Chapter Eleven

CAN A LOW CARBON FUTURE EXIST WITHOUT NUCLEAR POWER?[1]

There is a growing realisation that climate change is a phenomenon with the potential to change the way we live. The Royal Commission on Environmental Pollution[2] brought the issue into stark focus by declaring that emissions would have to go well beyond the Kyoto targets to have any beneficial impact. Indeed the Commission called for a 60% reduction of carbon dioxide (CO_2) emissions by 2050, and possibly 80% by 2100, to stabilise its atmospheric concentration to 550 parts per million, or roughly twice what they were in the immediate pre-industrial period. From an environmental standpoint it is disappointing that 550 ppm is being presented as acceptable because at these atmospheric CO_2 levels global temperatures are projected to rise well beyond those seen over the last thousand years.

There is little doubt that to achieve stabilisation will require a major transition in the way we produce and use energy in the future. But as the Royal Commission recognised in their report, there are a number of ways to reach such targets and these are dependent on a number of interactive factors in the energy system. It is important to address all these factors in order to address the role of nuclear power in a low carbon future. This paper will focus attention on the UK situation in the belief that many of the messages are equally applicable to Europe and beyond.

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[1] Chris Anastasi, Senior Environmental Advisor, British Energy plc

[2] Royal Commission on Environmental Pollution, Energy – The Changing Climate Twenty-second Report, (HMSO, London, June 2000).

Drivers that shape the nuclear option

Many of the drivers that shape the nuclear option in Figure 1 are ones that shape all technologies such as the current status of the industry, the market, security-of-supply, technology developments, and of course the environment with climate change particularly important. But there are some drivers, such as safety, waste, proliferation and public attitudes that are particularly important for the nuclear industry.

Figure 1 - Drivers that shape the nuclear option

This paper will concentrate on those drivers in which there have been some significant developments over the last few years. But it will also highlight some observations on the other drivers so that there is a sufficient overview to assess whether a low carbon future can exist without nuclear power.

Current status of the nuclear power sector

The nuclear power sector in the UK is at a very interesting stage in its development. There are 12 power stations currently operating: four utilising the Magnox technology, seven Advanced Gas cooled Reactors (AGRs), and a single Pressurised Water Reactor (PWR). Collectively, these power stations generated almost 82TWh in 2003 or 21.5% of the UK's electricity demand. This is a major industry which having taken almost half a century to reach its maximum, is due to undergo a 'cliff-edge' decline over the next decade or so, as shown in Figure 2.

Figure 2 – UK nuclear power capacity

It is possible to life extend the more modern AGR power stations, albeit for 5 years in the first instance, but it will depend on a technical case being made and the prevailing economic environment. It makes sense not only for the operating company but also the UK economy to use these assets for as long as possible.

But life extensions will only delay an inevitable decline in the nuclear contribution to the generation mix in the absence of any new initiatives. By 2010 the last Magnox

power station at Wylfa would have closed. By 2015, the nuclear fleet may well consist of just three plants: the AGRs at Heysham and Torness and the PWR at Sizewell. In 2023 the UK will be left with just one nuclear power station. This rapid decline has major implications for the environment, market, and security-of-supply.

Climate change and other environmental benefits of nuclear

Nuclear power stations were built to deliver large quantities of baseload electricity - not to address climate change or other environmental issues since these were not as prominent in the early development of the industry. Nonetheless, nuclear generation is also emissions free i.e. it does not emit greenhouse gases in general, and carbon dioxide in particular, nor does it emit sulphur and nitrogen oxides, key components of photochemical air pollution, or ash, all produced by fossil generation.

In fact the country's 12 nuclear power stations ***avoided*** the emission of over 46 million tonnes carbon dioxide in 2003/04, because in the absence of nuclear the prevailing fossil fuel mix, with their associated emissions, would have been needed to produce this electricity. To put this into context, it would be necessary to remove almost three-quarters of the cars from UK roads to get the same carbon dioxide savings as that delivered by the nuclear power sector.

Overall, these plants have ***avoided*** the emission of about 1550 million tonnes of carbon dioxide since they stations started operating, a saving equivalent to all the emissions from the UK's generation sector over the last ten years. This is a major contribution to the country's climate change mitigation effort.

The UK like many other countries is committed to reducing its greenhouse gas emissions on the benchmark year 1990 i.e. 12.5% reduction by the Kyoto period 2008-12, of which 6-8% is carbon dioxide. The UK Government has consistently taken a leadership role in the climate change debate and has signaled its intent by *voluntarily* seeking a 20% reduction in carbon dioxide emissions by 2010. It has also responded positively to the Royal Commission's Report with a series of milestones leading to a 60% reduction by 2050.

