# The Future of Nuclear Power

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**THE ROLE OF NUCLEAR POWER IN A LOW CARBON UK ECONOMY**

Consultation Document

MAY 2007

This consultation follows the publication of the Energy White Paper. The wide range of measures set out in the White Paper take forward our commitment to meeting the two long-term energy challenges. They are:

- Tackling climate change by reducing carbon dioxide emissions both within the UK and abroad; and
- Ensuring secure, clean and affordable energy as we become increasingly dependent on imported fuel.

The Government will give greater consideration to the arguments and evidence – in particular any new arguments, information or evidence – than to simple expressions of support or opposition to new nuclear power stations when considering responses to this consultation.

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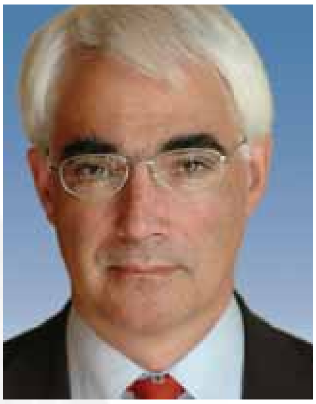
# Foreword by the Rt Hon. Alistair Darling MP



Energy is essential to almost every aspect of our lives and the success of our economy. The Government's Energy White Paper highlights the challenges we face in addressing climate change and ensuring security of energy supplies. The White Paper sets out the Government's new international and domestic energy strategy to address these long-term energy challenges and deliver our goals.

This is a consultation about nuclear power generation. Its purpose is to provide the Government with information which will help it to take the decision whether or not to allow energy companies to build new nuclear power stations in this country.

The Government wants to be able to make a decision on new nuclear power stations this year for three reasons:

1. Over the next two decades, a significant number of the power stations which currently generate our electricity – both nuclear and those that burn fossil fuels like coal and gas – are scheduled to close and need to be replaced.

2. Climate change, which is linked to man-made emissions of carbon dioxide from fossil fuel based energy sources, is accelerating.

3. Domestic supplies of fossil fuels, notably oil and gas from the North Sea, are running down and the UK is becoming increasingly dependent on imported fossil fuels.

The Government's overall response to these challenges is set out in the Energy White Paper, which is being published at the same time as this consultation. So this consultation should be understood in the context of our energy policy as a whole.

This consultation considers whether it is in the public interest to allow energy companies to invest in new nuclear power stations. The Government will take a decision later this year on whether to give energy companies this option. The purpose of this consultation is to let the Government have your response.

# Executive Summary

## Our energy challenge: climate change and energy security

1. Energy is an essential part of everyday life in the UK. We use it to heat and light our homes, to power our businesses and to transport people and goods. Without a clean, secure and sufficient supply of energy we would not be able to function as an economy or a modern society. In delivering this energy we face two major challenges: climate change and energy security.

2. Climate change represents a significant risk to global ecosystems, the world economy and human populations. The scientific evidence is compelling that human activities, and in particular emissions of greenhouse gases such as carbon dioxide, are changing the world's climate. In 2005, 40% of global carbon dioxide emissions were created by the generation of electricity[1].

3. Temperatures and sea levels are rising. There is no scientific consensus on just how long we have to avoid dangerous and irreversible climate change, but the overwhelming majority of experts believe that climate change is already underway, and without action now to dramatically reduce carbon dioxide emissions, we will have a hugely damaging effect on our country, planet and way of life.

4. The Stern Review of the economic impacts of climate change[2] highlighted the need for an urgent, coordinated international response. The analysis is stark. It suggests that working together to mitigate the problems of climate change now would cost about 1% of global GDP per annum by 2050 with a range of up to 4% to take account of a number of variables including the availability of technologies. But as a comparison, it could cost around 5% of global GDP per annum in the long term if we do nothing. This cost could rise, to as much as 20% of GDP, if we take into account a wider range of issues such as human health and the environment.

5. Historically, the UK has met most of its energy needs from domestic sources: coal, until the middle of the 20$^{th}$ century, and since the 1970s, oil and gas from the North Sea have driven our economy. Since the 1950s, nuclear power, fuelled by imported uranium, has generated a significant proportion of our electricity, reaching a peak of 30% of electricity output in the 1990s. Over the past decade nuclear power met about one-fifth of our electricity needs. If we had built fossil fuelled power stations rather than nuclear power stations, the UK's total carbon emissions from all sectors might have been 5% to 12% higher in 2004[3].

6. In the future, the UK will increasingly depend on imported oil and gas at a time of rising global demand and prices, and when energy supplies are becoming more politicised. At the same time, we know that over the next two decades or so almost one third of our coal and oil fired power stations are likely to close

1 International Energy Agency (IEA), *World Energy Outlook*, 2006.
2 Sir Nicholas Stern, *The Stern Review: The Economics of Climate Change*, October 2006
3 Sustainable Development Commission, *The Role of Nuclear Power in a Low Carbon Economy, Paper 2: Reducing $CO_2$ emissions – Nuclear and the Alternatives*, March 2006.

because of environmental legislation, and while nuclear operators may achieve life extensions at the existing UK plants, all but one of our nuclear power stations are due to have closed by 2023, based on their published lives. This will create new risks that need to be managed by our energy strategy.

7. Our aim should be to continue to raise living standards and the quality of life by growing our economy, while at the same time cutting waste and using every unit of energy as efficiently as possible. But based on existing strategies to reduce energy demand, the IEA predict global energy consumption is likely to grow by about 50% by 2030[4]. Therefore we will also need to transform the way we produce the energy we need for light, heat and mobility.

### Question 1
### 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?

## Government's energy strategy

8. The strategy the Government has adopted for meeting the twin challenges of tackling climate change and ensuring energy security focuses on:
- saving energy;
- developing cleaner energy supplies; and
- securing reliable energy supplies at prices set in competitive markets.

Our strategy is set out in more detail in the Energy White Paper, published alongside this consultation[5].

9. Competitive energy markets, with independent regulation, are the most cost-effective and efficient way of generating, distributing and supplying energy. In those markets, investment decisions are best made by the private sector and independent regulation is essential to ensure that the markets function properly. However, energy markets on their own will not deliver our wider social and environmental objectives, particularly tackling climate change. That is why we have taken action, both at home and internationally to create a framework of incentives, rules and regulations that encourage energy saving and investment in low carbon technologies.

10. Capping and trading is a central tool for achieving carbon emission reductions. The EU's Emissions Trading Scheme (ETS) sets caps on emissions and puts a price on carbon emissions for the first time. This gives firms the incentive to make investments consistent with our carbon goals, whether by driving energy efficiency or investments in low-carbon energy. Electricity generating technologies such as renewables and nuclear power, benefit because they have low carbon emissions, giving them an advantage as an investment option compared with fossil fuel power stations.

