Comments in response to the Energy Review 2006

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All comments relate to the nuclear power aspects of the consultation document. Dr Nuttall is author of *Nuclear Renaissance – technologies and policies for the future of nuclear power,* IOP/CRC Press, 2005. This is not an academic document and not all third party sources of information have been cited. This is because some of the comments relate to ideas that may have been learned under the *Chatham House Rule* or in similar non-academic circumstances. This submission is made in a personal capacity and my professional affiliation is only provided so as to aid with identification. The views expressed here are not necessarily those of my employer.

The Economics of Nuclear Power

Real options modelling by Fabien Roques et al. has demonstrated, for the UK liberalised electricity market, that there is negligible benefit for a gas-dominated utility to broaden its generating base to include new nuclear power plants. Intuitively one might expect that such a utility might benefit from the ability to hedge risks associated with volatility in the price of natural gas for electricity generation. If electricity prices were stable and independent of natural gas prices, Roques et al.'s modelling suggests that such beneficial hedging would indeed be possible. However, in the UK market electricity prices are strongly correlated with natural gas prices (as are carbon prices). This yields a remarkably stable 'spark spread' and ensures that natural gas price volatility causes little harm to utilities with major investments in gas-powered generation. Consumers, of all types, are however adversely affected by such electricity price volatility and, in most cases, they find it hard to hedge themselves against this risk. The authors therefore are presenting evidence of a market failure in generation that might require government intervention to protect the consumer and the public interest. A copy of the relevant research paper is attached.

Load Following Nuclear Power

The Energy Review 2006 makes the following statement:

... [nuclear power] has the disadvantage that it cannot easily follow peaks and troughs in energy demand.

This statement overstates the issue and implies that future nuclear power will be only base-load for technical reasons. While it is indeed the case that Britain's gas-cooled power reactors (Magnox series and AGR series) were incapable of load following for technical reasons, this is not the case for the water-cooled and water-moderated reactors envisaged for the next wave of nuclear new build. Britain already has one such nuclear power station in operation - Sizewell B in Suffolk (a modified Westinghouse SNUPPS plant). When planned in the 1980s by the CEGB it was expected that this plant would be the first of a wave of nuclear power plants that would provide the core of Britain's electricity supply for the early twenty-first century. As such it was expected that at times of low demand nuclear power might be operating close to the margin of the UK merit order. Therefore, Sizewell B was specified to be able to follow load and to be able to operate with a somewhat eroded power quality on the grid. These attributes of Sizewell B have never been used in commercial operation because of economic, not technical, reasons. For all nuclear power plants, including Sizewell B, the cost structure is predominantly fixed costs associated with the cost of capital for construction and to a lesser extent for decommissioning. Fuel and other discretionary marginal costs are proportionately very low and for this reason there is little or no economic benefit in operating such plants as anything other than base-load in our electricity market in which nuclear is approximately 20% of capacity and in which gas generated electricity is price-making (see preceding bullet). A draft note providing further insight on these issues has been prepared by my MPhil student Laurent Pouret and it is attached.

Life Extensions and Prompt Shutdown for Existing Nuclear Power Plants

While there is much international experience in extending the lifetimes of light water reactors, it is important to recognise that the aging elements of the UK nuclear fleet are based upon fundamentally different nuclear engineering and as such the benefits to be obtained from international experience of lifetime extensions are extremely limited. The issues facing the Magnox generation of plants and the AGR series are fundamentally different from those facing light water reactor systems.

The Magnox plants are currently being phased out. Only four are still generating electricity and only two are expected to be running next year. There is no prospect for life extension of these reactors. All fuel from the Magnox fleet must, for NII mandated technical reasons, be reprocessed. This is done at the B 205 facility at Sellafield. One of the two dissolvers in this plant has been out of operation for many years and it will not return to service. An issue of concern to policy-makers would occur if the second B 205 dissolver were to breakdown. Such a situation would surely force the near-immediate final shutdown of all remain Magnox power plants. Even in that case, there would then be a difficult and substantial spent fuel legacy requiring management. Options would include:

Restarting B 205, do whatever it takes, i.e. whatever the cost.

Run Magnox fuel through THORP - this is tricky because Magnox fuel comprises uranium metal whereas THORP is designed for less reactive oxide fuels. Putting Magnox fuel in the THORP dissolver would lead to large amounts of gaseous hydrogen being liberated.

Reprocess Magnox fuel in France, i.e. enter into a reprocessing contract with Areva-Cogema to reprocess Magnox spent fuel at La Hague. Does La Hague have capacity to reprocess metal fuels?

Dry store Magnox fuel, perhaps even in cases where it has previously been wetted. This would require a fundamental reassessment of Magnox spent fuel safety issues and attentive monitoring of spent fuel. This strategy might only be possible for Wylfa fuel. Wylfa has a unique 'dry' Magnox fuel handling system, although perhaps it is better described as damp rather than truly dry. The other three remaining Magnox plants store spent fuel in ponds.