The power sector has seen a steady decline in CO_2 emissions over the last 15 years, brought about by a switch from coal to gas in the power sector, and new plant and productivity gains in the nuclear power industry. Because of these developments, and the expected benefits of its Climate Change Programme, the UK will meet its Kyoto target as shown in Figure 3 (irrespective of whether the carbon component of this 12.5% reduction target is 6% or 8%).

Figure 3 – Meeting UK carbon dioxide targets

However, the Government is still some way short of its 20% CO_2 reduction 'target' by 2010. The EU Emissions Trading Scheme (ETS), an economic instrument that 'caps' emissions at the sector and national level, will make an important contribution to this target, when it starts on 1st January 2005, as will any life extension and further productivity gains in the nuclear sector.

The EU ETS will have a major impact on the generation sector by promoting fuel switching from high carbon intensity carriers such as coal, to low or zero emission technologies such as gas or nuclear and renewables respectively. A new technology hierarchy will emerge, the pace dependent on the carbon 'caps' imposed in the National Allocation Plans of the EU Member States and the cost of carbon on the European market.

Interestingly, the projected annual emissions avoided during any life extension programme of the AGRs are comparable with the expected annual savings from the EU ETS in Phase 1. Also, the latter, along with the Large Combustion Plant Directive[3] (LCPD) (which addresses sulphur and nitrogen oxide emissions for fossil generation) are helping to create a level playing field for all technologies and this will change their relative economics with nuclear in a much more favourable position.

Dealing with the waste

[3] Revised Directive on Large Combustion Plants, 2001/80/EC.

If nuclear generation has a number of important benefits for the environment, the waste issue is the Achilles heel for the industry. There is a general lack of understanding about nuclear waste. The reality is that radioactive waste volumes are relatively small, their character is not uniquely hazardous, and the Regulator, quite rightly, oversees activities to ensure they are transported and stored safely. To put waste into context, the spent fuel from one year's operation of one of our AGR stations amounts to about 35 tonnes or a volume of about 22 cu metres - this is about the same volume as one third of a single decker bus.

Looking forward, there have been technology developments that have improved the waste situation. Figure 4 compares an early Magnox station at Chapelcross in the UK, a 200MW plant which started generating electricity in 1959 and closed in June 2004, with the new fifth reactor in Finland, a 1600 MW station expected to begin generating electricity in 2009.

Figure 4 – Ecological footprint reduced through innovation

What is clearly evident is that the ecological footprint of modern reactors is much smaller than the earlier designs. The new reactor in Finland is not only physically much smaller but it also produces much less waste than the early reactors in the UK. This is very encouraging for the industry, but a solution to the long-term waste issue is required. There are actually no technology barriers to addressing this issue - the solution developed in Finland suggests it does require political will, and a transparent and inclusive consultation process.

They begun with a repository, shown in Figure 5, to house all their low and intermediate level waste, built in the early 1990's at a modest cost. This facility has operated successfully for well over a decade and has given them the confidence to embark upon a high level waste repository to house the waste of all their reactors including the new station (an artist impression is also shown in Figure 5). The Finnish experience also suggests that the economics of waste appear not to be a significant barrier to the nuclear option.

Figure 5 – Addressing the waste issue at Olkiluoto, Finland

The environmental benefits of nuclear power, and the costs in terms of waste production are just two of the important issues that will determine the future role of nuclear in a carbon constrained world. But there are other drivers that will be equally important such as the long-term evolution of the electricity market and the economics of new build.

The electricity market and economics of new build

The market in the UK has seen major changes over the last five years. At one time it seemed that there would be an extended period of low prices. This catalysed some significant changes in the generation sector with some plants changing ownership while others were simply mothballed. The ability of nuclear to survive in the private sector was also called into question. During this low wholesale price regime only renewables were built because the Government is committed to seeing this industry grow. It delivered policy initiatives to achieve this, the most important being a Renewables Obligation, driven by the market and subsidised by customers.

Electricity prices have risen over the last 18 months or so, brought about by higher gas and coal prices and also a relatively low reserve margin. Implementation of the EU ETS and the LCPD, both aimed at reducing emissions from fossil generation, makes fossil generation, and coal in particular, vulnerable; this may also be the case for the reserve margin. Electricity prices look set to rise with these initiatives.