4 International Energy Agency (IEA), *World Energy Outlook*, 2006.
5 Energy White Paper 2007, *Meeting the Energy Challenge* http://www.dti.gov.uk/energy/whitepaper

11. At home, since 2002, we have required a growing percentage of electricity to be generated from renewable sources through the Renewables Obligation. The level of the Obligation is currently set to increase in annual steps from 6.7% in 2006/07 to 15.4% by 2015 and to remain at that level until 2027 when the mechanism is due to end. However, as announced in the Energy White Paper we will raise the levels of the Obligation up to 20% as necessary to keep ahead of actual levels of generation.

12. We therefore remain committed to the Renewables Obligation as a mechanism to ensure continuing investment in renewable electricity generation technologies. In the Energy White Paper we set out our proposals to strengthen and modify the Renewables Obligation. These proposals, to be implemented in 2009, will increase the level of renewables investment and deployment. It is very likely that following the European Council agreement on renewables we shall need to take further measures to increase the supply of renewable generation in the UK.

13. The proposals in the Energy White Paper, published with this consultation, along with the draft Climate Change Bill strengthen the policy framework on energy security and the reduction of carbon levels through carbon budgeting and an effective carbon price. These will be constants in the face of future uncertainty and developments, such as the details of how the EU's renewables target will be implemented and its contribution to carbon reduction in the period to 2020.

## EU Energy Policy

14. Since the Energy Review Report in 2006, the European Council agreed in March 2007 to a common strategy for energy security and tackling climate change. This includes further steps to complete the internal market in gas and electricity, and endorsement of the objective to save 20% of the EU's energy consumption in 2020 compared with current projections. The agreement commits the EU to a binding target of reducing greenhouse gas emissions by 20% by 2020 and by 30% in the context of international action. The agreement assigns the EU emissions trading scheme the central role in the EU's long-term strategy for reducing greenhouse gas emissions.

15. The European Council agreement also recognises the potential importance of carbon capture and storage and sets a target for the share of energy from renewables of 20% by 2020. The target covers the energy we use in heat and transport as well as electricity. The Council also agreed a 10% binding minimum target, to be achieved by all Member States, for the share of biofuels in EU petrol and diesel consumption; this is subject to conditions, including that the production of biofuels is sustainable.

16. The 20% renewables target is an ambitious goal representing a large increase in Member States' renewables capacity. Latest data show that the current share of renewables in the UK's total energy mix is around 2% and for the EU as a whole around 6%[6]. Projections indicate that, on the basis of existing policies in the UK and the EU, by 2020, renewables would contribute around 5% of the UK's consumption and are unlikely to exceed 10% of the EU's[7].

17. The European Commission has been asked to bring forward detailed proposals - including for each Member State's contribution to the EU targets on greenhouse gases and renewables - by the end of this year. In developing the proposals, the Commission will need to take account of individual national circumstances and discuss and agree their proposals with Member States and the European Parliament during 2008/09. In developing proposals for the renewables target, the Commission will need, as agreed by the European Council, to give due regard to a fair and adequate allocation, taking account of different national starting points and potentials, including the existing level of renewable energies and energy mix.

18. All this means there is some uncertainty as to the size and nature of the UK's contribution to the EU greenhouse gas and renewables targets. To inform our discussions and negotiations, we will need to analyse the full implications of the proposed UK contributions including: technical feasibility, cost effectiveness, our existing and potential capacity for deployment of low carbon technologies including renewables, our overall energy mix and the wider implications for energy policy including energy security and reliability.

19. We are already in discussion with European counterparts on these issues. In parallel we are conducting detailed analysis to explore how the EU Spring Council agreement can be implemented in the most effective way. We shall be engaging actively with interested parties, including energy producers and users, in taking this work forward.

20. After a decision has been reached on each Member State's contribution to the EU agreement, it is very likely that the UK will need to take further measures, beyond those set out in the Energy White Paper published alongside this consultation, to make our contribution to meeting these targets, and in particular to increase the share of renewable electricity, heat and transport, in our mix by 2020.

6 The UK figure is from the Digest of the United Kingdom Energy Statistics (DUKES), 2006. The European figures come from Eurostat. http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136239,0_45571447&_dad=portal&_schema=PORTAL

7 The UK figure is based on DTI projections – for more detail see *UK Energy and $CO_2$ Emissions Projections*, May 2007 http://www.dti.gov.uk/energy/whitepaper. The European figures come from the EU Commission Renewable Energy Road Map. *Renewable energies in the 21st century: building a more sustainable future* COM(2006)848 final.

## Why we need to consider the future role of nuclear power now

21. Nuclear power has been part of the UK's energy mix for the past five decades. Currently it provides about 18% of the electricity we use in our homes and workplaces. In the UK, about one third of our emissions of carbon dioxide come from electricity generation[8]. The vast majority of those emissions come from coal and gas power plants.

22. Energy companies will need to invest in around 30-35GW of new electricity generating capacity – as coal and nuclear plants retire – over the next two decades, with around two-thirds needed by 2020. This is equivalent to about one-third of our existing capacity.

23. The UK needs a clear and stable regulatory framework to reduce uncertainty for business to help ensure sufficient and timely investment in technologies that contribute to our energy goals.

24. Of the capacity that is likely to close over the two decades, two thirds is from carbon intensive fossil fuel generation and about 10GW is nuclear and therefore low carbon. So companies' decisions on the type of power stations they invest in to replace this capacity will have significant implications for the level of carbon emissions. As an illustration, if our existing nuclear power stations were all replaced with fossil fuel fired power stations, our emissions would be between eight and sixteen MtC (million tonnes of carbon) a year higher as a result (depending on the mix of gas and coal-fired power stations). This would be equivalent to about 30-60% of the total carbon savings we project to achieve under our central scenario from all the measures we are bringing forward in the Energy White Paper[9]. Our gas demand would also be higher, at a time when we are becoming more dependent on imported sources of fossil fuels.

25. New nuclear power stations have long lead times. This time is necessary to secure the relevant regulatory and development consents which must be obtained before construction can begin, and there is also a long construction period compared to other generating technologies[10]. New nuclear power stations are therefore unlikely to make a significant contribution to the need for new capacity before 2020.

8 Updated Emissions Projections, July 2006, DTI, http://www.dti.gov.uk/files/file31861.pdf
9 DTI: *Energy White Paper, Meeting the Energy Challenge*, http://www.dti.gov.uk/energy/whitepaper
10 Our conservative assumption is that for the first new nuclear plant the pre-construction period would last around 8 years (to secure the necessary consents) and the construction period would last around 5 years. For subsequent plants this is assumed to be 5 and 5 years; respectively.

26. Even with our expectations that the share of renewables will grow, it is likely that fossil fuel generation will meet some of this need. However, beyond that date there are still significant amounts of new capacity needed; for example, in 2023 one third or 3GW of our nuclear capacity will still be operational, based on published lifetimes. Given the likely increase in fossil fuel generation before this date, it is important that much of this capacity is replaced with low carbon technologies. New nuclear power stations could make an important contribution, as outlined in this consultation document, to meeting our needs for low carbon electricity generation and energy security in this period and beyond to 2050. Because of the lead-times, without clarity now we will foreclose the opportunity for nuclear power.

