

But this lecture is being given on 6 May. This is the date on which in 1626 Manhattan Island was bought for the equivalent of $24, and to demonstrate the power of political pressure, I will, a little mischievously, recall just one more nuclear disaster. What happened at Shoreham on nearby Long Island was, however, only a financial calamity and not really a nuclear one at all. Here the utility company concerned decided in 1966 to construct a nuclear plant for an estimated $75 million. The plant was duly completed in 1983 but then, under continuing political pressure, was finally abandoned in 1989 without its having generated a single unit of electricity, and this at the staggering cost of $6 billion: a much worse case even than Dungeness B!

The Chernobyl accident helped significantly to bring down the Soviet Union, and that at Three Mile Island severely blighted the American nuclear industry. The event at

Windscale, which like Chernobyl has been described as 'an accident waiting to happen', was certainly nasty and could easily have been much worse, but it at least had the advantage that it happened at the outset of commercial reactor construction in Britain. Its impact on the UK's nuclear safety culture was therefore both far-reaching and lasting. Precisely because there has been no recent nuclear construction in the UK, it is vital that the country's former safety culture be fully reasserted. Categorically, this must not be taken for granted. In addition, unlike construction, safety and its regulation are, in the last analysis and completely inescapably, government responsibilities.

Confidence

What seems to me another positive feature of Britain's nuclear past may seem in conflict with the negative point in regard to self-delusion which I made earlier, but it is not really a case of entering the same item on both sides of the ledger. This is the confidence with which, in the early decades, so many difficult nuclear goals were tackled simultaneously. Thus in reactor development alone, apart from Magnox and the AGR there were also developed the High Temperature Reactor, the Steam Generating Heavy Water Reactor and the Dounreay and Prototype Fast Reactors. There was much other civil work too, on enrichment, reprocessing and waste disposal, all spun off the original military programme. Britain may have had no business investing so heavily or so soon in so much nuclear technology. That is a political issue. On the ground, however, the striking aspect was the almost Victorian *élan* with which the scientists and engineers carried forward their work. Britain needs to rediscover more such self-belief, and beyond as well as within the nuclear field, provided only that it does not again tip over into self-delusion.

I have now mentioned the fast reactor. Capable of either burning plutonium or breeding it for later burning, this is an elegant reactor concept, but technical problems, low uranium prices and politics between them derailed the American, French and German fast reactor programmes in the 1990s, as well as the British. The Russians and Japanese, however, continue with the technology, and also India with its thorium near-breeder. The fast reactor's day may yet come, though it will not be soon.

Over and above my initial caveat about drawing conclusions from history, is the world now so different as to invalidate even the most well-founded historical lessons? On the one hand, this century seems still more favourable towards complicated technology than was the 20th, above all because of the remarkable strides in computing power, which benefit both the design and the operation of complex facilities. But on the other hand, there has been one wholly malign 21st century development, the emergence of major international terrorism. Incidents of the 9/11 kind were just not part of orthodox thinking before that date. Happily, studies since 9/11 have shown that nuclear plants are unattractive targets for even sophisticated terrorists. A fully-fuelled jumbo jet crashing into a modern reactor or waste facility would be an extremely unpleasant event, but it would not lead to a nuclear explosion, or in all probability to anything like the loss of life more easily achieved, as unhappily has been demonstrated, against much softer targets. Historically, nuclear reactors were provided with containment against substantially worse accidents than experience suggests are now likely to occur, and of course that containment would work equally well against human evil.

To sum up, no inventory of lessons from the history of UK nuclear power can be definitive, but at best only suggestive, so let me, in forty words, summarise mine:

- take the public along with the policy
- be sceptical towards all claims
- get in the international mainstream
- strive to make decisions commercial
- be scrupulous about the economics
- aim for steady state
- firmly re-establish a culture of safety
- recover *élan*

This prescription will not guarantee success second time around, nothing could do that, but after reflecting at length on the past, it represents my own best shot.

TIMELINE OF UK CIVIL NUCLEAR ENERGY cont

1966

Prototype Fast Breeder Reactor at Dounreay ordered. Seen as potentially key component of third generation of nuclear power stations.

