Response to Government's "The Future of Nuclear Power" consultation

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About the Sussex Energy Group

The Sussex Energy Group (SEG) at SPRU (Science & Technology Policy Research) is a team of 18 researchers dedicated to understanding the challenges and opportunities for transitions to a sustainable energy economy. We undertake academically excellent and inter-disciplinary social science research that is also centrally relevant to the needs of policy-makers and practitioners. We pursue these questions in close interaction with a diverse group of those who will need to make the changes happen. Core funding to the group is provided by the Economic and Social Research Council.

This response has been written by Prof. Gordon MacKerron, Dr. Jim Watson, Dr Alister Scott, Ms Mari Martiskainen, Dr David Ockwell and Professor Andrew Stirling using supporting evidence from other Sussex Energy Group members.

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Introduction to this response

This response to Government's consultation on building new nuclear power stations is based on the knowledge and expertise of researchers in the Sussex Energy Group (SEG) who specialise in relevant areas of energy policy. In particular, we have focussed on areas where SEG has, in the past, conducted specific, relevant analysis. This focuses around four key areas:

1. The legitimacy of this consultation
2. The economics of nuclear power
3. Nuclear waste and decommissioning
4. The contribution of nuclear power to energy security

On the basis of the information presented in this consultation, as well as the process that has been followed in conducting the consultation and the accompanying political rhetoric, we remain unconvinced that the case in favour of building new nuclear power stations has been made. Our reasons are set out below in response to the individual questions posed in the consultation.

Q1. To what extent do you believe that tackling climate change and ensuring the security of energy supplies are critical challenges for the UK that require significant action in the near term and a sustained strategy between now and 2050?

Like most other analysts involved in contemporary energy policy, we are acutely aware of both the scale and urgency of these twin challenges of energy security and climate change.

Increasingly, there is wide consensus around the science (IPCC) and economics (e.g. Stern) of climate change and the need to dramatically reduce our emissions to levels possibly 80% lower than current.

There is less of a consensus about energy security, both about the character of the multiple dimensions of energy security (of which we say more under Q3) and about the risk/urgency profiles of each of these dimensions. For many, energy security has become synonymous with mistrust of 'nasty foreigners' and a fear that we could be held to ransom by those with ample reserves of, for example, gas or oil. In brief, our view is that in any economic exchange, both parties stand to gain from trade and both parties would stand to lose from any breakdown in relations. While there may occasionally be short-term challenges, in the main we are of the view that trade is likely to continue to the benefit of all involved.

What is more, even for an issue like climate change where we see a high degree of consensus around the natural science, this provides few if any clues as to what the best course or courses of 'significant action' might be. This is a matter for evidence and analysis. In particular, there is a danger that decision-makers will be tempted to make grand gestures rather than pursue less glamorous but more effective and economically sound options. Consensus around the challenges does not imply consensus around the best means to address the challenges.

Q2. Do you agree or disagree with the Government's views on carbon emissions from new nuclear power stations? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

We are of the view that bodies such as the Sustainable Development Commission have done competent reviews of the evidence on this topic, and we accept their conclusion that by any measure, nuclear power is likely to be a low-carbon option. Our questions centre around the economic and technical dimensions of this option: how do we deal with the technological challenges that nuclear power raises, and at what price does nuclear power deliver carbon reduction in comparison to other options?

Q3: Do you agree or disagree with the Government's views on the security of supply impact of new nuclear power stations?

Energy security has risen up the global political agenda during the past few years. There are many reasons for this: rapid increases in oil and gas prices, heightened awareness of terrorism after the attack on the World Trade Centre in 2001, the war in Iraq, and the blackouts that hit several electricity networks in summer 2003 in North America and the UK.

The importance of this issue means that it merits careful analysis before concluding that a particular strategy or set of options will help to strengthen UK energy security. A clear case has not yet been made that a programme of new nuclear power plants will have a positive impact on energy security. Whilst nuclear power can strengthen some dimensions of energy security, it is far from clear that it can do so on many others. Furthermore, it is not clear that energy security strategies that include substantial investment in this technology would be a better 'insurance policy' against energy security threats than other strategies.

Unpacking energy security

There are many ways to deconstruct energy security into its component parts. In our response, we have deliberately used the phrase 'energy security' rather than security of supply since the latter term can provide the mistaken impression that all energy security issues are about threats that are external to the UK. One approach to analysis is to consider each of the risks or threats to UK energy security in turn. Whilst many of these overlap and interact, such an approach can aid the analysis of proposed strategies, such as the programme of new nuclear power stations, which are proposed as ways of strengthening security. In recent research by the Sussex Energy Group[1], four main categories of threat or risk to UK energy security have been identified and analysed. Briefly, these are:

- Fossil fuel scarcity & external disruptions
- Lack of domestic investment in infrastructure
- Technology or infrastructure failure
- Domestic activism or terrorism

Fossil fuel scarcity & external disruptions. This includes threats from absolute scarcity, for example due to what some commentators call 'peak oil'. It also includes threats due to the location of fossil fuel reserves and production, and threats to international transport routes for fossil fuels such as pipelines due to disputes and terrorism. With respect to absolute scarcity, there is a split of opinion on the extent to which oil production is about to peak. However, a key weakness of arguments by proponents of 'peak oil' is their static view of fossil fuel reserves. They downplay the impact of fossil fuel prices and extraction technology on future availability – factors which have led to much larger reserves being available than was anticipated at the time of the 1970s oil shocks. With this in mind, we would argue that the location of reserves and the vulnerability of transport routes are more important issues, but these two also tend to get overplayed as threats to the UK. Even at times when the UK was more self sufficient in fossil fuels (especially in the 1970s), it was vulnerable to the economic impacts of rapid increases in oil and gas prices.