27. The existing approach on new nuclear build was set out in 2003[11]:

*"Nuclear power is currently an important source of carbon-free electricity. However, its current economics make it an unattractive option for new, carbon-free generating capacity and there are also important issues of nuclear waste to be resolved. These issues include our legacy waste and continued waste arising from other sources. This white paper does not contain specific proposals for building new nuclear power stations. However, we do not rule out the possibility that at some point in the future new nuclear build might be necessary if we are to meet our carbon targets. Before any decision to proceed with the building of new nuclear power stations, there will need to be the fullest public consultation and the publication of a further white paper setting out our proposals."*

28. Since 2003 there have been a number of developments, which have led the Government to consider afresh the potential contribution of new nuclear power stations. Firstly, there has been significant progress in tackling the legacy waste issue:

- we have technical solutions for waste disposal that scientific consensus and experience from abroad suggest could accommodate all types of wastes from existing and new nuclear power stations;
- there is now an implementing body (the Nuclear Decommissioning Authority), with expertise in this area, and Government is reconstituting the Committee on Radioactive Waste Management (CoRWM) in order to provide continued independent scrutiny and advice; and
- a framework for implementing long-term waste disposal in a geological repository will be consulted on in the coming months.

29. The Government has also made progress in considering the issue of waste management in relation to potential new nuclear power stations:

- this consultation provides the opportunity to discuss the ethical, intergenerational and public acceptability issues associated with a decision to allow the private sector to invest in new nuclear power stations and generate new nuclear waste;

11 HMG Cm 5761: *Energy White Paper, Our Energy Future – creating a low carbon economy*, 2003.

- the Government is developing specific proposals to protect the taxpayer. Under these proposals, private sector developers would meet the full decommissioning costs and full share of waste management costs. The proposals would be implemented in the event that we conclude that energy companies should be allowed to invest in new nuclear power stations. They would need to be in place before proposals for new power stations could go ahead.

30. Secondly, the high-level economic analysis of nuclear power, prepared for the Energy Review, concluded that under likely scenarios for gas and carbon prices and taking prudent estimates of nuclear costs, nuclear power would offer general economic benefit to the UK in terms of reduced carbon emissions and security of supply benefits[12]. Therefore, the Government believes that it has a potential contribution to make, alongside other low-carbon generating technologies.

31. Thirdly, some energy companies have expressed a strong interest in investing in new nuclear power stations. They assess that new nuclear power stations could be an economically attractive low-carbon investment, which could help diversify their generation portfolios. Their renewed interest reflects assessments that with carbon being priced to reflect its impacts and gas prices likely to be higher than previously expected, the economics of new nuclear power stations are becoming more favourable.

32. Nuclear power stations have long lead times. If they are to be an option to replace the capacity closing over the next two decades, and in particular after 2020, a decision on whether allowing energy companies the option of investing in new nuclear power stations would be in the public interest, needs to be taken now. Energy companies would need to begin their initial preparations in the near future in order to have a reasonable prospect of building new generation in this period. Not taking the public interest decision now would foreclose the option of new nuclear being one of our options for tackling climate change and achieving energy security.

## Our preliminary view on nuclear power

33. We face a great deal of uncertainty about our energy supplies over the next couple of decades. Most obviously the pace of climate change and geopolitical developments. But there are also uncertainties relating to future fossil fuel and carbon prices; the speed at which we can achieve greater energy efficiency and therefore likely levels of energy demand here and globally; the speed, direction and future economics of development in the renewable sector; and the technical feasibility and costs associated with applying carbon capture and storage technologies to electricity generation on a commercial scale.

12 DTI Analysis, http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

34. Faced with these uncertainties the Government believes we need diversity and flexibility in the energy mix and a policy framework that opens up the full range of low carbon options. As well as renewables, those options should include the use of gas and coal with carbon capture and storage along with nuclear power. We agree with the recently published fourth report of the Intergovernmental Panel on Climate Change (IPCC) that nuclear power could have a role to play alongside other low carbon energy sources in reducing carbon emissions[13].

35. Tackling climate change and ensuring energy security will require action on many fronts: both supply and demand, engaging individuals and business. Unnecessarily ruling out any of the options available is likely to increase the risks of not achieving these objectives. Our preliminary view is that preventing energy companies from investing in new nuclear power stations would increase the risk of not achieving our long-term climate change and energy security goals, or achieving them at higher cost.

36. Apart from large-scale hydro – the opportunities for which have been largely exhausted in the UK – nuclear power is the only low-carbon form of baseload generation, which is proven on a commercial scale. Without nuclear power as an option, the alternative would be for energy companies to invest in significant fossil fuel capacity, whether of the conventional kind or fitted with carbon capture and storage technology, and to build renewable capacity over and above our existing targets, particularly as we will need to replace existing nuclear stations as they retire.

37. Nuclear power also has disadvantages, including producing radioactive waste that needs long-term management and presenting health and safety risks. The Government believes that they can be managed and mitigated so that they do not in themselves provide a reason for not allowing energy companies the option of investing in new nuclear power stations.

38. The Government is committed to the fullest public consultation on its proposals before a decision is taken on whether it would be in the public interest for energy companies to have the option of investing in new nuclear power stations. Such a decision would mean nuclear power stations could be developed alongside renewables and other low-carbon technologies, as part of the electricity sector's contribution to tackling the challenges of climate change and energy security.

39. This is an important decision that will have implications for society for decades to come, and on which some people will have strong views. Therefore we are keen to gather responses from a range of perspectives to allow us to assess the factors before reaching a firm conclusion. This consultation takes account of the ruling of the High Court in February and the Government's commitment in 2003[14] to the fullest public consultation and the publication of a further White Paper setting out confirmed proposals for new nuclear power stations.

40. This consultation will help the Government to take a decision on the future of nuclear power in the UK, and whether it should be an option for

13 Intergovernmental Panel on Climate Change (IPCC) Working Group III Report, *Mitigation of Climate Change, Summary for policy makers*, May 2007, http://www.ipcc.ch/SPM040507.pdf
14 Energy White Paper *Our Energy Future – creating a low carbon economy*, HMG Cm 5761, 2003.

companies investing in the UK's energy market. In reaching our preliminary view, we have considered a number of issues relating to nuclear power. In this consultation document we set out the information and evidence that Government has considered in reaching its preliminary view:

- nuclear power and carbon emissions (chapter two);
- security of supply impacts of nuclear power (chapter three);
- economics of nuclear power (chapter four);
- the value of having low carbon electricity generation options: nuclear power and the alternatives (chapter five);
- safety and security of nuclear power (chapter six);
- transport of nuclear materials (chapter seven);
- waste and decommissioning (chapter eight);
- nuclear power and the environment (chapter nine);
- the supply of nuclear fuel (chapter ten);
- supply chain and skills implications (chapter eleven); and
- reprocessing of spent fuel (chapter twelve).