1967

23 October. 'Fuel Policy' Draft White Paper submitted to Cabinet. Affirms 1965 plans. 'Nuclear power stations cause no air pollution. They can be sited near areas of consumption without affecting the cost of generation, and so there is less need for additional high voltage transmission lines. A regular sequence of new nuclear stations is desirable if the full development potential of this new technology is to be realised.' C(67) 165; National Archives CAB 129/133

1970

June. Conservative Party elected to government.

1972

8 August. Statement in Parliament approved by Cabinet. Secretary of State for Trade and Industry [John Davies], entitled 'Future of the Nuclear Industry'. He summarises the paper to Cabinet: 'It emphasised the Government's intention to press ahead rapidly with the development of the fast breeder reactor (FBR) in the hope of placing the first full scale order for it in the late 1970s and of using it thereafter for the major part of nuclear generating plant orders from the mid-1980s onwards.' The statement itself begins 'Decisions in the field of nuclear reactor policy have immense importance for the future strength of British industry and for the security and cost of energy supply. The government is resolved to build upon the major achievements of the AEA in the past and to ensure the development of a powerful capability for the future in which the AEA will continue to play a vital part. We have decided therefore to intensify the installation of nuclear plants as far as technological progress, environmental constraints, industrial capability and generating plant requirements permit.' Presentation, CM (72) 40; National Archives CAB 128/50/41. Statement, CM (72) 90; National Archives CAB 129/164/15

1973

20 March. Cabinet agrees to formation of a National Nuclear Corporation established with dominant participation by GEC. The Secretary for Trade and Industry (Peter Walker) confirms that 'The Electricity Council, the CEGB and the AEA had confirmed their view that GEC were the only company at present capable of leading the new organisation'. CM 17 (73); National Archives CAB 128/51/18

October. 'Yom Kippur' War in the Middle East leads to oil shortages and four-fold price rise.

TIMELINE OF UK CIVIL NUCLEAR ENERGY cont

December. CEGB tells Parliament of plans to order 32 PWR reactors over the subsequent decade.

1974

28 February. Labour Party elected to government.

13 June. Secretary of State for Energy [Eric Varley] reports, 'No option commanded general agreement, and any choice would entail some commercial risk; but in his view the primary considerations were safety, reliability in operation, and the need to support British technology, and on these grounds he considered that the Steam Generating Heavy Water Reactor (SGHWR) should be adopted for the next nuclear orders. In this judgment he was fortified by the fact that the [Cabinet Office's] Central Policy Review Staff had independently reached the same conclusion; and although the weight of argument had seemed compelling even before the recent disaster to the chemical plant at Flixborough, that event further reinforced the need to ensure that the Government's choice of nuclear reactor would command public confidence.'

10 July. Secretary of State for Energy [Eric Varley] announces SGHWR chosen as basis for third nuclear programme

1976

Nuclear Power and the Environment, Sixth Report of the Royal Commission on the Environment chaired by Sir Brian Flowers (Flowers report), expresses anxiety about environmental dangers of plutonium.

June. Pound Sterling reaches record low against the dollar.

19 July. As part of general public expenditure cuts, SGHWR programme put on ice. 'In discussion it was argued that the deferment of the SGHWR could mean the collapse of the industry itself, which employed some 25,000 people. Deferment of the SGHWR would revive demands for its cancellation, although on present plans the reactor was needed in Scotland and could not be replaced.' CM 16 (76); National Archives CAB 128/59/16

December. British Government forced to borrow from IMF.

1978

January. SGHWR cancelled. Two AGRs ordered.

Windscale Inquiry under Justice Parker gives green light to Thermal Oxide Reprocessing Plant (Thorp).

1979

March. Accident at the the Three Mile Island reactor near Harrisburg, Pennsylvania.

Sources

The only direct quotations are from Lorna Arnold, *Windscale 1957* (London: Macmillan, 1992): 'era of illusion', p. 159 and 'an accident waiting to happen', p. 124; and Royal Commission on Environmental Pollution, 6th Report, Cmnd. 6618, September 1976, *Nuclear Power and the Environment*, paras 181 and 511.

I have naturally relied heavily on my own book: Roger Williams, *The Nuclear Power Decisions* (London: Croom Helm, 1980).