Lack of domestic investment in infrastructure. This includes investment in power plant capacity, electricity transmission and distribution lines, import facilities (such as LNG terminals) and oil and gas pipelines and storage facilities in the UK's waters. Our observation is that most recent discussions about this category of risk have focused on a hypothetical one – i.e. the projections of an 'electricity gap' due to the closure of coal and nuclear power plants over the next few years. The strong impression has been given that a crisis is imminent in the electricity supply system. This neglects the record of high investment in new generation capacity since the electricity industry was privatised (over 25GW), and the large number of new (mainly gas-fired) projects that are being developed now. The evidence is that the market will deliver new investment when required – but that it may not be the right kind of investment (i.e. it may not be low carbon enough) without further government intervention. By contrast, the debate has neglected those threats due to underinvestment that have had material impacts on security and have had an economic impact through price rises. These include the Rough storage facility fire in early 2006 and the more recent disruption to the CATS gas pipeline. Both incidents led to abrupt price increases and there is case for arguing that there is a lack of redundancy in the UK's gas pipeline networks and storage facilities.

Technology or infrastructure failure. This includes technical failures of infrastructure and failures due to the impacts of extreme weather, some of which may be attributed to

[1] This research is being conducted by Alister Scott and Jim Watson on the re-emergence of nuclear power. A full working paper that elaborates our analysis of the energy security implications of new nuclear build will be available on the Sussex Energy Group website shortly (see www.sussex.ac.uk/sussexenergygroup).

climate change. Technical failures are a feature of all large infrastructure systems and are usually absorbed due to redundancy. But if they become widespread 'class failures' in a prominent part of the system infrastructure, the consequences can be more serious. Class failures in the UK have affected the gas-fired power plants that have been built in the last 15 years. However, large capacity margins have meant that the effects could be managed even when these failures coincided with the winter demand peak – but only just. Examples of weather impacts include the underperformance of France's nuclear power plants in summer 2003 due to intense heat. These plants were unable to operate at their design capacity due to a lack of cooling water – this was a contributing factor in the blackout that affected a large part of continental Europe at that time. Other examples include the threat to a key substation in the recent floods in the west of England and more importantly, the effect of hurricanes such as Katrina on offshore oil and gas facilities in the Gulf of Mexico.

Domestic activism or terrorism. This includes the possibility that terrorist groups will sabotage key parts of energy infrastructure such as pipelines and power plants. It also covers blockades or strikes due to industrial disputes or civil disobedience. Threats of this kind – particularly non-terrorist ones – are often underplayed. Yet in the last quarter of a century, some of the most important threats to UK energy security have taken this form. The miners' strike of 1984/85 caused the electricity industry serious difficulties in maintaining supplies from coal fired power stations. Similarly the fuel protests of 2001 disrupted the distribution of petrol to consumers and exposed the vulnerability of distribution systems to targeted blockades of just a few key depots.

Given this range of threats, our view is that the government has put forward a partial analysis of energy security in the consultation document. The document emphasises those dimensions of that have had less material impact on UK energy security in recent years (i.e. lack of generation capacity and energy imports) whilst downplaying or omitting those dimensions that have had real impacts on prices and/or availability (i.e. domestic disputes and underinvestment in onshore gas networks and storage). Although the pattern of future threats may differ from those of the immediate past, the case for a fuller analysis still stands.

Can nuclear strengthen security?

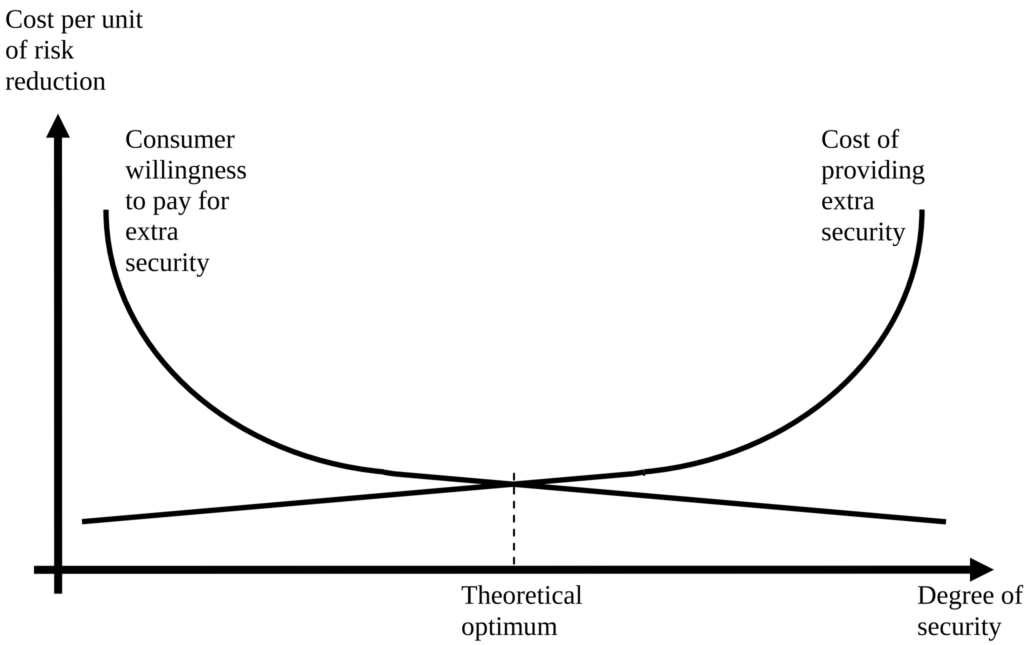
Putting this concern to one side, the key question still remains: can a new series of nuclear power plants address the security threats that the UK is likely to face in the coming decades? Before analysing this with respect to the four categories of security threat summarised above, it is useful to comment on two framing issues that are raised in the consultation document. First, it is important to understand the key features of diversity, a strategy that is often put forward as a way of strengthening energy security. Second, it is useful to look a little more closely at the economics of energy security.