41. The information and evidence, and the Government's preliminary conclusions, in each of these chapters is summarised below. There are questions at the end of each section; respondents are invited to answer these questions based on the information in this summary and the full material in the document as necessary.

## Nuclear power and carbon emissions

42. Nuclear power, unlike fossil fuelled power generation is carbon-free at the point of generation and is low carbon overall. Some carbon dioxide emissions arise at other points in the lifecycle, for example during the mining of uranium, fuel preparation, and construction and decommissioning of the power station, but this is true to some extent for all electricity generating technologies and different technologies produce different quantities of emissions.

43. To provide an accurate picture of the potential contribution that nuclear power stations could make to tackling climate change, a full-lifecycle analysis must be made. In other words, the emissions from every phase must be measured. There are a number of assumptions that need to be made in undertaking such an analysis. For example, the type of electricity used for the preparation of nuclear fuel: if it were from coal-fired power stations, emissions would be significantly higher than if nuclear or renewable sources were used in the fuel preparation process. As a result of these variables, there is a fairly wide range of estimates in the studies that have looked at lifecycle carbon dioxide emissions from nuclear power.

44. Research by the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-Operation and Development (OECD), and the International Atomic Energy Authority (IAEA)[15] found that nuclear power emits low amounts of carbon dioxide across the whole lifecycle, between 7g/kWh and 22g/kWh. This is similar to the carbon dioxide emissions from wind power and much less than fossil fuelled plant[16]. Emissions from gas and coal-fired power stations are estimated to be over 380g/kWh and 830g/kWh, respectively[17].

15 Sustainable Development Commission, *The Role of Nuclear Power in a Low Carbon Economy*, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives, March 2006.
16 Sustainable Development Commission, *The Role of Nuclear Power in a Low Carbon Economy*, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives, March 2006.
17 OECD Nuclear Energy Agency

45. **The Government believes that, based on the significant evidence available, the lifecycle carbon emissions from nuclear power stations are about the same as wind generated electricity with significantly lower carbon emissions than fossil fuel fired generation. As an illustration, if our existing nuclear power stations were all replaced with fossil fuel fired power stations, our emissions would be between 8 and 16MtC (million tonnes of carbon) a year higher as a result (depending on the mix of gas and coal-fired power stations). This would be equivalent to about 30-60% of the total carbon savings we project to achieve under our central scenario from all the measures we are bringing forward in the Energy White Paper. Therefore, the Government believes that new nuclear power stations could make a significant contribution to tackling climate change. We recognise that nuclear power alone cannot tackle climate change, but these figures show that it could make an important contribution as part of a balanced energy policy.**

### Question 2
### 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?

**Security of supply benefits of nuclear power**

46. The Government is committed to ensuring sufficient, reliable, diverse supplies of energy at affordable prices for electricity, heating and transport. Where supplies of energy are limited or insecure, the result is likely to be unexpectedly high or volatile energy prices. The UK faces two main security of supply challenges:

- our increasing reliance on imports of oil and gas in a world where energy demand is rising and in some cases energy is becoming more politicised; and
- our requirement for substantial, and timely, private sector investment over the next two decades in: new gas import infrastructure and storage; electricity generation to meet rising demand and replace retiring stations; and the replacement of ageing transmission and distribution networks.

47. Having a diverse supply of energy is an important factor in security of supply. This can mean both diversity in the type of fuel used, and also diversity in the geographic distribution of fuel sources. Avoiding over-dependence on single sources lessens the impact of "technology failure" or supply chain interruptions.

48. To this extent, nuclear power, by generating about 18% of our electricity, already makes an important contribution to the security of our energy supplies, adding diversity to the energy mix and avoiding an over-dependence on imported fossil fuels, particularly gas. However, by 2024, all but one of our nuclear power stations will have closed, based on current published accounting lifetimes.

49. There are also particular characteristics of nuclear power stations that contribute to the security of our energy supplies. Nuclear generation extends the geographic spread of our energy imports, because uranium reserves are located in areas like Australia and Canada, which are different locations to where the global fossil fuel reserves are found[18]. Its cost profile, with high capital but low fuel and operating costs, means that the generation costs are relatively immune to fluctuations in fuel prices. This is in contrast to fossil fuel generation, and having nuclear power as part of the mix adds an element of stability to wholesale energy prices in the UK. Nuclear power is most economic when run continually, so it is well placed to meet the need for baseload capacity in the UK. Nuclear power would complement the expansion in more intermittent renewable generation such as wind power.

50. **The Government believes that the best way to achieve secure energy supplies is by encouraging a diversified mix of generating technologies, and that energy companies should have the widest choice of technologies in which to invest. We know that our nuclear power stations are coming to the end of their lives; not allowing energy companies to invest in new nuclear power stations would increase our dependence on fewer technologies and expose the UK to risks to the security of our energy supplies.**

51. **The Government believes that allowing energy companies the option of investing in nuclear power stations would make a contribution to maintaining a diverse generating mix, with the flexibility to respond to future developments that we cannot yet envisage. Allowing energy companies the option of investing would therefore make an important contribution to the security of our energy supplies.**

## Question 3
## Do you agree or disagree with the Government's views on the security of supply impact of new nuclear power stations? What are your reasons? Are there any significant considerations that you believe are missing? If so, what are they?

18 NEA and IAEA, *Uranium 2005: Resources, Production and Demand*, 2006 (The "Red Book")

## Economics of nuclear power

52. It would be for private sector energy companies to propose and fund the construction and operation of any new nuclear power stations, including meeting the full costs of decommissioning and full share of waste management costs. As with the existing nuclear power stations, there is a potential government liability in accordance with international Conventions to cover third party damages in the unlikely event of a major accident. If, within this framework, private sector energy companies concluded that nuclear power stations were not economic, or the financial risks were too great, then they would not build them.

53. Whether nuclear power stations are economically attractive will depend on, amongst other things, the contracts into which developers enter for the electricity they generate, and their financing costs. The proposed Government facilitative action (see chapter thirteen) would be important in reducing uncertainty during the preconstruction period. Uncertainty in the regulatory framework can increase costs for investors, especially financing costs.

54. The Government has updated the indicative cost-benefit analysis of new nuclear power stations that was prepared for the Energy Review Report last year. Our analysis uses a range of prices for carbon and gas, and a range to reflect uncertainties in the costs of nuclear generation, in particular waste and decommissioning costs. Our range of cost estimates also reflects different views on the future commitment to pricing carbon and the extent to which gas prices will remain linked to oil prices, which is currently an important factor in gas prices. The conclusions are consistent with and backed up by those used in the 2006 IEA World Energy Outlook report[19].