Britain's first nuclear programme was announced in the White Paper *A Programme of Nuclear Power*, Cmd. 9389 of February 1955; and *An Appraisal of the Technical and Economic Aspects of Dungeness B Nuclear Power Station*, published by the Central Electricity Generating Board in May 1965 led on to Britain's second nuclear power programme.

The House of Lords inquiry for which I was a specialist adviser reported as Select Committee on Science and Technology, Session 1988–89, 2nd Report, *Research and Development in Nuclear Power* (London: HMSO, December 1987), HL Paper 14-I.

On global warming, where the literature is now huge, I have been particularly influenced by Gabrielle Walker and Sir David King, *The Hot Topic* (London: Bloomsbury Publishing, 2008).

For up to date figures, other than the internet I have mainly used Ian Hore-Lacy, *Nuclear Energy in the 21st Century* (London: World Nuclear University Press, 2006).

For Shoreham I have relied upon David P. McCaffrey, *The Politics of Nuclear Power* (London: Kluwer Academic Publishers, 1991).

Among other sources to which I owe a debt is W.J. Nuttall, *Nuclear Renaissance* (London: Taylor & Francis, 2005).

Professor Williams retired as Chairman of the Higher Education Funding Council for Wales in May 2008. He is a former Vice Chancellor of the University of Reading.

BETWEEN 1976 and 1980, **Richard Wilson** *was the assistant secretary within the Department of Energy responsible for nuclear power policy, including thermal reactor choice, fast reactor policy, and the financing of the UK atomic energy authority. Now Lord Wilson of Dinton offers his own list of lessons from the past.*

AFTER HIROSHIMA AND NAGASAKI, scientists and politicians who had been involved in the development of atomic energy felt a 'dark foreboding'.[1] This was succeeded by a desire to use the new science to generate electricity for peaceful purposes. A Government White Paper of the early 1950s described atomic energy as the most important development since the discovery of fire, and led to a surge of research and construction which made Britain's nuclear programme a world leader into the 1970s. Stations in the original Magnox programme are, amazingly, still in use.

Increasingly, however, the programme aroused strong passions. Some were carried over from opposition to nuclear weapons. Some reflected environmental concerns which carried increasing weight after the Flowers Report in 1976, reinforced by the Three Mile Island and Chernobyl incidents. Witnesses at the Windscale Inquiry expressed deep anxiety about radiation. And within the nuclear industry, the long debate about the relative merits of American water-cooled technology and British gas-cooled technology had not much less intensity than a war of religion.

Any new programme of nuclear power stations will have advantages not available thirty years ago. There is now far more operating experience of all types of nuclear reactor than in those early years; and the debates about thermal reactor choice have been settled decisively in favour of pressurised water technology. But experience with these earlier programmes still offers lessons for contemporary policy makers.

Political will

Perhaps the first lesson is the importance of political commitment and drive. Each nuclear power station is a huge construction project, very expensive and technologically complex. Given their potential for controversy, new nuclear power stations will not be built unless there is single-minded political will behind them, whoever builds them and however they are financed. The first nuclear power programme of Magnox stations, announced in 1953–55, had that support. It also benefited from strong leadership under Lord Hinton and a sense of excitement exemplified by The Queen opening the first Magnox station Calder Hall in 1956. Even so, it needed all these favourable conditions to carry it through a host of problems, including design changes (such as the switch to on-load refuelling), escalating costs and delays in construction times.

A nuclear power programme without continuing political drive will not be built. The Thatcher government committed itself in 1980 to the construction of one new nuclear power station order each year for a decade. After Sizewell the commitment evaporated without comment, for a variety of reasons.

Established design

A second lesson is the importance of having a reliable established design whose safety case can be demonstrated and which can be replicated. Although the UK's early nuclear programmes based on gas-cooled technology and the breeding of fuel in the Fast Reactor were intellectually elegant, they were bedevilled in practice by the difficulty of having too many construction consortia building different designs.

This was illustrated by the 1965 decision on Advanced Gas-cooled Reactors (AGRs) which turned out to be disastrous. The Minister for Supply, Fred Lee, told the House of Commons 'we have hit the jackpot ... we have the greatest break-through of all time.'[2] But the wish for competition in design and speedy construction led to the adoption of inadequately worked-up designs. Consortia began construction too soon, technical problems emerged, costs escalated and companies began to collapse. The first station, Dungeness, suffered major delays because of problems with the containment, pressure vessel and boilers: making it work was 'watch-making by the tonne' as one participant observed. It was ordered in 1965 for completion in 1970–71 and eventually came on stream in 1983, thirteen years late. The fact that the station did eventually generate electricity – and is still doing so – was a considerable achievement for British engineering, but not the sort which is easily advertised.

Linked to the importance of a settled design is the need to avoid escalating costs. The eventual cost of Dungeness B was four times the original estimate, after allowing for inflation. The Steam Generating Heavy Water Reactor (SGHWR), chosen in 1974 for the next generation of nuclear power stations, was similarly abandoned two years later because of the excessive cost of the design, a message conveyed bravely by the late Sir John Hill, chairman of the UK Atomic Energy Authority, to Mr Tony Benn, the new Secretary of State for Energy, in the summer of 1976.

Establishing the economics of nuclear stations is difficult. Even with the co-operation of all parties and determined political support from the Thatcher government, it was very hard in 1980 to establish reliable figures. What is clear is that having a tested design which can be replicated does much to help contain those costs and the risk of delays in construction.

Public consultation

A third lesson is not to promise more by way of public consultation than can realistically be delivered or afforded within the planned timescale. Sir Roger Williams is of course right to emphasise the desirability of trying to take the public along with policy, and one can sympathise with his wish for nuclear power to be 'owned' by the public. But it is easier said than done.

Tony Benn, faced with the demand to choose a new thermal reactor system for new nuclear power station orders after Sir John Hill's demarche, wanted a major public consultation exercise.

- He took evidence from every interested party, ranging from departmental officials through all industrial interests to environmental groups.
- He consulted the French Government as they embarked on a major sustained programme of building Pressurised Water Reactors (PWRs). (When asked how they conducted public consultation, their Minister replied: 'We have a saying: when you are draining the swamp, you do not consult the frogs.')
- He was open with the press, and published an extensive Thermal Reactor Assessment which compared the designs, costs and relative safety cases of the Advanced Gas-cooled Reactors, Pressurised Water Reactors, and the Steam Generating Heavy Water Reactor.
- He held a summit over several days at Sunningdale to which all parties, including environmental groups such as the Friends of the Earth, were invited.

Despite his political gifts, it is not clear that this effort really made much difference to public opinion. The same may be said of the Sizewell Inquiry, which the Thatcher Government intended should be finished before the end of

TIMELINE OF UK CIVIL NUCLEAR ENERGY cont

May. Conservative Party elected to government.

December. Secretary of State for Energy [David Howell] announces to Parliament programme of 10 reactors over decade from 1982 laid out by CEGB with support of the government.

1981

Iran-Iraq War causes oil price to increase from $14 a barrel in 1978 to $35 a barrel.

1986

First half of year. Oil price collapse to about $11 a barrel.

Inquiry on establishing the first British Pressurised Water Reactor at Sizewell reports.

April. Explosion in the Soviet Union's Chernobyl plant leads to radioactive contamination of British soil.

1987

Sizewell B, the first British PWR, ordered. The last nuclear power station of the 20th century in Britain.

1989

CEGB privatised, but nuclear power stations withdrawn from privatisation because of anticipated costs of decommissioning.

1990

Nuclear Electric born as nationalised government-owned company.

1996

Non-Magnox reactors (AGRs and PWR) transferred to British Energy which is floated on the Stock Exchange, and Magnox reactors transferred to the government-owned British Nuclear Fuels Ltd (BNFL).

1997

May. Labour Party elected to government.

1999

British production of oil and gas peaks.

2006

Steep rise in world price of energy.

2008

January. White Paper on Nuclear Power proposes 'new' nuclear power programme.

2009

2 February. Two former sites of the UKAEA, Harwell and Winfrith, combine to become one company, Research Sites Restoration Limited (RSRL). (Harwell Press Release)

Timeline prepared by Professorr Robert Bud (Science Museum and Queen Mary University of London) and Professor Peter Hennessy FBA (Queen Mary University of London).

1982 but which lasted three years longer than that, until 1985. Three Mile Island and Chernobyl had more impact.

On the other hand, fifty years of safe operation of nuclear power stations may perhaps have a more positive influence on public opinion than anything which governments may say. So too may concerns about global warming and about the prospect of a shortage of electricity generating capacity. If nuclear power is understood to be the best hope of meeting demand for electricity without making global warming worse, the public may come to 'own' it in a way which government exhortation on its own could not achieve.

In short, one may sympathise with the desire to secure public acceptance of nuclear power, and governments must make the effort to achieve it; but there may be a limit to what governments can do unless events happen to be moving their way. Here as elsewhere, timing is all.

Timescales

A fourth lesson is that the construction of nuclear power stations tends to take longer from announcement to commercial operation than governments expect. The White Paper of 1955 announced that twelve Magnox stations would be on stream by 1965: in the event the last station came on stream in 1971. The AGRs announced in 1965 aimed at completion of the last station in 1975, whereas the last one was in fact connected to the grid in 1983 and the stations were not all in commercial operation until the late 1980s. Admittedly these first programmes were handicapped by the fact that stations were often prototypes. The two further AGRs announced in 1978 came into commercial operations at around the same time as stations in the first programme, demonstrating the importance of standardising design.

Planning too may contribute greatly to delay. Sizewell B, announced in 1980, did not come on stream until 1995, largely due to the planning process. Its actual construction was to time and cost.

Past experience suggests that as a rule of thumb construction of a nuclear power station in this country takes at best a decade from announcement to commercial operation if conditions are right and can take much longer if there are problems, for instance with planning or design.

One advantage enjoyed by earlier programmes but not available now was the good supply in this country of scientists and engineers with the experience of building nuclear stations. The generation who built the earlier programmes of nuclear power has largely died out. One can sympathise with Sir Roger Williams's wish for a new generation of engineers and scientists with élan, but it takes time to generate such a breed. In the meantime there is a skills shortage to be overcome, probably from abroad.

Safety

A fifth lesson is the need for government to ensure that sufficient resources are devoted to safety and radioactive waste management.

One potential area for delay for instance is the need for the Nuclear Directorate of the Health and Safety Executive to be satisfied with the safety case for a station and to give a site licence for its construction. The availability of sufficient resources in the Directorate's predecessor, the Nuclear Installations Inspectorate, was a serious headache in the past and may be so again. The main problems in the past related to the availability of qualified staff, but they can also require a strong capability to do research in support of the safety case. Even with a settled design, questions requiring research can unexpectedly arise.

The need to resolve the issue of the long-term disposal of radioactive waste is a further area where government involvement is inevitable. Sir Roger Williams summarised the position. It is a problem that will not go away.

The role of Government

In conclusion, it will be clear from all the above that government has a central role in the development of nuclear power.

- Building new nuclear stations requires sustained and determined political commitment on every front.
- Although the public has tended to be immune to government pronouncements about nuclear power in the past, there is a duty on government to articulate the case clearly, in terms of both energy policy (not least at any planning inquiry) and climate change. It may be that the public may give the case a fair wind now.
- The timescale for building new nuclear stations tends to be longer than expected and is a trap for the unwary Minister. Planning, design changes and lack of skilled manpower can all contribute to delay. Asking the private sector to build competing designs was a serious mistake which consumed much ministerial time in earlier programmes.
- The public holds government responsible for the safety of nuclear power stations. A strong research capability is important to underpin the nuclear programme, not least the safety aspects.
- There has to be progress on the long-term disposal of highly radioactive waste. Underestimating the importance of environmental issues was another mistake of the 1970s.
- The scale of finance for nuclear stations, including the cost of decommissioning, is great. Governments usually come under pressure to support the private sector in the end.

Notes

1 Margaret Gowing, *Britain and Atomic Energy 1939–1945* (Macmillan, 1964), p. 386.

2 *Official Report*, 25 May 1965; Vol. 713, c. 237–8.

Lord Wilson of Dinton is Master of Emmanuel College, Cambridge.