Combined Cycle Gas Technology has been the new build benchmark over the last decade. Historically, nuclear has been a more expensive option than gas. However this could change in the future because of a number of reasons. As indicated earlier, rising gas prices have led to higher electricity prices; the EU ETS will also place a cost on carbon emissions and further increase the operating cost of gas generation.

For the UK there is the added complication of having very little gas storage capacity, and relatively few pipeline links to the continent. As the UK's need for gas imports

grow, new facilities will have to be built, again imposing additional costs on gas generation.

It is also possible that the cost of new nuclear will be lower than before due to the development of new technology. The first generation reactors were small, pushing the boundaries of the technologies. The various second-generation reactors have all been successful in delivering large quantities of electricity and these have served to establish the industry in the mainstream energy mix. It is fair to say that the Pressurised Water Reactor appears the 'winning' technology today.

The nuclear industry continues to innovate. *'Generation III'* technology has focussed on evolutionary concepts with safety and economics paramount - the new Finnish reactor is from this group. New *'Generation IV'* designs aim to improve further the safety and waste aspects of the technology, and to ensure they are proliferation resistant. Such innovations can only improve the acceptability and cost competitiveness of the industry.

The development of new funding mechanisms, consistent with the market framework, as occurred in the funding of the new Finnish reactor, will also help bring nuclear alongside the mainstream technologies. It is possible that the costs of nuclear and those of gas could converge in the not too distant future but whether 'parity' is a sufficient condition to encourage investment in the nuclear option is not clear. Valuing other attributes that nuclear brings, such as security-of-supply, stable electricity prices, and so on, would help the option.

Addressing security-of-supply concerns

Security-of-supply has risen in prominence over the last two or three years, particularly in the UK. The Government's projections[4] for the generation sector have stimulated much of this concern. In the absence of new policy initiatives, these projections show the demise of coal and nuclear continues unabated over the next two

[4] Department of Trade and Industry, *Energy Projections for the UK,* Energy Paper 68, (DTI, London, 2002).

decades resulting in a sector in which gas technology contributes 70-80% of the electricity supplied. Also, by 2025 the UK will be almost totally reliant on gas supplies outside of its immediate control: from Russia, the Middle East and North Africa.

The Government's projections are based on an analysis of historical trends in energy use and such factors as economic growth and fuel prices. They also take into account some recent policies such as the Climate Change Levy and the Renewables Obligation but not the Emissions Trading Scheme, which, as indicated earlier, will likely reinforce the penetration of gas at the expense of coal.

There are conflicting views in the UK about whether this situation compromises security-of-supply. This country has enjoyed excellent electricity security-of-supply for most of the 20th century, originally through its indigenous coal supply and more recently through a mix that includes gas, also 'indigenous' to the UK. Nuclear can be considered an 'indigenous' generation technology since the fuel is plentiful and readily available from relatively secure regions, and with a fuel price likely to remain unaltered for relatively long periods of time.

The Government's projections suggest that the sum of coal, nuclear and renewables will fall dramatically over the next two decades, and by 2020 85% of gas will be imported. It is difficult to establish what constitutes an acceptable security-of-supply for a country but this is a dramatic change for the UK since it has not developed safeguards such as gas storage capacity, common in other European countries.

This view of the future electricity mix has implications not only for security-of-supply but also for carbon dioxide emissions, as shown in Figure 6. In the absence of major new initiatives the hard-earned carbon dioxide reductions achieved by the electricity sector are reversed post 2010, brought about by the dominance of gas in the generation mix, despite the fact that it is a much less carbon intensive fuel than coal.

Figure 6 - Projected carbon dioxide emissions from the power sector

A scenario, in which nuclear is maintained at a reasonable level in the electricity supply mix would offer not only significant carbon dioxide savings and help maintain the reductions established in the period 1990-2005, but also provide a measure of security-of-supply for the economy. Nuclear could also facilitate the use of indigenous coal by diluting the latter's carbon dioxide emissions to levels similar to those from gas generation, thus enhancing security-of-supply further.

The question remains however, as to whether the market as it is currently constituted can deliver this 'plural' mix in a timely way or whether it will require policy initiatives that 'value' security-of-supply in the same way as the emissions trading scheme values carbon.

Opening the nuclear option

All the drivers in Figure 1 will need to be addressed if nuclear is to continue making a major contribution to the UK's climate change programme throughout this century. In many ways the debate is now about *opening the nuclear option* as much as *keeping the nuclear option open.* Some observations on the other drivers in this figure are worth highlighting.