55. **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 in terms of reduced carbon emissions and security of supply benefits under likely scenarios for gas and carbon prices. As an illustration, under central gas and nuclear cases, and with a future carbon price of €36/t$CO_2$, the net present value over 40 years of adding 10GW of nuclear capacity would be of the order of £15 billion.**

### Question 4

### 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?

19 International Energy Agency, *World Energy Outlook 2006*.

## The value of having low carbon electricity generation: nuclear power and the alternatives

56. There are many uncertainties in the energy market, both internationally and at home. For example, it is difficult to predict fossil fuel, raw materials and carbon prices long into the future, we do not know with certainty which and at what speed new renewable technologies, such as marine generation might develop, and it is not guaranteed that it will be technically feasible or economic to apply carbon capture and storage technology safely to electricity generation on a commercial scale.

57. Moreover, there are even greater uncertainties about the future of the electricity market. Some technological developments could result in a significant increase in the demand for electricity in the future. For example, if hydrogen and electric technologies develop in the transport sector, then it could have a significant impact on electricity demand[20]. Faster than expected economic growth could also create increased demand for electricity, as could the need to rely more on electricity for the provision of heat, as fossil fuel reserves continue to decline. The possibility of electricity storage technologies developing on an economic scale is another uncertainty that could affect demand.

58. There is also uncertainty in the science of climate change and the potential constraints that this could put on our energy strategy. Our goal to reduce carbon emissions by at least 60% of 1990 levels by 2050 was in line with the then recommendations of the Royal Commission on Environmental Pollution[21]. The draft Climate Change Bill has provisions to amend our targets for reductions in carbon emissions in the light of significant developments in climate science or in international law or policy. A larger reduction in carbon emissions would increase the need for low carbon energy sources.

59. Given these risks and uncertainties about the way the world and energy markets may develop, it is very difficult to predict which composition of the fuel mix or share of each technology in the mix is most appropriate to minimise the risks and costs associated with achieving our energy goals. For this reason, we believe companies are better placed to weigh up this complex range of interrelated factors affecting the profitability of investing in electricity generation (including how these factors might evolve over time). Providing firms with a portfolio of options offers a hedge against risks like technology failure or over-dependence on a limited range of fuel supplies.

60. It is possible, using economic modelling, to estimate the impact in the medium and long-term of excluding the option for private sector investment in new nuclear power stations on our ability to meet our energy policy goals to tackle climate change and ensure energy security. In this consultation document and as part of our work for the Energy White Paper, we have used two different models to examine possible scenarios with and without the option of nuclear power.

20 For instance, a successful transition to electric and hydrogen vehicles could see UK electricity demand rise by 16 to 34% on 2005 levels. E4tech. A review of the UK Innovation System of low carbon Road transport, http://www.dft.gov.uk/pgr/scienceresearch/technology

21 The Royal Commission for Environmental Pollution, 22nd Report *Energy – The Changing Climate* http://www.rcep.org.uk/newenergy.htm

61. To examine how investment in new electricity generation capacity might evolve in the period to 2030, we have used a dynamic model to simulate investment decisions[22]. According to our analysis, in the period up to 2020, excluding nuclear power has relatively little impact on our energy security and climate change goals. This is because the long lead times for new nuclear power stations mean that even if we decide that it is in the public interest to allow private sector companies the option to invest in new nuclear power, significant new capacity is not likely to be operational before 2020.

62. According to our economic modelling, in the period from 2020-2030, not allowing investment in new nuclear power stations would increase the risk to the security of our energy supplies because between 2-4GW less new generation capacity is built. The modelling also suggests there would be a less diverse generation mix as investors have fewer available options. This implies there would be less spare generation capacity to cope with unexpected variations in demand or problems with electricity supply. Given the carbon price assumptions in the modelling, nuclear power becomes the cheapest generation technology by around 2023. Consequently, the modelling shows that expectations of electricity prices do not rise sufficiently to stimulate new investment in other more expensive technologies until much later in the 2020s.

63. This projected lower level of investment would put pressure on wholesale electricity prices, because there would be less capacity than otherwise to meet increases in demand during peak periods. In the period between 2020-2030, the modelling suggests that wholesale prices would be around 4% higher, on average, than if nuclear was included as an option. At the same time, our carbon emissions in the period between 2020-2030 could be around 4MtC higher, on average, than if nuclear was included as an option. As indication of the significance of this figure, 4MtC would be equivalent to around 16% of the annual carbon savings projected in 2020 to be achieved under the central scenario from all the measures in the Energy White Paper "Meeting the Energy Challenge".

64. It is extremely difficult to predict how the energy system will develop in the very long-term (the next 40-50 years). It is therefore much harder to predict what investments in new electricity capacity firms will choose to make over this period. Indeed, even if the option of investing in nuclear were available, companies may still decide to invest in other technologies if they considered them to be more attractive investment options. Their investment decisions are affected by their view of future electricity demand, the underlying costs of new investments, their expectations of future electricity, fuel and carbon prices, expected closures of existing power stations and the construction lead times for new power stations.

22 Redpoint Energy, *Dynamics of GB Electricity Generation Investment: Prices, Security of Supply, $CO_2$ Emissions and Policy Options*, 2007.

65. However, for the period to 2050, we have used a model of the entire UK energy system (UK MARKAL-Macro model) to explore the changes to the amount and use of energy required if we are to deliver our goal of reducing carbon emissions by 60% by 2050 at least cost[23]. In all the scenarios we examined where nuclear is available as an option, our modelling shows new nuclear power playing a role in meeting our 2050 goals, even where the cost of alternative technologies falls significantly.

66. Where nuclear is excluded as an investment option, the modelling shows that to meet the 60% goal, more investment is needed in alternatives such as wind, and coal with carbon capture and storage. For example, wind would have to grow from the current level of around 1-2% today to 30% of the generation mix in 2050 in such a scenario. In addition, further carbon emissions savings in other sectors such as transport would be required. We would need to see profound behavioural changes in the way we use energy. For instance, demand for electricity would have to decline by 6% compared to today's levels even though over the same period the economy is projected to grow to three times its current size.

67. Our modelling indicates that excluding nuclear is a more expensive route to achieving our carbon goal even though in our modelling, the costs of alternative technologies are assumed to fall over time as they mature. It also assumes that we are able successfully to deploy CCS safely and cost-effectively on a large scale even though currently, the technology has not yet been proven at a commercial scale. The modelling also does not capture a number of risks implicit in our assumptions. For example, technology costs may not fall as much or as quickly as assumed.

68. **The Government believes that given the wide range of uncertainties it is difficult to predict with certainty the future need for and use of energy and electricity.**

69. **We have modelled a number of different future scenarios as part of the analysis to support the Energy White Paper. The modelling indicates that it might be possible under certain assumptions, to reduce the UK's carbon emissions by 60% by 2050 without new nuclear power stations. However, if we were to plan on this basis, we would be in danger of not meeting our policy goals:**

- **Security of supply: we would be reliant on a more limited number of technologies to achieve our goals, some of which (e.g. carbon capture and storage) are yet to be proven on a commercial scale with power generation. This would expose the UK to greater security of supply risks, because our electricity supplies would probably be less diverse as a result of excluding nuclear; and**

- **reducing carbon emissions: by removing one of the currently more cost-effective low carbon options, we would increase the risk of failing to meet our long term carbon reduction goal.**

23 DTI, *The UK MARKAL model in the 2007 Energy White Paper,* http://www.dti.gov.uk/energy/whitepaper
Strachan N., R. Kannan and S. Pye (2007), *Final Report on DTI-DEFRA Scenarios and Sensitivities using the UK MARKAL and MARKAL-Macro Energy System Models*, http://www.ukerc.ac.uk/content/view/142/112

70. **By excluding nuclear as an option, our modelling also indicates that meeting our carbon emissions reduction goal would be more expensive.**

71. **Therefore, the Government believes that giving energy companies the option of investing in new nuclear power stations lowers the costs and risks associated with achieving our energy goals to tackle climate change and ensure energy security.**

Question 5
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?