For the AGR stations the key issue relates to the possibility of life extensions along the lines of that recently approved for Dungeness-B. However, that station has had a far lower lifetime load than other AGR stations. A particular issue for further AGR lifetime extension approvals will be the status of the graphite moderator. This is especially important, as it is extremely doubtful that it would be possible to replace the graphite in an aging AGR reactor. Therefore any reactor with graphite in a poor condition will be unsuitable for life extension. Policy-makers must recognise the important and relatively unusual safety issues underpinning AGR life extension and recognise that the possibility that some further AGR life-extensions might not be possible.

Siting of Nuclear Power Plants

Any decision in favour of the principle of new nuclear build in the UK would soon be followed by questions as to where the new power stations might be constructed. A modest programme of, say, four AP-1000 (1,000 MWe) plants or three EPR (1,700 MWe) plants would be relatively straightforward, and candidate sites are already the subject of some discussion (Sizewell C, Hinkley Point C etc.). Such deployments would replace the nuclear electricity contribution from the relatively small Magnox series of power plants, the last of which (Wylfa) will be leaving service in 2010. If however there is a need, and a desire, to go much beyond the replacement of old capacity, then the situation may be more problematic. Siting a major programme of, for instance, ten EPR stations at or near existing nuclear power station sites could be a difficult matter. Some of the existing nuclear power station sites (such as Dungeness, Hartlepool, and Trawsfynydd) are, for diverse reasons, arguably less suitable than 'green field' sites such as Druridge Bay in Northumberland (formerly considered as a possible nuclear power plant location by the CEGB). Also sites of former nuclear research facilities (e.g. Winfrith), or even the sites of current coal-fired power stations might be worthy of consideration for new nuclear build. Issues to consider include planning, water supply, geology, grid connections, local community attitudes etc. It is important to recognise that a genuine policy of new nuclear build with local public acceptance faces the possibility that candidate sites may need to be abandoned despite strong technical merits. The issue of nuclear siting is the subject of a research collaboration we have underway with the Parliamentary Office of Science and Technology and with Lancaster University.

Safety Regulation of New Nuclear Build

The last nuclear power plant constructed in the UK (Sizewell B) was a project initiated and led by the Central Electricity Generating Board. It was able to play the roles of both design authority and final owner operator. The CEGB of the 1980s had extensive experience working with the Nuclear Installations Inspectorate and other UK safety-related bodies. Following market liberalisation and the break-up of vertical integration in the UK electricity industry, the situation is now much more complicated. Utilities such as EdF, e-ON, RWE and British Energy all have extensive experience operating commercial nuclear power plants, but only one (British Energy) has a familiarity with British approaches to nuclear safety regulation. Should the three continental firms be expected to familiarise themselves with British practice? Or is it more sensible for British safety regulation to shift to a more continental approach? The former option could add significant cost and difficulty to the continental utilities, given the severe shortage of suitably qualified and experienced persons (SQEPs) available in the UK. Electricity generating companies would probably act as owner-operators of the nuclear plants, but it is not clear that they will have design authority. Will such authority rest with reactor designers such as Westinghouse or Areva-Framatome, or might it rest with possible constructors, such as Bechtel or AMEC-NNC? Scrutiny and evaluation of such matters are the subject of a major academic research bid led by Lancaster University, and involving Cambridge University, that has recently been submitted to the Engineering and Physical Sciences Research Council.

'Pre-Licensing'

The Energy Review 2006 has not been helped by what appears to be an unfortunate use of terminology. It states on page 15: “The Government have requested that the Health and Safety Executive (HSE) report [on],… in the event of the building of new nuclear power stations, the potential role of pre-licensing assessments of candidate designs.”. The review appears to refer to pre-licensing in the sense of the idea of generic approval for a particular design of nuclear power plant.

The term 'pre-licensing' is however widely used in the United States for the separate idea of pre-licensing a site for possible nuclear power plant construction. In reviewing responses to the review it will be important to disentangle this point of possible confusion. If the nuclear policy process moves forward to the next stage (e.g. a White Paper) then a move to clear and unambiguous terminology would be helpful.

Skills for Nuclear Power

This topic is a matter of some divergence of opinion within the nuclear industry. On the one hand there is a school of thought that says that there is no cause for concern regarding nuclear skills. Arguments deployed include:

That the nuclear industry does not need significant number of new nuclear physicists and engineers for new nuclear build. Rather what is needed are general engineers and the industry is more than capable of adding the specialist skills required.

That there is no reason to doubt that the market will deliver, and indeed as nuclear new build has started to appear to be more likely, increased enrolments in nuclear-related higher education courses are increasing.

However, those with a less sanguine outlook point to the following aspects:

The age profile of technical experts involved in the nuclear industry is worryingly elderly

Safety regulators are worryingly understaffed and in seeking to recruit staff must retain their independence from the nuclear industry that they regulate

Other countries are also considering a new wave of nuclear construction, such as the United States, and this might cause a damaging brain drain from the UK

A large proportion of jobs for people with nuclear knowledge are in the public sector (nuclear medicine in the National Health Service, the Royal Navy, the Atomic Weapons Establishment, the Nuclear Decommissioning Authority etc.) Any move towards far greater private sector recruitment will spur a competition for talent with the public sector and if important missions of government are to be maintained and properly staffed, then costs to the taxpayer will surely rise.

The training of highly skilled people is the most effective way to ensure national understanding of, and receptivity to, new innovations. In order to properly take-forward new ideas emerging from overseas it is vital to be able to assimilate new codified knowledge and digest it in the context of a highly-developed tacit knowledge base. Having too few skilled people in a given sector reduces options. If the UK is to 'keep the nuclear option open' a critical mass of skilled young people is required.

Radioactive Wastes

I concur with the following views recently reported to me by Nirex UK:

> *To date consideration of waste issues from a new build programme in the UK has largely focussed on the volumes of wastes, in particular spent nuclear fuel. Waste volume is not the only criteria which may impact on the design or capacity of a waste management or disposal facility. Radionuclide inventories and chemical and physical characteristics could all have an impact on how an option is implemented. Care should be taken when comparing radionuclide inventories from a new build programme with that from the current UK nuclear programme. Estimating the percentage increase in the radioactivity from wastes produced from new reactors is complex as the increase is dependent on a number of assumptions. For example higher burn up for fuels in new reactors would lead to higher specific activities. Moreover the reference time chosen for the comparison is dependant on the presence of short-lived radionuclides, which dominate when fuel is taken out of the reactor.*

I also would like to draw you attention to the attached paper concerning the possible benefits to the UK of high levels of involvement in international research into the partitioning and transmutation of radioactive wastes.

Nuclear Energy Research

Any survey of research and development in the UK for the last thirty years reveals a dramatic decline in energy-related research and development with the most dramatic decline being seen in the area of nuclear fission research. Anecdotal evidence supports the suggestion that industrially sponsored energy research decreased as an unintended consequence or government policy to achieve privatisation and competition in the UK energy industries during the 1990s. During this period energy laboratories operated by the CEGB and the UKAEA were broken-up, redirected and closed down. These actions were not the result of a considered national research policy, but rather a rather overlooked consequence of competition policy. By contrast, government research laboratories outside energy such as the National Physical Laboratory or the laboratories of the former Defence Evaluation and Research Authority have been successfully modernised via, in the latter case, part-privatisation or, as in the former case, a shift to Government-Owned Contractor-Operated (GOCO) arrangements.

If any thought was given to the energy laboratories it seems to have relied upon the assumption that in the energy sector research is a commodity to be sponsored or acquired by private users. Such a conclusion is, at best, controversial and numerous technology policy specialists devote their endeavours to understand better whether research is a commodity or a public good. This question is the subject of active European Union research right now.

It is also important to recognise the relationship between energy research and energy prices. Intuitively one might regard high energy prices as a signal and spur for further research. In one case at least this mechanism is not working. For the UK Fusion research programme at Culham in Oxfordshire volatile and high electricity prices are a severe problem. The laboratory operates on a fixed income and is a major user of electricity in support of its research. It is an unfortunate irony that today's high electricity prices run the risk of causing unanticipated harm to our Fusion research endeavours. This would appear to be a market failure requiring policy intervention.

The Chancellor's announcement in his 2006 budget for a National Institute ofr Ebnergy Technologies is a most welcome step. It is noted that the intent is to make this a virtual entity, but I would suggest that we might have the basis here of the National Energy Laboratory system that the UK so desperately needs.

Nuclear Heat and Nuclear Hydrogen

Nuclear electricity generation and nuclear power are widely regarded as two sides of the same coin. Even today this is far from an accurate impression of the capacity of nuclear power. For instance, navy submarines make extensive direct use of reactor heat for propulsion rather than using all the reactor power for electricity generation. Nuclear fission power is well suited to industrial process heat applications or district heating. The world's first civil nuclear power plant at Obninsk in Russia spent most of its long life serving that function.

There is currently much interest in energy policy circles for a long-term a shift in energy carriers away from electricity and petroleum towards hydrogen and the *hydrogen economy.* Two major challenges face the hydrogen economy first on-vehicle storage and fuelling and second sufficient bulk hydrogen production capacity to displace the roughly one million oil wells currently in operation today.

The dominant approach to clean hydrogen production relies upon intermediation via electricity, originally generated in a carbon-free way, for instance using renewables. An alternative clean source of electricity is nuclear power. Hydrogen production using surplus nuclear electricity would allow nuclear power to operate far higher in the electricity generation merit order (see comments under bullet *Load Following Nuclear Power*). Despite the clear advantages of such strategies they nevertheless suffer from severe energy inefficiencies relating to the generation (and perhaps the transmission) of electricity. Recently General Atomics of San Diego California, the High Temperature Engineering Test Reactor (HTTR) project in Japan, the South African Pebble Bed Modular reactor project and the US Generation IV nuclear future power project have all identified the benefits of the use of high temperature gas-cooled reactors for high-temperature thermo-chemical catalytic direct hydrogen production from water. This has far higher energy efficiency than electrolysis but relies upon safety approval for a combined nuclear fission power station and thermo-chemical plant. Given possible safety-regulation difficulties, and conscious of other positive benefits to be obtained, Dr Nuttall, Dr Bartek Glowacki and Richard Clarke have recently proposed the *Fusion Island* concept for thermo-chemical hydrogen production using nuclear fusion and liquid hydrogen based cryogenics for MgB_2 superconducting magnets. The Fusion Island concept has significant environmental, economic, security of supply and safety benefits over alternative hydrogen production strategies. The concept was awarded third place in the 2006 East of England Energy Group Innovation Awards 2006 and a copy of a magazine article describing the concept is attached. Nuclear power is not the only way to produce hydrogen for the hydrogen economy or to provide industrial process heat, but these important capabilities of nuclear power should not be neglected. In addition any move towards a cryogenic hydrogen economy (a such as that advocated in the Fusion Island concept) would inevitably produce large quantities of liquid oxygen. This would facilitate the development of very high temperature oxy-fuel combustion of fossil fuels and very straightforward CO_2 capture (no nitrogen separations required) for sequestration or storage. A shift to a cryogenic hydrogen economy really holds the prospect of a largely decarbonised transport and electricity system for the mid to late twenty-first century. If as some prominent commentators have recently predicted and the world has already passed the tipping point for climate instability the pressures for radical decarbonisation will only grow. This commentator believes that it is easier to change our energy system than it will be to adjust human nature towards an acceptance of the ascetic lives required for climate-friendly living in the absence of nuclear power and carbon capture and storage. A draft paper is attached in which Dr Nuttall argues that, rather than being a force of technocratic authoritarianism nuclear power represents an opportunity to preserve our stable liberal societies into the late twenty-first authoritarianism. The prospect of the green-authoritarianism required to stabilise the climate without nuclear power should be a greater public fear than the dangers of nuclear power.

Bibliography:

F A Roques et al. Electricity Policy Research Group Working Paper EPRG 05/09 available at: http://www.electricitypolicy.org.uk/pubs/wp.html

W J Nuttall et al. *A Trip to Fusion Island*, The Engineer, available at: http://www.msm.cam.ac.uk/ascg/materials/fusionisland.php

W J Nuttall, Electricity Policy Research Group Working Paper EPRG 06/12 available at: http://www.electricitypolicy.org.uk/pubs/wp.html

L Pouret *Load Following Nuclear Power*, a draft paper based on part-completed MPhil research

W J Nuttall, D G Ireland, J S Al-Khalili and W Gelletly, Potential for British Research into the transmutation of radioactive wastes and problematic nuclear materials, Int'l J. Critical Infrastructures, **1** (4) pp380-393 (2005)

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"Nuclear Installations Inspectorate" – more formally today this is the Nuclear Safety Directorate [NSD] of the Health and Safety Executive [HSE]

Thermal Oxide Reprocessing Plant, Sellafield

Our Energy Challenge, Energy Review, January 2006, Page 15.

From HYPERLINK "http://www.nrc.gov/waste/hlw-disposal/pre-licensing.html" http://www.nrc.gov/waste/hlw-disposal/pre-licensing.html: During the pre-licensing phase, NRC has four primary responsibilities:

Review of the Department of Energy's (DOE) HYPERLINK "http://www.nrc.gov/waste/hlw-disposal/site-characterization.html" site characterization process

HYPERLINK "http://www.nrc.gov/waste/hlw-disposal/site-recommendation.html" Site Recommendation Process

HYPERLINK "http://www.nrc.gov/waste/hlw-disposal/reg-initiatives/review-envir-impact.html" Review of DOE's Environmental Impact Statement for Yucca Mountain

HYPERLINK "http://www.nrc.gov/waste/hlw-disposal/regs-guides-comm.html" High-Level Waste Disposal Regulations, Guidance, and Communications

See Tony Coverdale's report for the DTI Nuclear Skills Group available at: http://www.dti.gov.uk/energy/nuclear/skills/full_report.pdf

Professor Ian Fells has pointed out in a private communication that similar issues apply to *sweet-water* production via desalination as a possible way of using surplus nuclear electricity to serve an important future need in southern England