Diversity. Whilst proponents of particular energy options often claim that their option will increase diversity, it is sometimes forgotten that diversity is a system property. In other words, certain options could strengthen diversity, but the extent to which this is the case depends on what other options are deployed. Diversity has several dimensions that can help to strengthen energy security. These include diverse routes for imported fuels (e.g. oil and gas) and diverse sources of energy (e.g. solar and biomass heating as well as gas heating in homes). But diversity is about more than just having a lot of different options in an energy system. For example, our colleague Andrew Stirling has identified three sub-properties of diversity: variety, balance and disparity (Stirling 1998). Variety is a simple measure of the number of different options that are deployed in an overall energy portfolio. Balance refers to the profile of shares of these different options within a portfolio. For example, an electricity system in which one option accounts for 60% of annual output and four further options account for 10% each would be less diverse than a portfolio of five options that generate 20% of annual electricity each. Finally, disparity captures the extent to which options are different from each other. A portfolio that includes ten different lower carbon coal technologies is likely to be less diverse than a portfolio that encompasses ten renewable energy technologies. This is because the 'renewable energy' category includes many more disparate options.

Another important caveat for strategies of diversity is that constituent technologies within an energy system will not be deployed in isolation from each other. Technological options are developed and deployed within a common energy system and therefore, some interaction between options is to be expected. The phenomenon of technological 'lock-in' (Unruh 2000) is important here too. Technologies that do not fundamentally challenge the technical and institutional architecture of the current energy system may be easier to develop and deploy – and may dominate a portfolio if the implications are not thought through.

Economics. As Figure 1 shows, there different degrees of energy security have different implications for the costs of providing that security. Up to a certain point, consumers are willing to pay a significant amount for each improvement in the level of security. However, as security improves, the willingness to pay for further improvements tails off. At the same time, the costs of providing an ever greater level of security rises as the standard required is increased. There will be a point at which the incremental cost of improving security further will be higher that the consumers' willingness to pay. In short, this means that it is prohibitively expensive to provide absolute security – and that the potential costs of different security strategies need to be evaluated *alongside* the extent to which they are likely to reduce security threats or risks. The economics of nuclear power are explored more fully in our response to question 4 of this consultation.

Figure 1. Trade offs in energy security



Source: (NERA 2002)

With these two framing issues in mind, an initial assessment of the likely impact of a new programme of nuclear power stations on UK energy security can be made:

Fossil fuel scarcity & external disruptions. The extent to which nuclear power can mitigate threats due to scarcity and external disruptions depends first on whether there is evidence for impending fossil fuel scarcity. At present, it is not possible to verify the claims of those that predict limits to availability (e.g. due to ‘peak oil’). It is however important to observe that there are many skeptics of the ‘peak oil’ argument and that a significant amount of the ‘peak oil’ literature is not peer reviewed. Whilst the supply of fossil fuels is clearly not infinite, we believe that environmental limits due to climate change will be more important than peak oil in curbing fossil fuel use. What may be more important in this context is the impact on new nuclear on the UK economy’s exposure to the economic effects of fossil fuel price volatility. A substantial programme would help to some extent - though it must be borne in mind that many other options (i.e. renewables and demand reduction) can also help here.

The usefulness of nuclear power as an option to reduce these threats also depends on the counter-factual scenario – i.e. would the alternative investments to new nuclear power be more likely to expose the UK to these largely external threats. As this submission has already argued, the most likely investment option large scale power generation is gas. In addition, there are also a significant number of plans for new coal plants and renewables will also continue to expand due to the Renewables Obligation. Furthermore, a more serious programme of energy demand reduction through routes such as the new Supplier Obligation could reduce the overall need for new sources of supply.

One of the key arguments that is made by Ministers (including the former Prime Minister) is that new nuclear will lessen UK dependence on imports, specifically imports of Russian gas[2]. However, projections by Oxera for the 2007 Energy White Paper show that the UK's gas supplies will in fact be sourced from a variety of locations and through a range of transit routes (Oxera 2007). In the period in 2020 this includes some continuation of supplies from the UK continental shelf, piped gas from Norway, LNG imports from countries such as Qatar and supplies from continental Europe via interconnectors. Only the last of these includes Russian gas. It could be argued therefore that gas supplies could get more secure (not less) since supply origins and routes will get more diverse. Furthermore, we believe that the narrative of a 'Russian gas threat' is also oversold because much of the UK's gas is not used for power generation at all. This sector accounts for around 30% of UK gas demand[3]. The rest is used for industrial processes and domestic heating. Therefore the argument that nuclear can significantly replace gas does not stand up to scrutiny unless the intention is to support a much larger nuclear fleet than we have now which would replace gas fired power *and* generate electricity for home heating, industry and so on. This 'replace and expand' strategy may have some supporters, but is has not been discussed as much as a pure 'replacement' strategy. It would be more likely to have implications for other dimensions of security.