## Safety and security of nuclear power

72. Nuclear power stations pose safety, security, health and non-proliferation risks that need to be managed. Accordingly, there is a regulatory regime in the UK that caters for existing facilities and would protect against the risks arising from any new nuclear power stations. This regime is subject to international scrutiny. A recent review by the International Atomic Energy Agency (IAEA) concluded that the UK's regulatory regime was well advanced, flexible and transparent, and the inspectors were highly trained, well-experienced experts[24].

73. Before any nuclear power station can be constructed, permission is required from the Nuclear Installations Inspectorate (NII), a division of the Health and Safety Executive. The NII publish a number of Safety Assessment Principles that set out guidance on what it looks for when considering the safety of a nuclear power station.

74. The UK has not had an incident at a civil nuclear power station where there has been an offsite release of radioactive material[25]. Analysis by the European Commission on the potential for nuclear events suggests that in the UK the probability of a major accident – the meltdown of the reactor's core along with failure of the containment structure – is one in 2.4 billion per reactor year[26]. By comparison, it is thought that the risks of a meteorite over a kilometre hitting the earth, which could have significant global environmental impacts, could be one in 0.5 million per year[27].

75. However, a major nuclear accident, although having an extremely low likelihood of occurring, would have potentially severe and wide-ranging consequences, so we have to consider very carefully whether it is reasonable to run such a risk.

76. The health risk of exposure to radiation from nuclear power stations is very small, and there are statutory radiation dose limits in place, both for workers in the nuclear industry and the general public[28]. The average dose to a member of the public as a result of discharges from the nuclear power industry is 0.015% of the annual dose from all sources[29]. The independent

24 HSE report – *The health and safety risks and regulatory strategy related to energy developments. An expert report contributing to the Government's Energy Review* 2006.
25 Sustainable Development Commission, *Paper 6: Safety and Security*, March 2006.
26 European Commission, *Externalities of Energy (ExternE), Methodology 2005 Update.*
27 NASA Asteroid and Comet Impact Hazards, http://128.102.32.13/impact/intro_faq.cfm
28 Ionising Radiation Regulations 1999.
29 Radiation Doses – Maps and Magnitudes Second Edition, National Radiological Protection Board, now part of Health Protection Agency.

Committee on Medical Aspects of Radiation in the Environment (COMARE) has not identified any evidence of increased incidents of childhood cancer in areas surrounding nuclear power stations[30].

77. Although nuclear power stations pose some unavoidable terrorism risks, the Office for Civil Nuclear Security (OCNS), the security regulator, is satisfied that the existing security regime is robust and effective and that allowing new nuclear power stations to be built would be unlikely to materially increase the risks to the UK, because any proposals for new nuclear power stations would be only be permitted to proceed if they met the stringent regulatory requirements in full, based on the most up to date threat assessments.

78. The UK Safeguard Office, who oversee non-proliferation risks, believe that the risk of diversion of nuclear materials from the building and operation of modern nuclear power stations in the UK is very small, because of the regulatory and market framework and the nature of the designs of nuclear power stations that might be put forward.

79. **Based on the advice of the independent nuclear regulators, and the advances in the designs of nuclear power stations that might be proposed by energy companies, the Government believes that the safety, security, health and non-proliferation risks of new nuclear power stations are very small and that there is an effective regulatory framework in place that ensures that these risks are minimised and sensibly managed by industry. Therefore, the Government believes that they do not provide a reason to prevent energy companies from investing in new nuclear power stations.**

### Question 6
### 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?

**Transport of nuclear materials**

80. Generating electricity from nuclear power stations requires the transport of nuclear materials, such as uranium for fuel fabrication and spent fuel. There is a wide range of radioactive material that needs to be transported for the nuclear power industry; however, it is only certain materials such as spent fuel where radioactivity levels, and therefore associated risks, are high. The relative risks associated with the transport of the material are reflected in the regulatory protections. For example, the regulatory requirements for flasks used to transport spent fuel, the most radioactive nuclear material that is transported, are the most stringent. By contrast, raw and enriched uranium, and even freshly prepared fuel are not very radioactive.

30 *The incidence of childhood cancer around nuclear installations in Great Britain, COMARE 11th Report,* July 2006.

81. Transport of nuclear fuel by rail, road and sea has been carried out for the past 40 years by several countries that use nuclear power. In this time, in the European Union, there have been no accidents involving the transport of nuclear materials that have caused death or serious injury to persons or significant harm to the environment from a radiological cause[31].

82. Workers in the transport industry receive an average annual dose of radiation of less than 0.7 millisieverts (mSv) from the transport of radioactive material. This is much less than the limit for radiation workers of 20 mSv per year, and is even below the dose limit of 1mSv for the general public from activities covered under the Ionising Radiations Regulations 1999. Conservative estimates of the dose to the general public from the transport of radioactive materials are a hundredth this level, no more than 0.006 mSv per year[32], compared to an average annual dose from natural background radiation of 2.6mSv[33]. According to the Health Protection Agency, these doses are extremely low[34].

83. All such transport is subject to regulatory requirements aimed at ensuring that these movements are carried out in a safe and secure fashion. This is embedded in IAEA regulations and implemented in the UK by the Department for Transport (Dangerous Goods Division). The European Parliament concluded in 2001, in its resolution on Transport of Radioactive Material, that the risks associated with the transport of radioactive material are low[35].

84. Based on the assumption that spent fuel would not be reprocessed (see chapter twelve) and that developers would be expected to provide appropriate storage arrangements capable of being maintained safely until the spent fuel is ultimately removed for disposal (chapter eight), allowing private sector energy companies to invest in new nuclear power stations would not create the need to transport spent fuel to a reprocessing facility and then subsequently to a repository. Instead, spent fuel would be held in interim storage, during which time, the initial radioactivity would decline as the more active isotopes decay, and only a single movement, of somewhat less radioactive waste, could be made to the repository.

85. **Given the safety record for the transport of nuclear materials, the assumption that spent fuel will not be reprocessed and the strict safety and security regulatory framework in place, the Government believes that the risks of transporting nuclear materials are very small and that there is an effective regulatory framework in place that ensures that these risks are minimised and sensibly managed by industry. Therefore, the Government believes that they do not provide a reason to not allow energy companies to invest in new nuclear power stations.**

31 Health Protection Agency, *Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail,* http://www.hpa.org.uk/radiation/publications/w_series_reports/2005/nrpb_w66.pdf.
32 Health Protection Agency, *Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail,* http://www.hpa.org.uk/radiation/publications/w_series_reports/2005/nrpb_w66.pdf.
33 Sustainable Development Commission, *Paper 6: Safety and Security.*
34 Health Protection Agency, *Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail,* http://www.hpa.org.uk/radiation/publications/w_series_reports/2005/nrpb_w66.pdf.
35 Official Journal of the European Community, *Safe transport of radioactive material,* A5-0040/2001, 2001

## Question 7
## 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?

**Waste and decommissioning**

86. Nuclear power stations generate long-lived radioactive waste that needs to be handled and stored carefully and ultimately disposed of in an appropriate long-term management facility. The UK has a significant legacy of nuclear waste. Although the majority of this waste is of a low level of radioactivity, there are also higher level wastes and spent fuel from nuclear power stations that need to be managed.

87. In 2007, the Government updated its policy on low level waste management and gave responsibility to the Nuclear Decommissioning Authority (NDA) for developing and maintaining a national strategy for the handling of low level nuclear waste. This will include identifying additional disposal capacity because the UK's existing facility will not provide enough capacity for the expected waste from the decommissioning of the existing UK nuclear power stations.

88. In 2001, Government launched the Managing Radioactive Waste Safely programme to consider the issues of managing and disposing of the UK's higher level radioactive waste. As part of this programme, in October 2006, the Government's response to the independent Committee on Radioactive Waste Management's (CoRWM) recommendations acknowledged that geological disposal coupled with safe and secure interim storage is the best nuclear waste management approach currently available for existing waste.

89. The Government will shortly publish a consultation on the implementation process for developing a long-term waste management solution. The responsibility for planning and implementing geological disposal has been given to the Nuclear Decommissioning Authority.

90. The CoRWM terms of reference focussed principally on legacy waste and the focus of CoRWM's public and stakeholder engagement was always on the existing and committed wastes and materials as there were no new build proposals for them to consider in detail. However, as part of their report on the inventory of waste that needed to be managed, the Committee made reference to the potential implications of a new build scenario. CoRWM set down that its: *"recommendations are directed to existing and committed waste arisings"*[36]. CoRWM stated that they had: *"no position on the desirability or otherwise of nuclear new build"*[37] and CoRWM believed that *"its recommendations should not be seen as either a red or green light for nuclear new build"*[38].

91. CoRWM stated that: *"solutions for existing and unavoidable future wastes would also be robust in the light of all reasonably foreseeable developments in nuclear energy and waste management practices"*[39], although they felt that

36 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
37 CoRWM statement on Nuclear New Build 16 December 2005.
38 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
39 CoRWM statement on Nuclear New Build 16 December 2005.

*"significant practical issues would arise, including the size, number and location of waste management facilities"*[40]. CoRWM also commented that *"the prospect of a new nuclear programme might undermine support for CoRWM from some stakeholders and citizens and make it more difficult to achieve public confidence"*[41]. CoRWM considered that *"should a new build programme be introduced… it would require a quite separate process to test and validate proposals for the management of wastes arising"*[42].

92. We agree with CoRWM that the creation of new waste involves ethical considerations. The key ethical question that needs to be considered as part of the discussion on the future role of nuclear power is ***whether*** to create new waste; once new waste is created it would need to be managed and disposed of, in the same way as existing waste. We believe that the most appropriate way to consider both the public acceptability and ethical issues is as a part of the discussion of the wider climate change and energy security considerations.

93. Nuclear power could provide significant benefits to future generations, particularly in terms of reducing carbon emissions and contributing to energy security and thereby supporting economic growth. It is likely to be more cost effective than alternative forms of low-carbon generation[43]. However, the creation of nuclear waste is also a potential burden while it requires active management or care and maintenance, and radioactive waste remains potentially hazardous for many years to come. This needs to be balanced against the likelihood that without new nuclear power, a greater proportion of the capacity needed to replace the existing nuclear and fossil fuel stations would come from additional fossil fuel power stations. Increasing the amount of fossil fuel plant would increase the emissions of carbon dioxide into the atmosphere, adding to the growing problem of man-made climate change. Further, a decision not to allow energy companies the option of investing in new nuclear power stations would mean that one less source of electricity generation would be available to future generations, which could have implications for future diversity and security of supply. The ethical issues around radioactive waste are discussed further in the CoRWM report on "Ethics and Decision Making for Radioactive Waste"[44] (although the discussions reported in that document focus primarily on legacy waste).

94. Allowing energy companies to build new nuclear power stations would create new radioactive waste that needs to be managed. Compared to the existing nuclear power stations in the UK, the designs of power stations that might be constructed would create less waste by volume because of the improved, more efficient reactor designs which use fewer components. Because of their longer expected lives, they would generate more electricity. However this means that there would be a larger increase in the radioactivity compared to the increase in volume of waste – principally from spent fuel – although as with all radioactive substances the activity would decline over time.

95. Scientific consensus and international experience suggests that waste from new nuclear power stations does not raise such different technical issues compared with nuclear waste from legacy nuclear programmes as to require a

40 CoRWM statement on Nuclear New Build 16 December 2005, Addendum (March 2006).
41 CoRWM statement on Nuclear New Build 16 December 2005.
42 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
43 DTI Cost Benefit Analysis of Nuclear Power, http://www.dti.gov.uk/energy/whitepaper
44 Ethics and Decision Making for Radioactive Waste – CoRWM Document Number 1692.

different technical solution. It could therefore technically be accommodated in the same disposal facilities for intermediate level waste and high level waste/spent fuel as the existing legacy. If waste from new nuclear power stations were accommodated together with legacy waste, it would increase the overall size and cost of a geological disposal facility. However, it is likely that some of the initial infrastructure costs would be common to legacy and new wastes. The additional costs resulting from accommodating new build waste would arise principally from the construction of additional vaults.

96. The number of new nuclear power stations that energy companies might choose to build would have an impact on whether all of the new waste could be stored in the same repository as the legacy waste. The impact of the increase in the time during which the repository would need to remain open if waste from new nuclear power stations were to be added, would also need to be assessed. These issues would be addressed through the Managing Radioactive Waste Safely (MRWS) programme.

97. Placing waste in a geological repository is a long-term solution. CoRWM envisaged a facility being opened around the middle of this century, and receiving waste for several decades. In the meantime, waste from any new nuclear power stations would be managed in accordance with the Government's requirements and the NDA national strategy for interim storage. This is likely to require on-site storage in facilities capable of holding the waste in a safe condition for long periods until the waste repository is ready to receive it.

98. Any private sector developers of new nuclear power stations would be required to meet their full decommissioning and full share of waste management costs. In the report of the Energy Review, the Government established principles that would underpin arrangements to ensure that operators of nuclear power stations were obliged to accumulate sufficient and secure funds to cover these costs. The development of these robust financing arrangements is considered further in this consultation document. The arrangements would need to be agreed before proposals for new nuclear power stations could proceed.