When it came to technology options, the UK Government's recent White Paper[5] focussed attention on the development of renewables technologies and energy efficiency measures, essentially 'parking' the nuclear option for foreseeable future. Nonetheless, it has ruled nothing in or out for the medium to long term, including the nuclear option, focussing on measures to *keep the nuclear option open*.

International developments will help determine the fate of the nuclear option in the UK. For example, nuclear is firmly on the energy agenda in the USA and there are a number of new nuclear projects in the Far East, providing a 'boost' to the nuclear industry. However, concerns about proliferation have surfaced again recently.In the

[5] Department of Trade and Industry, *Our Energy Future – Creating a Low Carbon Economy*, Energy White Paper, (DTI, London, February 2003).

same way as nuclear generation avoids the emissions of harmful pollutants, it also avoids the consumption of finite fossil fuel reserves that would have been used for power generation, particularly gas. In 2003/04 this amounted to about 16.6 billion cubic metres, valued at about £1.3 billion pounds[6]. There is no mechanism that values this enormous benefit to the economy at this time.

There are growing concerns that a lack of a long-term future for the nuclear industry in the UK is damaging it from a human resources point of view. The age distribution is now relatively poor and the industry is working hard to maintain the skills needed to remain effective going forward. Skills retention is an important part of the Government's 'programme' for *keeping the nuclear option open*.

There is little doubt that prominent NGOs such as Greenpeace remain opposed to nuclear power, although it is also true that some notable long standing environmentalists such as Professor James Lovelock,[7] have come out in support of nuclear because of the climate change benefits this option provides. The professional institutions have also encouraged Government to maintain the nuclear option because of the security-of-supply and environmental benefits associated with this form of generation.

The media today have a much better understanding of energy and environment issues. The coverage may be sensational at times but it is also true they have done much to educate the public over the last few years. There is a growing recognition that all energy carriers have problems and where once there was vocal opposition against nuclear, the public is much more likely to voice their concerns equally against most new plant. As was shown in Finland, public involvement is crucial to all decisions related to nuclear. There is little doubt that much needs to be done by the industry and government before the public will entertain new nuclear build.

Visions of the future

[6] This assumes gas is priced at 20p/therm.
[7] See McCarthy M, 'Only Nuclear Power Can Now Halt Global Warming' (2004) *The Independent*, 24 May.

Finally, it is worthwhile investigating the wider energy scene over the next few decades. There are many visions of the future, but Shell is renowned for their global scenarios, providing useful insights into the way that the world's energy system may unfold.

Figure 7 – Shell 'Spirit of the Coming Age' scenario

Spirit of the Coming Age[8] provides a number of important messages common to many other scenarios. In this vision of the future primary energy consumption will continue to grow throughout the 21st century driven by higher populations and development in Asia, Africa and the Middle East, and to lesser extent Latin America. Energy consumption in developed countries will also grow, albeit at a modest rate.

The world is unlikely to depend on a small number of major carriers as it has in the past - rather, the world's energy demands will be met with a more diverse mix of technologies. This does not mean each region will have the same technology diet - more likely, the mix of each region will differ, sometime significantly, depending on growth patterns and level of development, the availability or otherwise of indigenous resources, proximity to gas and liquid fossil fuels, and so on.

Nuclear generation will continue to grow with many new projects in the Far East, and in the longer term, Latin America and the Middle East. It appears that nuclear in Europe may simply stabilise at its current levels, neither growing nor falling.

Carbon dioxide emissions stabilise just below 550 ppm with this scenario helped by the emergence of natural gas as the dominant fossil fuel in place of the higher carbon intensive coal and oil; also apparent is a major development of renewables and a tripling of nuclear capacity. But at 550 ppm the world will be a very uncomfortable place for many people and it is possible that as our understanding of climate change impacts becomes better a value well below this will be the target.

[8] 'Energy Needs, Choices and Possibilities: Scenarios to 2050' *Global Business Environment*, (Shell International, Holland, 2001).

Conclusion

Can a low carbon future exist without nuclear power? A number of recent developments have placed the nuclear option more in the mainstream with many stakeholders at least willing to discuss its potential contribution to our energy mix. A level playing field is emerging in which some if not all the attributes associated with nuclear generation are being valued; in time it is possible that all attributes will be similarly valued. In these circumstances, nuclear will be seen to be an important, and possibly the preferred technology for mitigating the worst excesses of climate change.