Lack of domestic investment in infrastructure. In principle, the construction of new nuclear power stations could help to replace the power generation capacity that is due to retire over the next two decades. However, due to long lead times, nuclear power would be one of the slowest ways to bring new capacity on line. The 2007 Energy White Paper clearly illustrates this with an expectation that only one nuclear plant (at most) is likely to be operational by 2020. By contrast, gas-fired capacity, many renewable electricity sources and demand reduction measures can be implemented more quickly. In addition to this, plans for the implementation of demonstration plants with carbon capture and storage (CCS) foresee a shorter timescale for operation than is the case for nuclear power. For this option, there are of course significant technical and economic risks which mean that it would be unwise to rely on plants with CCS to perform at normal commercial levels of reliability for some time.

In theory, nuclear power could also reduce the need for gas infrastructure reinforcement if it were deployed under a 'replace and expand' scenario over the medium to long term. However, it is unlikely that even this level of investment would negate the need for some measures to ensure that gas infrastructure – particularly for storage – is more adequate than it is now. Furthermore, even if gas use were reduced significantly in the longer term, similar issues of redundancy and storage capacity would arise with respect to electricity networks or perhaps (in the very long term) hydrogen networks for both stationary and transport end users.

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[2] Prime Minister Tony Blair, Speech to the CBI Annual Dinner, 16th May 2006.
[3] See DBERR statistics on 'Supply and Consumption of Natural Gas and Colliery Methane' at http://www.dti.gov.uk/energy/statistics/source/gas/page18525.html

Technology or infrastructure failure. The reliability of nuclear power plants has improved in many countries in recent years. Availability figures are now comparable with those of fossil fuel power generation technologies. Safety concerns have also receded now that time has passed since the Chernobyl accident. The presence of a diverse mix of technologies in an electricity system that have a high level of technological disparity is a good way of guarding against generic failures in one or more technologies. Therefore, if new nuclear were to simply replace existing capacity, the threat to security from a generic failure would be lower than if a 'replace and expand' strategy were followed. The experience of France in summer 2003 shows that an electricity system dominated by nuclear technology can be vulnerable to technical underperformance and a consequent inability to meet demand. But this could also be true of fossil fuel plants – whether powered by coal or gas – and renewable technologies too.

There are three caveats to this relatively positive assessment. First the new plants that would be built in the UK use new reactor designs that bring with them a higher risk of underperformance and failure than more established designs. Second, whilst nuclear safety has improved, a nuclear accident would have very serious and far reaching consequences which are more serious than those from failures of all other energy technologies. The risk of such accidents cannot therefore be ignored. Third, a programme of new nuclear plants cannot guard against non-electricity infrastructure failures such as the impact of extreme weather on offshore oil installations. Again, the picture could be different if a 'replace and expand' strategy were followed in which nuclear-generated electricity or hydrogen made a significant impact on the transport sector. But this would then increase security risks from generic technical failures.

A further issue is worth briefly mentioning within this category of risk. The threat to electricity security is not only due to a lack of timely investment, but is also due to operational risks that could prevent the electricity system from supplying consumers at a given point in time. Analysis we conducted with colleagues from the Tyndall Centre for Climate Change Research illustrates this point. This research tested the four original scenarios for a 60% reduction in UK carbon emissions developed by the Royal Commission on Environmental Pollution in 2000. Two of these scenarios included nuclear power (or fossil with carbon capture) and the other two did not. A security analysis of all scenarios for a typical year showed that those without nuclear power were able to balance supply and demand for more half hourly periods than those with a nuclear power (Watson et al. 2004).

Domestic activism or terrorism. Nuclear power plants have been discussed as potential terrorist targets – as have other parts of energy infrastructure such as gas pipelines and LNG terminals. Such risks need to be taken seriously. The potential consequences of an attack on a nuclear plant are more serious than attacks on other forms of infrastructure. To some extent, resistance to such attacks can be incorporated into reactor designs but, as with energy security more generally, there is a trade off between reducing risk and increasing cost.

Historically speaking, nuclear power has been less vulnerable to industrial disputes than coal. There is no equivalent within the nuclear industry to the disputes between government and the mineworkers union. However, this does not mean that nuclear is immune to civil disruption. In the future, there could be industrial disputes or campaigns by activists that are similar to those that disrupted 'nuclear trains' in Germany a few years ago. Furthermore, a programme of new nuclear power plants cannot directly reduce the vulnerability of other fuel distribution infrastructure to such disruptions. Again, it might be possible for nuclear power to do so but only in the very long term under a 'replace and expand' scenario that is rarely discussed with any level of seriousness.

Conclusion

Overall, this brief analysis shows that a new nuclear power programme may be able to help reduce some specific energy security risks. These include some impact on the share of fossil fuels in the UK energy mix, thereby reducing the exposure of the UK economy to rapid increases in fossil fuel prices. They also include a contribution to technological disparity in an electricity system in which nuclear power retains a modest share alongside a wide range of other options. The impact on these risks (and many others) would be modest under a pure 'replacement' scenario for new nuclear. A more ambitious 'replace and expand' programme of investment could reduce some risks further, but such a programme could also exacerbate other risks.

We are not convinced that there is a strong security case for new nuclear, especially if the costs and risks of strategies that include new nuclear are considered alongside those of strategies that do not. A systematic analysis of these has not been carried out by government to support its case. Instead, there has been a partial analysis of some risks but a neglect of others. The evidence shows that nuclear power may *not* be able to mitigate some of these neglected risks such as domestic threats due to terrorism and civil unrest, and underinvestment in infrastructure. Within the risks that are mentioned in the consultation document, there has been a particular focus on the expectation that the UK will import significant quantities of natural gas. This has been cited as a particular 'security problem' but without a clear rationale. The evidence so far is that the diversity of sources and supply routes for natural gas are expected to *increase* over the next decade. Furthermore, the argument that new nuclear power can solve this 'problem' does not stand up to scrutiny.

Q4. Do you agree or disagree with the Government's views on the economics of new nuclear power stations? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

The Government's position on the economics of new nuclear power, stated in the consultation document, is as follows:

> *'Based on this conservative analysis of the economics of nuclear power, the Government believes that nuclear power stations would yield economic benefits to the UK…'* (*Consultation Document*, p. 74)

We are of the view that this is not a robust conclusion: it does not properly acknowledge the uncertainty that inevitably attaches to the introduction into the UK of technology that is both novel and politically contentious. This means that the presentation of the 'economics' of nuclear power (summarised in Table 4.4 on page 73-74 of the consultation) does not fairly represent the uncertainties.

The centrepiece of the Government's economic case is a 'cost-benefit analysis' of the net welfare balance of nuclear generation using a central set of assumptions and then sensitivities in relation to gas prices, nuclear construction costs and the price of carbon. This yields a matrix of 25 cells, 17 of which show a net welfare gain and eight of which show a net welfare loss. This section of our response considers:

- the realism of the construction cost analysis
- the assumptions and framework used in advancing future carbon prices
- some methodological issues in the 'net welfare' calculation

Construction costs

Easily the most important single element in the overall economics of nuclear power is the construction (capital) cost, accounting for well over half of total generating cost. Government has tried to introduce conservatism into its capital cost estimate for nuclear power by setting its central estimate at a level it regards as conservative (higher than some international estimates) and then by conducting sensitivity tests of both lower and higher capital costs.

The historic capital cost record of nuclear power in the UK is dire, but any future practice will almost inevitably provide improvements on this record. There are several reasons for this: big project management techniques have improved over the last 25 years in the UK; the prospect of genuine international tendering should restrain cost growth; and a firm or consortium taking on nuclear projects would offer something closer to a turnkey contract than the cost-plus contracts that previously were the norm.

But none of this means that capital costs of new reactors can be predicted with anything like a high degree of certainty. There are three main reasons for this:

- the novelty of the reactor designs that might be used in the UK;
- the issues surrounding standardised designs and 'programme' build; and
- the political and regulatory risks that attach to new designs.

In all these cases the resulting uncertainties are such as to skew the distribution of possible costs towards the 'upper tail' of the distribution – the chances of cost overruns are much higher than of cost savings.

Novelty

All the reactor designs currently offered by vendors represent significant technological change compared to reactors currently in operation. The one exception to this is provided by variants of the BWR design that have been constructed in East Asia. But it is widely and realistically observed that the reactor designs that are likely to win the support of firms/consortia that will make proposals in the UK are probably restricted to the EPR (a European design from Areva) and the AP 1000 (a Westinghouse design now owned by Toshiba). In neither case has any reactor yet been completed: in the EPR case the first, in Finland, is two years into construction; in the AP-1000 case, none have yet been started. This represents a high level of technologically-derived risk to capital cost estimates.

The EPR is the most conservative of the designs currently being offered. It is explicitly marketed in terms of its similarity to the N1400 series of reactors built in France: differing mainly in extended scale (potentially up to around 1750MW) and with relatively small improvements in safety characteristics and performance. Yet the first example in Finland is now running two years late with only two years construction completed, and its capital cost has already escalated (according to recent reports in *Nucleonics Week* 2007) by some 25%. The sensitivity test for 'high nuclear cost' in Table 4 in the consultation document is a 30% increase on the central estimate - a figure that looks modest in relation to Finnish experience even over the first two years of construction.

Programmes and economies of scale

The nuclear industry has argued for some time that it is only possible to achieve acceptably low cost in nuclear construction if a series of identical reactors is built as part of a programme. The number of identical reactors needed to reap these learning economies of replication is usually suggested to be around eight. Experience in Korea suggests that the savings by the time of an eighth unit may be as high as 30% compared to the cost of the first unit. But the corollary is that a very small number of reactors will have relatively high costs.

In the UK the Conservative Government which came to power in 1979 proposed a programme of 10 reactors, later reduced to four, and eventually ending up with just one (built at very high cost) – Sizewell B. Conditions then were relatively favourable to a programme, in the shape of a centralised state utility (the CEGB) able to finance a large programme and pass any excess costs on to consumers. Conditions now, in a liberalised and more fragmented market, are much less favourable to large, lumpy, 'programme' investment and this must substantially increase the risk that only a limited number of reactors will be built – significantly raising costs, even if all other factors were conducive to cost control.

Nor is it very plausible that a wider European 'programme' of identical reactor build would enable more than a small fraction of replication economies to be gained. There is a variety of reasons for this, but mainly that the existence of national safety regulatory systems almost certainly will mean that a nominally identical reactor built in more than one country will develop unique features in each country, substantially mitigating the economies of replication. It is already the case, for example, that different regulatory systems mean that the EPR under construction in Finland is significantly different in design from the Flamanville EPR about to start construction in France.

Political and regulatory risk
Risks here are in some ways connected to those analysed immediately above. There has been little progress towards common regulatory practice even among EU countries. Nation states strongly guard their right to exercise local and unique powers over the exact design of reactors. They are under strong public pressure to be able to claim that the precise design of a reactor within their own jurisdiction is as safe as or safer than those approved elsewhere. The regulatory requirements that flow from these pressures are unpredictable in advance and can add, sometimes substantially, to capital costs.

In addition, the processes of planning approval can also add to time and cost, especially where there is significant local or wider public opposition to plant construction. Again, these sources of risk suggest that the capital cost profile of nuclear costs are heavily skewed towards risks of cost overruns.

This brief analysis suggests that although Government has attempted to introduce conservatism into its capital cost estimates, it has not fully succeeded. The risks of the high nuclear construction cost case are substantially greater than hopes for a low construction cost case, and a 30% excess seems a modest sensitivity in relation to the risks described.

Carbon prices
One of the determinants of the net nuclear welfare balance is the carbon price. The government tests the effects of five different possible carbon prices, ranging from zero to 36 Euros/tonne of carbon dioxide. These various prices are meant to reflect different levels of stringency in the carbon trading market, which is implicitly assumed to be dominated by the EU Emissions Trading Scheme. At higher carbon prices the net welfare benefit of nuclear power is significantly higher than at a zero price. For the central gas price and nuclear construction costs case, a 36 Euro price increases the net welfare benefit from a virtual 'breakeven' value of £40m/GW to £1500m/GW.

However this raises a major problem with the Government's analysis. If the assumption is made that future carbon prices will continue to be determined by the operation of the EU ETS without any floor price for carbon, businesses are likely to give little or any credit for a positive carbon price in calculating the potential profitability of nuclear investment. But this raises the problem of what exactly the ‘net welfare balance’ analysis means.

Methodology of the net welfare balance calculation

In the kind of discounted cash flow (cost-benefit) analysis Government has used to calculate ‘net welfare balances’ there are two obvious approaches. One is to value all variables as private investors will experience them. This would be a ‘private’ cost-benefit analysis, and much attention would be given to risk. Alternatively Government could conduct a ‘social’ cost-benefit analysis in which an attempt would be made to value all variables at their ‘real resource’ values, accounting for all externalities – real costs or benefits which the current structure of markets will not take into account.

The Government’s description of its analysis (in its ‘Nuclear Power Generation Cost Benefit Analysis’) is to claim that it is

> ‘economic rather than financial, and covers the range of costs and benefits’
> (DTI 2007, p.2)

But in practice the analysis underlying the Table in the consultation referred to above is a hybrid of the two, though in practice much closer to a private financial than an ‘economic’ analysis. The Government argues that an external benefit of nuclear (i.e not appropriable by investors in nuclear power) is avoidance of investment worth £100m/GW that alternative gas-fired plants would need to spend on backup oil distillate capacity. It argues that this is the quantifiable security of supply benefit of nuclear power, but it is not made clear whether this sum is included within the net welfare benefit calculation.

Elsewhere the calculations appear to be of a private-market-based character, with the exception that there is no explicit consideration of risk – for example in the carbon price. The cost of capital is assumed to be 10% (real post tax). This is a rate avowedly taken from ‘industry’, and much higher than the rates that the Treasury Green Book would suggest. The carbon prices appear to be based on probable EU ETS market outcomes rather than estimates of the social cost of carbon, though as remarked earlier, business would – for risk reasons – almost certainly not factor any positive carbon price into its calculations. And while some external costs of nuclear are discussed briefly (para. 4.29 pp. 65-66) they are ‘not usually considered as costs’ on the grounds either that they are too improbable (accident risk) or too difficult to calculate (proliferation risk).

In the end therefore the net welfare balance can neither tell us what incentives face business (a private CBA) or what the national resource balance would be (an economic CBA). So the status of the eight negative and 17 positive welfare balance calculations is unclear. It does not justify the strong statement from Government quoted at the head of this section. More realistic is the statement in the accompanying more detailed cost-benefit analysis that (p.3)

> *‘The analysis highlights considerable uncertainty surrounding the economic appraisal’*

In other words the simple answer to the question ‘what are the economics of nuclear power’ is: we don’t know.

Q5. Do you agree or disagree with the Government's views on the value of having nuclear power as an option? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

The answer to the question of the 'value' of having nuclear power as an option depends on a wide range of factors, including the costs of alternative low-carbon options, as well as the costs of nuclear power itself. We argued above in response to question 4 that the stand-alone costs of nuclear are a matter of deep uncertainty and if they turn out higher than Government currently assumes the value of the nuclear option necessarily declines.

But the value of nuclear power as an option is a systemic question, and depends on the development of other policies and technologies, as well as a wide range of actions in other countries. The problem in the modelling work supporting Government's view on this subject is that it appears to assume that developments elsewhere in the energy business would be unaffected by a UK decision to disallow nuclear new build. This would be especially serious in the case that there was a widespread international nuclear moratorium. In such a case efforts to develop other low-carbon sources would almost certainly intensify and lead to lower non-nuclear low-carbon costs than would otherwise be the case. Such uncertainties about the future mean that it is very difficult to say whether or not the option of nuclear power has positive value or not from a wider, systemic perspective.

Q6. Do you agree or disagree with the Government's views on the safety, security, health and non-proliferation issues? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

We take no view, lacking relevant competence, on safety and health issues associated with the development of nuclear power. While having some competence in the areas of security and non-proliferation we find it hard to comment on Government's views in this area, as we are necessarily – given the sensitivity of the subject-matter – unable to have access to the kind of information that would allow Government's view to be properly scrutinised. But it is worth noting that Government's own confidence in the limited nature of the risks in these areas and their sensible management depends heavily on the advice they receive from the relevant regulators, whose job is to ensure those risks are acceptably small. Much more confidence could be placed in such assurances if Government were able to acquire some competent but institutionally independent advice.

Q7. Do you agree or disagree with the Government's views on the transport of nuclear materials? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

We take no view, lacking relevant competence, on this question.

Question 8, 9 and 10 – combined answer

Q8. Do you agree or disagree with the Government's views on waste and decommissioning? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?
Q9. What are the implications for the management of existing nuclear waste of taking a decision to allow energy companies to build new nuclear power stations?
Q10. What do you think are the ethical considerations related to a decision to allow new nuclear power stations to be built? And how should these be balanced against the need to address climate change?

Our views on this question largely echo those of the Committee on Radioactive Waste Management. The case for treating geological disposal as the desirable end-point for legacy wastes is strong, though implementation will inevitably take several decades and require a genuine willingness to participate on the part of any host community.

The issue of radioactive waste from new build is politically, socially and ethically distinct from the technical questions of how it should be managed. There are, as Government suggests, important ethical issues at stake: the deliberate decision to create new wastes has potentially harmful consequences for thousands of years, and therefore sharply raises questions of inter-generational equity. But a full ethical consideration needs to consider the inter-generational consequences of *not* creating new radioactive wastes, and here much depends on what view is taken of the economic, climate change and security benefits of further nuclear construction. The balance of the ethical argument may rest on judgments or empirical forecasts of the expected safety of geological disposal of wastes versus the economic, environmental and security consequences of not going ahead with nuclear power.

We strongly welcome Government's introduction of such ethical issues into the nuclear debate and believe the issues raised need much more public airing, as they are both important and new to the debate. It seems extremely unlikely that they can have been adequately deliberated on in the current round of consultation. If, after such deliberation, the balance of ethical argument is in favour of allowing new nuclear construction to go ahead, there is no doubt that it would be desirable to locate new wastes alongside legacy wastes, both in storage and geological disposal, though the prospects of uncertain future quantities of wastes arriving at a repository site would make the issue of negotiating an agreement with a willing community much more difficult than if only a finite quantity of legacy wastes were to be involved.

Q11. Do you agree or disagree with the Government's views on environmental issues? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

The environmental impacts of nuclear power stations are clearly distinct from other forms of power station as the spent fuel has implications for thousands of years to come and is subject to higher degrees of uncertainty than the by-products of other forms of power generation. It is for this reason that proposals for new nuclear power stations need to be subject to more extensive and wide ranging public consultation than other forms of power station. Standard environmental impact assessments are unlikely to be sufficient to facilitate the required breadth of public consultation needed to consider the environmental impacts of new nuclear power stations.

At a more technical level, the fact that nuclear power stations have to be sited near large sources of water raises specific environmental concerns relating to the impacts of future climate change. Sea level rise and increased incidences of flooding both pose challenging implications for the safety of nuclear power stations.

Q12. Do you agree or disagree with the Government's views on the supply of nuclear fuel? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

We agree that there will be sufficient high-grade uranium resources available for many decades to come. Due partly to earlier military constraints, an unattractively low uranium price, and the deliberate leakage of ex-military uranium onto world markets, there has been much less world-wide exploration for uranium than for fossil fuels. Substantial exploration and development are now under way and uranium supply is unlikely to be problematic on physical grounds for a long time to come.

Q13. Do you agree or disagree with the Government's views on the supply chain and skills capacity? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

There are undoubtedly potential short-term problems in skills supply, as the nuclear industry has been an unattractive career choice for some time, and many skilled people are now close to retirement. However it seems likely that the international supply chain and domestic skills upgrading efforts would be able to manage such problems.

Q14. Do you agree or disagree with the Government's views on reprocessing? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

We strongly agree with Government's view that any future nuclear development should be based on an explicit rejection of spent fuel reprocessing. The history of reprocessing has been little short of disastrous in the UK from economic, technological and wider safety and proliferation perspectives. The original premise justifying reprocessing - the need for plutonium fuel in fast breeder reactors, as uranium would rapidly become scarce and expensive - has plainly proved to be false. As a result much expense, technological effort and enhanced risk have resulted from producing a main output (plutonium), for which there are no economic uses. There is no sign, given the plentiful availability of uranium (see Question 12 above) that this situation will change for a long time.

Meanwhile reprocessing is very expensive and its ancillary activities of waste vitrification and mixed oxide fuel production have worked badly. Reprocessing creates large increases in the volumes of intermediate level waste to manage. Plutonium itself is exceptionally radiotoxic and raises major proliferation risks. It has aroused understandable public opposition from a wide variety of sources.

Any commitment to reprocessing in any nuclear new build would therefore be wholly mistaken. Abandonment of reprocessing is probably an essential political condition if nuclear power were to become a future option for the UK.

Q15. Are there any other issues or information that you believe need to be considered before taking a decision on giving energy companies the option of investing in nuclear power stations? And why?

There are two additional issues that we have identified which require consideration before taking a decision on giving energy companies the option of investing in nuclear power stations. Firstly, demand reduction and energy efficiency needs to be properly compared against supply based decisions, including building new nuclear power stations. Secondly, extensive and legitimate public consultation needs to be undertaken. As outlined below, we do not believe that this consultation satisfies this need.

Demand reduction and energy efficiency

The International Energy Agency predicts that with a business-as-usual scenario, global energy demand will increase by an average of 1.6% per year by 2030, with over 70% of the predicted demand increase coming from developing countries (IEA 2006). However, the IEA's Alternative Policy Scenario suggests that more efficient energy production and energy efficiency would contribute almost 80% of avoided CO_2 emissions, compared to 20% from switching to low- and zero-carbon fuels such as nuclear power. The Government acknowledges that to reduce emissions, action is required on both supply and demand, though this consultation clearly concentrates on supply. Demand reduction and energy efficiency are equally important as choosing zero or low-carbon electricity generation technologies in order for the UK to achieve emissions reductions. By framing this consultation as if nuclear is the only consideration when responding to the problems of climate change and security of supply, this consultation fails to consider the most fundamental issue in terms of responding to these problems, namely reducing demand for electricity in the first place.

Domestic buildings produce around 28% of the UK's CO2 emissions, and if householders' transport use is taken into account, that figure rises to around 50%. Both sectors need increased regulatory and policy support in order to achieve emissions reductions. There have for instance been calls for the Carbon Emissions Reduction Target to be extended to non-domestic consumers, including the public, commercial and industrial sectors (Toke 2007). In the case of domestic buildings much more effort is required by the Government to ensure that Building Regulations are tightened for new-build houses and followed up by appropriate enforcement, while emissions from existing housing stock need to be tackled too. The use of increased energy efficiency measures such as insulation can also help tackle fuel poverty and increase the general quality of housing stock (Kelly 2006).

Much has been said by policy makers about behavioural change in recent months, an area which clearly requires further research to establish how and to what extent behavioural change measures can help reduce emissions from households. Early indications suggest that measures such as better billing and feedback can make people more aware of their energy use and reduce consumption by up to 15% (Darby 2006). The Government is already undertaking work in this area by running large-scale trials of technologies such as smart meters and electronic displays (some of which the Sussex Energy Group is involved in), while European legislation requires further action on the use of energy efficiency measures and energy services[4].

However, to suggest that people will indefinitely go on increasing their use of heating and buying more appliances is simplistic and does not take into account developments, for instance in appliances' energy efficiency or the potential for people to change their domestic energy using behaviours. It is true that our consumption is increasing, but it is also changing and people are becoming much more aware of the environmental impacts of the goods and services they buy. According to the Co-operative Bank, spending on 'green homes' for instance increased from £493 million in 1999 to £4,149 million in 2005 (Co-op 2006). There is clearly a market in the UK for products and services which are based on positive environmental impacts and people are increasingly willing to 'do the right thing' given the right regulatory and policy support.

[4] DIRECTIVE 2006/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC

The legitimacy of this consultation

Due to the fact that building new nuclear power stations has implications that are both uncertain and relevant to future generations for thousands of years to come, it is vital that any decision to build new nuclear power stations be based upon extensive and legitimate public consultation. The procedure followed during this consultation and the political rhetoric that has accompanied it has fundamental implications for the legitimacy of both the consultation itself and any decisions subsequently taken on the basis of its results.

Members of SEG were amongst the authors of a letter published in *Nature* in March 2006 (Tansey et al. 2006) arguing that the UK government's consultation around building a new generation of nuclear power stations was flawed and, as a result, would render the review illegitimate. This letter was later used as evidence in the successful legal action prosecuted by Greenpeace, which resulted in the need for the current consultation.

Unfortunately, the current consultation is arguably subject to similar problems to those that rendered the original consultation illegitimate.

There are two key problems with the current consultation. First, the options under consideration have already been strongly constrained by picking nuclear power out for special consideration. This is reinforced by the fact that the government is simultaneously consulting on fast-track approaches to approving applications to build new nuclear plants and facilitating their siting. It seems superfluous to undertake the general consultation about whether to approve the building of new nuclear power stations if detailed work is already being undertaken on how to facilitate their rapid construction. What is more, the general thrust of the proposed changes to the planning process – to slim down and speed up inquiries – further threatens to reduce the opportunities for public input and debate.

Second, since the launch of the new consultation, the then Prime Minister Tony Blair stated on several occasions that it will have no effect on the government's previous decision to support new nuclear. In his words, the new consultation process "… won't affect the policy at all" (Guardian 2007). Gordon Brown repeated this position within two weeks of coming into office. This contradicts the opening statement to the government's code of best practice on consultation, which states: "Effective consultation is a key part of the policy-making process. People's views can help shape policy developments and set the agenda for better public services" (Cabinet Office 2007).

These statements reproduce one of the problems we highlighted with the previous consultation: announcing or presuming the results of a consultation before, or during, the process seriously undermines its legitimacy. The implication is that consultation is viewed as a legal and procedural necessity rather than a serious input into decisions that will have implications for thousands of years.

On the basis of the above problems we have serious misgivings about the legitimacy of this consultation process.

Q16. In the context of tackling climate change and ensuring energy security, do you agree or disagree that it would be in the public interest to give energy companies the option of investing in new nuclear power stations?

As there is currently nothing in law to prevent energy companies from investing in new nuclear power stations, we are assuming that this question implies that the government currently adopts an unofficial position of not granting consent to the building of new nuclear power stations under Section 36 of the Electricity Act 1989. On this basis, any decision to reverse this position must fulfil the following criteria:

Firstly, it must be subject to extensive and legitimate public consultation. As our comment in response to the previous question outlined, there are significant problems with this current consultation that threaten its legitimacy.

Secondly, any contribution of nuclear power to security of supply relies on the concept of ‘security of supply’ being properly understood. As we explained in our response to Question 3, once energy security is properly understood it is not clear that building new nuclear power stations would contribute to improving energy security in the UK.

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