99. **The Government believes that new waste could technically be disposed of in a geological repository and that this would be the best solution for managing waste from any new nuclear power stations. The Government considers that waste should be stored in safe and secure interim storage facilities prior to a geological repository becoming available.**

100. **We consider that it would be desirable to dispose of both new and legacy waste in the same repository facilities and that this should be explored through the MRWS process.**

101. **There are also important ethical issues to consider around whether to create new nuclear waste, including the ethical implications of not allowing nuclear power to play a role, and the risks of failing to meet long-term carbon emissions targets. The Government has taken a preliminary view that the balance of ethical considerations does not require ruling out the option of new nuclear power. However, we intend that these ethical issues should be considered through this consultation document and respondents are invited to give their views.**

## Question 8
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?

## Question 9
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?

## Question 10
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?

### Environmental impacts of nuclear power
102. Nuclear power stations, like any other form of power station, affect the local environment and landscape. Construction, transport of materials, water usage for cooling, mining, fuel fabrication and the transmission of electricity also lead to environmental effects. Not all of these considerations are unique to nuclear power. Other electricity generating capacity, including renewables, can have an impact on the landscape and on local wildlife.

103. The land necessary to build a 1.2GW nuclear power station is estimated at 25-75 hectares, compared to 100 hectares for a 1.8GW coal-fired power station[45], although additional space could be required to fit carbon capture and storage technology to a coal-fired power station. This compares to estimates by the British Wind Energy Association of 10,000 hectares for a 1GW windfarm[46].

104. An opportunity to assess and mitigate the environmental and landscape impacts of new power stations is through the electricity development consents process, which considers these issues in detail and provides an opportunity for public involvement in the process. The Government's recent white paper "Planning for a Sustainable Future" proposes reforms to the planning system for nationally significant infrastructure.[47] As part of the existing and proposed process, developers have to prepare a detailed Environmental Impact Assessment.

105. As with all energy infrastructure developments, it would be for private sector energy companies to decide where to put forward proposals for any new nuclear power stations, if the Government concludes after this consultation that they should be allowed to make such investments. Industry has indicated that the most viable sites are likely to be adjacent to existing nuclear power stations.

106. The Government proposes to undertake a strategic siting process to develop criteria for determining the suitability of sites. This strategic assessment would consider the high-level environmental impacts of new nuclear power stations.

45 http://www.publications.parliament.uk/pa/cm198889/cmhansrd/1989-02-03/Writtens-2.html
46 http://www.bwea.com/ref/faq.html#space
47 http://www.communities.gov.uk/planningwhitepaper

More information on detail of this assessment is in the accompanying consultation document on the detail of this proposal[48].

107. **The Government believes that the environmental impacts of new nuclear power stations would not be significantly different to other forms of electricity generation and given the UK and European requirements in place to assess and mitigate the impacts, that they are manageable. Therefore, the Government believes that they do not provide a reason to not allow energy companies the option of investing in new nuclear power stations.**

108. **We recognise the need for a strategic assessment of the environmental issues relating to new nuclear power stations. If the Government confirms its preliminary view that it is in the public interest to allow energy companies the option of investing in new nuclear power stations, we propose to undertake an SEA as part of a Strategic Siting Assessment, the detail of and proposed timetable for which is set out in a detailed consultation alongside this consultation on the issue in principle.**

## Question 11
## 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 supply of nuclear fuel

109. The UK does not have readily available indigenous sources of fuel for nuclear power stations and imports most of the uranium for the existing nuclear power stations from Australia. Therefore, in the context of increasing international demand for energy, we have considered availability and access to fuel. The IAEA/OECD estimate that conventional uranium resources that can be mined for less than $130kg/uranium (about $60/lb), roughly the average price in 2006[49], would last for 85 years based on the world's nuclear electricity generating capacity in 2004[50]. Much of these reserves are in Australia and Canada.

110. Since 2000, uranium prices have increased significantly. However, the price of nuclear fuel represents a much smaller part of the cost of electricity than it does for other generating technologies, so these price rises have not had a material impact on overall generating costs. The increasing price of uranium will make more of the reserves that have already been discovered economic to extract. It also provides an incentive for further exploration. On the basis of newly discovered reserves, there is no evidence to suggest that we will need to mine significantly lower-grade ores[51], in which case carbon lifecycle emissions of nuclear generation should not materially change.

111. **Based on the significant evidence that there are sufficient high-grade uranium ores available to meet future global demands, and the relatively small impact that allowing energy companies to invest in new nuclear power stations in the UK would have on global demand for uranium, the Government believes that there should be sufficient reserves to fuel any new nuclear power stations constructed in the UK.**

48 http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007
49 http://www.cameco.com/investor_relations/ux_history
50 NEA and IAEA, *Uranium 2005: Resources, Production and Demand*, 2006 (The "Red Book")
51 NEA and IAEA, *Uranium 2005: Resources, Production and Demand*, 2006 (The "Red Book")

## Question 12
## 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?

### Supply chain and skills capacity

112. As the demand grows globally for new power stations of any technology, there could be shortages in the capacity to supply some of the components and shortages of the human skills needed to build them.

113. Proposals by industry to build significant numbers of new nuclear power stations would require a strengthening of the science, engineering, project management and on-site trade/technician skills base in the medium term[52]. Industry would also need to train a new operations workforce over the course of construction.

114. If nuclear power is to be viable, the market needs to respond to interest from firms in developing new nuclear power stations by increasing its ability to meet rising demand. The long lead times for nuclear power stations allow time for industry to plan ahead through such measures as placing early contracts well in advance to secure slots in manufacturers' order books for the production of certain components, and for training and recruitment. Such moves could reduce the risks that industry will suffer from shortages of skills and a lack of capacity in the supply chain. Furthermore, the work of the Sector Skills Council is supporting skills development[53]. Initiatives such as the Nuclear Skills Academy and new higher-education programmes should also help to maintain the UK's skills base in nuclear science and technology.

115. **The Government believes that the international supply chain and skills market should be able to respond if the Government were to allow energy companies to invest in new nuclear power stations. This view is based on:**

- **the long lead times associated with new nuclear power stations;**
- **the financial incentives for the private sector to meet the demands created by the building of new nuclear power stations; and**
- **the facilitative work that Government, the academic sector and industry are undertaking to support skills development in the relevant sectors.**

**Therefore, the Government believes that the supply of skills and supply chain capacity do not provide a reason to prevent energy companies from investing in new nuclear power stations.**

## Question 13
## 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?

52 Nuclear Employers Survey 2005, http://www.cogent-ssc.com/research_and_policy/LMI_and_reports/Nuclear_Employers_Survey.pdf

53 A Skill Needs Assessment for the Nuclear Industry, http://www.cogent-ssc.com/pdf/SNA/Nuclear.pdf

### Reprocessing of spent fuel

116. