A Submission to the Cabinet Office PIU Energy Policy Review 2001

Global Protection-the possible role of Nuclear Power in the 21st Century and Beyond

By

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Much of the content of this submission is extracted from the author's work "Energy Perceptions" prepared as a personal millennium project and addressed to his grandchildren for their reading in future years. By setting down his thoughts and perceptions of the changing energy scene, he hopes they will understand the motivations and aspirations he shared with his colleagues during the second half of the 20th Century and will gain some feeling for the serious issues on which he ponders in retirement. These themes, written 18 month's ago, form the basis of this new work but are developed in the light of more recent information and activities. It is submitted with respect and with the hope that it will receive careful consideration.

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"It is our firm intention in the European Union to stabilize concentrations at 550ppm. That may well mean reductions five or six times greater than we agreed at Kyoto. It will require a fundamental reassessment by the governments and peoples of the World of their behaviour This is the biggest challenge of the next century"

Michael Meacher, UK Environment Minister October 1999

The Issue

In June 2001, the Prime Minister announced to the House of Commons that the Performance and Innovation Unit (PIU) of the Cabinet Office would carry out a review of the strategic issues surrounding energy policy for Britain and that he had asked the Unit to report to him at the end of the year. The review will focus on the challenge of global warming and the government's commitment to the Kyoto Protocol, while ensuring secure, diverse and reliable energy supplies at a competitive price. This communication is in response to an invitation to comment on the list of topics contained in a scoping note issued by the PIU in July.

From Mr Meacher's quotation *"...reductions five or six times greater than we agreed at Kyoto…"* we see Kyoto as the first small step along the way to a possible future in which the discharge from Britain of carbon dioxide to the atmosphere will be reduced to 40% of present levels. It would be wise therefore to search out ways and means of producing energy that once the first target set by Kyoto is met would evolve naturally to deal with the more demanding long term target. The increased use of Renewable Energy has found favour in Government policy and already we witness new developments at the large scale. We also see great advances in the use of natural gas for the generation of electricity but we are aware that within a few decades the country will be unable to enjoy the security of having copious supplies of cheap gas around its shores and, with other European countries, will need to look further a field to Russia, the Middle East and North Africa. For the first time in the nation's history will it be possible for agencies outside our sovereign territory to have control of our nation's lifeblood - the fuel to produce energy. The search is for energy that does not increase the level of carbon dioxide in the atmosphere and which cannot be regulated by the turn of a valve from beyond our shores. In addition to environmental solutions there is therefore a basic need worldwide for a fuel that will permit the generation of electricity over months possibly years to provide protection against global economic and political instabilities that would arise from sudden disruption of energy supply. Recent World history provides marked examples of such instabilities.

The magnitude of the electricity supplied in Britain and available by the flick of a switch every instant of every day is difficult to convey but one comparison is with the EURO STAR high-speed train. The average electric power consumed in Britain is equivalent to 3000 EUROSTARS with each one producing its full 16000 horsepower while speeding across Northern France. The current writer has difficulty in perceiving a future in which the British supply of this amount of electricity relies substantially on large-scale wind farms, solar arrays and the widespread growing of coppiced willow as an energy crop. The intermittent nature of the first two and for the third, the extreme logistics problems of transporting vast volumes of chipped green wood for gasification and burning, immediately raise severe questions of practical and economic viability.

France

The above perception of future electricity production in Britain is unreal when, across the English Channel, the French fleet of nuclear power and hydroelectric stations are, according to a recent Government publication (Refl. 2001), delivering electricity to their industry at the lowest cost level in Europe with the exception of Sweden. After all allowances are made for taxes French industry in 1998 used power 30% cheaper than British industry. The majority of these stations are fully expected to remain in service for the next 50 years. The security of supply will remain totally within French hands and this results from a firm strategic plan set 30 years ago. Year on year, the performance of these plant improves with associated reductions in production cost. The latest brought into service - the N4s - are achieving load factors of 90% or more - a figure undreamed of 20 years ago. The operator, Electricite de France sees the 1450-Mw N4 units as the most powerful and most advanced nuclear power reactors in the World and as a worthy "benchmark" for the next generation European Pressurized Water Reactor (EPR), which is jointly developed by France and Germany for licensing and subsequent construction in the two countries. This plant could also be used as a reference point for assessing the reintroduction of nuclear power construction in Britain, covering such matters as economics and safety. The continuity of industrial activities is of cardinal importance and we also see France bringing into service power stations supplied to China at Daya Bay and Ling-Ao with a collective power output of 4000Mw - nearly one third of Britain's current total nuclear capacity- a very substantial carbon dioxide emission reduction will result from the displacement of 4000Mw of inefficient coal-fired units common in China. This is a worthy contribution to the spirit of Kyoto.

Fast Breeders and Better Use of Uranium

From the time in 1940 when the two French physicists Drs Halban and Kowarski arrived in this country as refugees and started work in Cambridge on the physics of the "nuclear boiler"(Ref.2, 1941), France and Britain worked in very close collaboration and as a consequence their two development routes for 25 years ran in parallel. Separate paths were then followed with the French firmly committed to the construction of the US designed Pressurized Water Reactor (PWR). For a further 20 years, the two countries collaborated but with much technical and commercial rivalry on the fast breeder reactor when prototypes were built in both countries and a full size commercial version was built in France. As a result of the natural properties of plutonium - just as natural as the wind and the heat of the sun - a breeder fuelled with plutonium produces more fuel than it consumes so the surplus can be made available for use as the fuel of another nuclear power plant. The development was found to be extremely challenging, a technological struggle at every step of the way and very demanding - in money, in time and in manpower. We shall return to this matter later. The feasibility was in the end fully demonstrated and the British prototype was closed down from full power on 31st March 1994 at a time when it was working in full health and supplying sufficient power to provide all the electricity required by a city the size of Bristol. Clearly such a plant which was a test bed could not possibly compete with the economics of a fully commercial and replicated modern natural gas-fired power station and so its end was inevitable in a cash conscious World.

The physics of this class of reactor have been fully researched. A very simple calculation shows that the 150 tonnes of plutonium stocks now available in Britain has the potential to fuel fast breeders with a collective power output equal to the 12,500 Mw of the currently installed nuclear capacity in the country. The striking feature of these reactors is there would be no need for Britain to import any fuel for them for at least 1000 years. Hence, it is the ultimate in long-term fuel security. As explained above, the plutonium would multiply - perhaps triple during the course of a century and the excess might well be used to fuel new breeders or other reactors as the need arose. This was the vision of nuclear power and although the underlying technology of the breeder is demonstrated, the conventional economic profile of a large-scale development remains to be established. In common with all nuclear power stations, the breeder would not emit carbon dioxide - but the story does not end there. If we are allowed to raise our sights way beyond the initial one of meeting Britain's Kyoto commitment to the time when on a global scale every effort is being made to hold the level of carbon dioxide to 550ppm, the question arises by what amount are we able to reduce carbon dioxide emission by the all out use of nuclear power. This question was raised in the US two years ago and in recent times a definitive paper on the subject by a grandee of atomic power, Alvin M Weinberg has appeared in the British literature (Ref. 3,2 000). He reports that if all of the estimated uranium resource of 30 million tons were to be burned in the PWR type of reactor, 38ppm of carbon dioxide would be saved by avoiding the use of fossil fuel. In the global sense this might not seem to be very much but sufficient to win important time whilst other avenues are explored. Hence the current generation of nuclear power stations is not a panacea to deal with the energy problem of the deep future. There are things that can be done to extend the contribution, one of which is to put back into the new fuel the limited but significant amount of plutonium produced by the PWR during its previous fuel charge.

In a search for a more efficient way of using the uranium resource, it is necessary to recognize the existence of the Canadian CANDU reactor which because of its use of neutron friendly heavy water and natural uranium achieves a higher efficiency in its use of fuel than is possible with a PWR. Hence CANDU might therefore be able to extend the era of first generation nuclear power. It is striking that the original work by Halban and Kowarski, used the heavy water they had brought with them to England in 1940 and in the original paper (2,1941), the attractive qualities of heavy water are described but with the concerns as to how it might be produced. During the war, they moved to Canada to continue their work and it became the foundation of the industrial development of nuclear power in Canada CANDU reactors are fully developed and operate in many countries of the World. With the incentive to improve the efficiency of uranium utilization there are today, in embryonic form, concepts based on existing commercial reactors including the PWR which in the current writer's judgement would extend many times the 3 8ppm given in the Weinberg paper.

Weinberg goes on to evaluate the saving that might arise should all of the available uranium be used afterwards in a breeder reactor and reveals by means of straightforward paper and pencil calculations that the potential for saving is 5300ppm - a vast quantity possibly greater than the planet will ever need. The breeder may be seen by some as using a sledge hammer to crack a nut. He concludes that for nuclear to be really part of a long-term solution to controlling carbon dioxide level, the world must shift from Light Water Reactors (LWR) ultimately to breeder reactors, or find much more recoverable uranium and be prepared to remove it from the earth. For reasons given in the previous paragraph that particular conclusion is debatable. The initial reason for the development of breeders was the conservation of limited uranium resources of low cost. If the breeder is called upon, its role in the deep future will be associated with the control of carbon dioxide level in the earth's atmosphere and to provide the World with a stable source of energy.

The key scientific and technical reports written in Britain on breeders are carefully preserved together with final reviews indicating, as if as notes to the future, where mistakes were made and suggesting more promising avenues to follow next time. Mention has already been made of the tremendous technological challenge of the breeder. Round each and every corner, new and difficult phenomena were revealed. For the metallurgist reader, typical of these was the large but slow changes in the density and distortions of stainless steel when located in the extremely high fast neutron field at the centre of the reactor. This steel is used in the construction of the fuel assemblies and serious and therefore unacceptable distortions in the core construction resulted. Following painstaking and time consuming research, solutions were found and a future generation will read that a ferritic steel is largely resistant to such problems. By 1994, fuel assemblies were able to produce over their lifetime three times the energy set as the initial target for the project. The most severe problems arose with the conventional plant away from the reactor itself and, for the engineer reader, were located at the tube to tube sheet welds of the steam raising components. The confidence of British industry to produce satisfactory units was not realized and also in the interests of financial economy no test bed was built to prove the design and manufacture so that weaknesses could be revealed before committing them to the power station. Failures here had a devastating impact on timescale measured in years and the total money spent on the British prototype during its lifetime. In France meanwhile, their design did not employ tube to tube sheet welds and they allocated finance for the construction of a test bed with the result that the French prototype worked extremely well.

The British prototype breeder station was dismantled immediately following the final shut down in 1994. This may become a matter of great regret and bring into question the judgements exercised in that era. Fortunately, the French prototype remains intact. On the brighter side, the decommissioning and dismantling of the power station at Dounreay are the first moves towards restoring the environment there. What techniques are required? What are the hazards? How much does it cost? How long will it take? are all questions to which answers are needed and finding them is an important part of nuclear development. This responsibility is vested in the current generation of nuclear engineers and scientists - their answers will assist those that follow.

The High Temperature Reactor

The High Temperature Reactor currently identified with work in South Africa is gaining attention worldwide as a possible system for the future. In fact the HTR concept was conceived at Harwell in 1955 by Dr Peter Fortescue (when it was known as the HTGC). Specialist teams led by Dr LR Shepherd, Mr G Lockett and Mr R Huddle conducted background research and feasibility studies to establish the route that larger scale development should follow. The excited press reports of those days will be found in the *1955/1956* newspaper archives and will bear witness to the emergence of this advanced concept at Harwell. Not only was it geared to high power conversion efficiencies but the application to a closed cycle gas turbine was also foreseen as was high temperature process heat production. To add to these, there was also some possibility that the system could have breeding or near breeding capability; to achieve this goal, the HTGC fuel cycle was to be based on thorium and uranium233. In the early 1960's, nuclear measurements revealed that mother Nature had not been so kind in her assignment of nuclear properties to uranium233 as she had been to fissile plutonium. Whereas high efficiency in the use of fuel remains a feature of the HTGC, calculation indicated that it could only come close to breeding and was denied a self sustaining fuel cycle. Consequently, attempts to achieve breeding were discontinued. In 1958, the concept became a gift to Continental Europe and at Winfrith, Dorset, the Dragon Project was formed and a demonstration reactor built. It was the Dragon team that developed a demonstration of the high temperature engineering in its helium-cooled 20Mw reactor. It also perfected the special fuel of carbon and silicon carbide necessary for high temperature operation to the high standard demanded for adequate retention of radioactive fission products. This opened the way for the so-called Pebble Bed reactor developed in Germany and in the modern era taken up by South Africa, Japan and China The inherent safety attraction of its characteristic all ceramic core is now being appreciated worldwide. The work in South Africa shows promise that with a direct cycle gas-turbine attractive economics might be result from a smaller size of plant than is associated with a PWR commercial power station. Provided these features are borne out, when taken with the inherent safety, the choice of sites for these units would be wide. This, with the smaller size and the high temperature could open the way to the industrial production of hydrogen from water thus providing the source for the hydrogen/fuel cell technology - an alternative fuel for transport indirectly supplied by nuclear power.

A feature demanded by the physics of this reactor is the need for a higher concentration of fissile material than is needed by a PWR. The current writer performed work in 1961 to explore the prospect of burning plutonium in an HTR. This work (Ref.4, 1961),illustrates the potential to incinerate the initial charge of plutonium to very low levels of concentration. From all the above, it is clear that the HTR has the potential to operate in partnership with a breeder system of reactors burning the surplus plutonium from the breeder as its fuel. Alternatively it could work in conjunction with a reactor such as CANDU.

Strategy

We began with a quotation from Mr Meacher and the current writer followed with his assertion that if possible, it would be advantageous to identify a long-term strategy that would embrace the requirements of Kyoto and which like a stepping-stone would help us towards both the long-term and the deep future. Britain has the 4/5th most powerful economy in the World and so it carries high responsibility for bringing forward and working towards universal solutions that will contribute globally. The vision must rise from time to time in breadth and in depth to matters beyond the parochial techniques to be applied in Britain solely to meet the country's commitment to Kyoto by 2010. What is resourced in Britain should be seen as prototypic for the World. It might also be said that its wealth accumulated over the last two centuries is a result of the start it gave to the Industrial Revolution and this might be a unique added responsibility for Britain to shoulder.

The strategy for nuclear power starts from the current position where the earth's atmosphere is protected from the release of a large quantity of carbon dioxide that would result if the equivalent power were to be provided by fossil fuels as was once the case. To maintain this level of protection, it will be necessary to replace the existing power stations as they retire at the end of their service lives. If it is found that an increased contribution from nuclear to overall protection is called for then more nuclear power stations of the kind already in production will be built thus providing a smooth evolution to the medium term future. For reasons explained earlier concerning the uranium resource, there is a natural limit .on the number of current power station designs that can be built globally and this limits the protection they will be able to give the atmosphere. A perception of a long-term future in which all countries produce the same fraction of their electricity from nuclear as is done today in France is obviously false. For the level of protection provided by nuclear power, it will be necessary to discover more uranium in the earth and be prepared to extract it and/or to increase greatly the efficiency at which the uranium is used. This is the role of the breeder which has the potential to give high levels of protection into the deep future should it be required. A more modest contribution from a higher uranium efficient reactor than a PWR should not go overlooked in any strategy.

Our attention has concentrated on electricity production but with the prospect of a High Temperature Reactor that might work in double harness with the breeder there is the prospect for hydrogen production leading to hydrogen/fuel powered transport.

In summary the strategy is:

- Present - sustain the nuclear contribution to the protection of the atmosphere
- Near term - put in hand measures to replace the ageing reactors as they are withdrawn from

service. Monitor events worldwide and be prepared to adjust British installation rate as appropriate at the time

- Long term - from 2020 onwards be prepared to evolve to a more uranium efficient reactor or a breeder strategy to maintain protection. Explore the introduction of the HTR with particular reference to hydrogen production.

- Deep Future 2050 onwards - be ready for sustained breeder introduction if no other viable option available. Maintain momentum with HTR so that should the opportunity arise from the discovery of some new and more attractive energy source, the plutonium stocks could be safely incinerated.

- At all times seek out opportunity for full international collaboration on all matters nuclear.

The strategy for the next 30 years or longer is based on demonstrated commercially available technology and to the deep future is based on proven science which still awaits demonstration at the commercial level. It is intended for it to be a reference from which all may acquire a perception as to how the World might conceivably evolve from today to the 22^{nd} century or beyond but at all times maintaining protection of the planet. Whist such a strategy requires bedrock for its foundation through the realism of its technology, it does not need to be cut on tablets of stone but must be sufficiently flexible to accommodate change and to search continuously for better ways - but without this search impeding steady progress along the strategy. There will be a need to try out new ideas both nuclear and non-nuclear so that from among many fanciful proposals, a jewel can be allowed to emerge and become part of the reference strategy. As timely intervals, this strategy could be adjusted in the light of changing circumstances and new discoveries.

Nuclear Waste and Public Confidence Generally

The current writer is conscious that the reader may be suffering a growing frustration that no mention has yet been made of radioactive waste in particular and public opinion on nuclear power matters generally.

Whatever the future of nuclear power in Britain might be, the treatment of nuclear waste products at Sellafield and elsewhere cannot be avoided. Among the many criticisms that have been levelled on the handling of the nuclear waste issue, rarely is mention made of the successful achievements by British Nuclear Fuels and others on the stabilization of waste and its packaging for long term storage. Decisions cannot be taken on the location of final storage whether it is to be on the earth's surface, in shallow stores or in deep geological repositories. In Britain, decisions cannot be taken because for more than 20 years, the facilities for scientific research which require field tests and drilling into the earth have all been frustrated by public opposition at the planning stage. A paper by a British grandee, Sir John Hill (Ref.5, 2000) provides a detailed report of the various barriers to progress that where erected over the years. Meanwhile in France, Sweden and China research projects are underway and it is to these countries that one must turn to see progress. It is urgent for work to start here so that British scientists and engineers will eventually be able to bring forward results of parallel work on a topic of research that is inescapable. Protected from the noisy din of opposition, they would then be able to seek opportunity to explain their results and offer their assessment of the risk to all forms of life and the environment generally. It would then be possible to compare the magnitude of these risks to others that mankind faces in the short, medium and long term.

It may appear to some that the circumstances surrounding nuclear waste are a result of neglect. The reverse is the case. The problem of dealing with radioactive waste was recognized in the infancy of nuclear power. Assessments were made, technical judgements exercised and a disposal strategy worked out. The earliest date at which a repository would be required on technical grounds was defined and the technical work needed was deferred until nearer the time of construction. With the benefit of hindsight, the necessary timescale for demonstrating technical mastery of waste storage was in the end to be set by public opinion and political considerations rather than technical issues. It borders on tragedy that one minute fraction of the resources devoted to the breeder were not diverted during the 1970's to the proving of a repository. To repeat, this matter demands the utmost urgency.

For the British public opinion to swing in support of nuclear power it is necessary to cultivate a spirit of openness, to show using ordinary language that nuclear power is necessary, that the risks are explained, that the information they are given is truthful and is the very best that is available. The reasonableness and the commonsense in Britain will be important factors in the outcome but the willingness to play a fair and full role in World matters will be high on the list of criteria. The outcome cannot be presumed but it is hoped that the days of deploying media personalities in an attempt to influence opinion or trendy TV advertisements are over. Although consultation between government and public must continue, it cannot be assumed that only those who respond have opinions. It is right that such consultations can influence decisions but not necessarily determine them. There will be times when the wishes of the silent majority are encapsulated more in Government decisions based on vigorous leadership than those made by drifting comfortably on the stream of consultation responses.

Success will be marked when once more Britain feels able to applaud technological triumphs in the nuclear field.

Making it Work

To make the strategy work requires open minds at Government ministerial level and to face squarely what is declared by Government to be the biggest challenge of this century. So that ageing British reactors can be replaced if that is decided, it will be necessary to have in place by that time a thoroughly competent and fully trained scientific and engineering team within the regulatory body, the Nuclear Installations Inspectorate (NIl). To use an old fashioned term, this is a critical path item - the timescale of all that follows depends on it. It is asserted that within some negotiated framework, the generating company will purchase from either France and Germany or the United States a complete plant that has already acquired full licensing clearance for construction and operation in the respective countries.

First, it is recommended that at Government level arrangements are negotiated with the three countries mentioned to attach, on terms to be agreed, a significant team (about 10) of scientists and engineers to each of these Government's regulatory bodies for an appropriate period of time. By working within these overseas teams and contributing to their programs, they would become thoroughly acquainted with the design and the details on which the safety principles are based. The task would be translating these into the British way of thinking and would ultimately lead to a view on licensing in Britain. It cannot be emphasized too strongly that redesign of the plant is strictly forbidden and any talk of "higher British standards" should be treated with the utmost scepticism. Firm guidance should be issued that design modifications to a standard plant would require ministerial endorsement. Success with this would mean that a British plant purchaser from the outset of any negotiations with the vendor would know clearly how he stood with regard to finance, construction timescale and licensing.

Licensing is a government responsibility funded by the taxpayer. The cost of supporting these teams of technical civil servants would be minuscule on the scale of government spending in the energy field. A successful outcome, following vigorous negotiation with relevant Governments could reasonably take 6 months and at the outside 1 year to complete. Since it takes time to train, acquire knowledge and digest, the overall exercise could not be completed in months and it is urged therefore that a start is made along this path or one similar to it without delay. Support would not reflect Government intent to embark on construction but would, if properly explained, be seen by the man in the street as a sensible prudent step to be taking in 2002. The cost would be trivial.

Secondly, it is recommended that the Government takes immediate steps to free the barriers to progress that have existed for 20 years on the question of radioactive waste disposals. This matter is now a national scandal and the mere mention of the topic arouses an appalled response from the public. With this image, how many high quality scientists and engineers are prepared to dedicate their professional careers to solution of this problem? How many 18 year olds are encouraged by their schoolteachers to make a career in the radioactive waste industry? This situation must be turned around by Government providing an impetus that the topic is important that the environment must be protected and that it is determined to resolve this long standing issue. The current writer is familiar with proposals that are already on the table but irrespective of the urgency, he is unable to share in a concept of Britain going alone with its own unique program. This is the thinking of the past. In today's World so much more can be achieved by properly crafted international collaborations either bilateral or multilateral whichever is judged most appropriate. Mention has already been made of the French progress in this politically difficult field. It would seem that so much could be gained by collaborating on a euro for euro basis (or euro for fractional pound as desired) where our technical contribution would be complementary to the French and visa versa The human dimension too is key where anxieties overcome by one community might be expected to boost confidence in that of another. To be able to visit and see and to talk before a single particle of earth is removed in can be nothing but beneficial. The cost of such interaction would be small and the benefit of eye-to-eye contact to replace rumour and misinformation with fact would be immense. The French would gain equally once the British program gained momentum. To go forward in an insular way belongs to an era long since past.

The Government is urged therefore to create immediately a group of active working professionals with relevant technical capabilities and those with skills in behavioural science to explore how it might be brought about. Vitality and enthusiasm would be highly desirable attributes of members with a record of getting things done. The group's task would include first the production of an outline technical program taking into full account what is known of French work in progress and secondly just how the human dimension might best be tackled. This might take 6 months or so and the Government through its appropriate departments could then decide whether or not the result of the group's work was sufficiently encouraging to move forward with an approach to France. If presented in a straightforward way, it is unlikely that this initiative would appear strange to the majority and if the Government is of a mind, a consultation on the exploratory activity in progress would be appropriate during and at the end of the study. In the interests of timescale and therefore real cost control, it is important to create a working pattern that allows parallel activities - the young cannot afford the time to wait.

Thirdly, it is recommended that the Government policy to support large-scale testing of technically viable renewable energy processes should remain strong. From 2020 or possibly earlier, it may be necessary to enhance nuclear construction from a replacement policy to one in which the installation rate is accelerated. Under such circumstances, it is crucial that complete evidence to support an increased nuclear installation in preference to an alternative is totally transparent. It is of paramount importance that the technical and economic performance of all renewable large-scale demonstrations that enjoy the umbrella of protection from the taxpayer in some shape or form are subjected to continuous detailed audits. These must be made public and any pleading concerning commercial confidentiality should be firmly and completely rejected by the Government. It is recommended with equal strength that the reviews and audits be conducted by a group comprised primarily of engineers and industrialists, supported by economists. Members should be independent and actively engaged in industry and have an ability to detect the ring of truth or otherwise in submissions made. The whole process would be conducted on a rigorous intellectual basis. The size and model for the group should be based on the Monetary Policy Committee and, like that body, the minutes would be published. In the absence of such a highly competent team, the Government will remain in danger of buying one pig in a poke after the other. Continued strong support for large-scale testing of the renewables or other alternatives to provide meaningful performance data is vital for the nuclear strategy outlined earlier. With this final recommendation, the current writer cannot resist the temptation to quote the words of Abba Eban given in a speech in 1970:

"History teaches us that men and nations behave wisely once they have exhausted all other alternatives"

China

Although long for the purpose intended, this communication would be incomplete if some reference were not made to nuclear activities in China. From a modest beginning in 1980, nuclear power has advanced rapidly in recent years with the assistance of France, Canada and Russia; from France and Russia PWR construction is underway and some are already in service. From Canada the 1400Mw Qinshan Phase 3 CANDU plant is scheduled to start in 2003. China is therefore able to benefit from developments that took 50 years to complete, and under the international terms of contract is able to transfer construction experience to its own industry and then from first hand experience will be positioned to take sound decisions for her future. The range of activity is comprehensive and so is not restricted to the immediate issue of electricity generation. She is engaged in the development of advanced forms of PWR, has built and operates an HTR and has a breeder reactor under construction. Facilities for fuel production and reprocessing to service the reactors are in operation and a waste disposal repository is available for intermediate level waste. The stated underlying aim is for China to become totally self-reliant in all areas and to achieve World status in its performance and is a member of the World Association of Nuclear Operators. It is just like starting with a clean sheet of paper, bringing together all that has gone before and writing down the best route to follow. Because of this new start and unhampered by the baggage of the past (and also noting the political environment), it could serve to demonstrate to the World that nuclear power is available for widespread and safe application. From the size of the country and the intellectual power of her people, there can be no doubt that Chinese scientists and engineers will improve on past work and so discover better ways of proceeding.

Concluding Remarks

In conclusion, attention once more will be drawn to the then secret report (2) written by the so-called MAUD committee and seen exactly 60 years ago by the War Cabinet or more precisely by selected members of that Cabinet. The time was 3 month's before Pearl Harbour and here in the same document of very few pages the rudiments of an atomic bomb are explained and the outline given of power reactors concepts to replace coal and oil for power. From the outset the military and civilian applications were entwined and in perception have remained so. The technical concerns of those engaged in the work are reflected in the paper and picking up from the discussion in paragraph 1 of the power aspects we read:

"Experiments to determine if such an arrangement is possible have been carried out by various workers in this and other countries and most recently by Dr Halban and Dr Kowarski, who have proved that it can be done by mixing Uranium oxide in suitable proportions with a substance known as heavy water.

"Though this substance is at present is only available as a fairly rare chemical, and although quantities of the order of several tons would be required to make the apparatus work we consider that the method has considerable possibilities. The energy that can be theoretically be derived from uranium consumed in this way amounts to 12 million H.P. hours per lb. (sic!) and in addition large amounts of radio-active substances would be formed which might have important applications. Besides the production of heavy water there are a number of problems still to be solved in making and using such a device. It will be necessary to provide means of controlling the process and preventing an explosion, which though not violent enough to have much military value would wreck the apparatus and building. The rate at which power can be generated is in fact limited by the rate at which it can be taken away in the form of heat, either in steam or some other cooling material. Such a plant would produce radio~active effects of enormous intensity and the greatest care would have to be taken to shield the workers. It is clear that the scheme requires a long term development and we do not consider that it is worth serious consideration from the point of view of the present war."

There is much to be found in this, the second paragraph of the report. The discerning reader will have already picked up on those words in the fourth line about radio-active substances and will have detected the very first twinkle in the eye that led about 40 years later to the birth of the £4billion British company Amersham International that processes and dispatches over Britain and the World, radio isotopes many of which are used in the Departments of Nuclear Medicine.

A few lines further, the reader will noticed that the control of the reactor was at that time a complete unknown and workers in Britain had to wait 17 months for the discovery in the United States by Enrico Fermi that the control of such devices was surprisingly straightforward. This was found to be because in the fission process a very small fraction of the neutrons produced did not burst almost instantaneously from the uranium nucleus but were delayed by tens of seconds - the delayed neutrons. This totally natural property allowed power changes to be made over seconds, minutes or even hours without the man at the control desk requiring superhuman reaction times. Provided the reactor designer satisfies certain well defined rules in his reactor design then full advantage can be taken of the delayed neutron phenomena and he will have a stable and therefore well behaved reactor plant. If respect is not paid to these rules however then he will run the danger of serious damage with possible disastrous consequences. This is what happened at Chernobyl, exacerbated by a reckless attitude to operation. The World Association of Nuclear Operators created after the disaster will ensure that any inadequate design or below standard or suspect operations are pinpointed so that appropriate action can be taken.

An accurate evaluation of the long-term costs of a nuclear power strategy of the type proposed earlier is not possible. However, a good estimate for the first 20 years or so can be achieved if a standard PWR power station already in full production is ordered, following the Chinese method. Similar reasoning would apply for the Canadian CANDU and in due course, technical and commercial success with the HTR would also open that avenue. The position with the breeder is more problematical and although conventional wisdom states that it is uneconomic, there is absolutely no evidence to support this assertion on the economics of say plant number twenty in a series construction program. In 2001, it is futile to engage in conventional economic analysis. The modern roles of the breeder would be to protect the earth's atmosphere by reducing carbon dioxide emissions and to produce power as cheaply as possible. Because of it's great potential in the protection role, it is wholly appropriate that credit is shown on the balance sheet for this. When will the economists be able to advise on what financial allowance would be appropriate for mitigating the worst consequences of climate change?

The current writer wishes to conclude this work with a quotation broadcast by the BBC in May 2000:
"Judging whether the energy we can afford is something the planet can also afford is one of the challenges we shall need to face. Energy, and all that is entailed in producing it is no respecter of political boundaries, not something governments can decide in isolation. Probably the biggest challenge implied by the Kyoto Protocol is rediscovering we are 6 billion people united by a single climate"

What enormous challenges, what tremendous opportunities, what wonderful prospects there might be! Yes, but we ponder on how historians will record the first few years of the 21st century and, from what quarter strategic leadership might come in 25 years time.

Summary Recommendations

It is respectfully recommended that the Government:

- Initiate or accelerate the training of Regulatory Technical staff (NIT) in modem PWR plant technology by negotiating arrangements for the long-term secondments of teams overseas.

- Support developments required for the provision of a radioactive waste repository in Britain and explore the prospects of collaboration with France.

- Continue strong support of large scale renewable energy and other non-nuclear energy alternatives but within a framework that ensures complete, transparent and public audits of performance

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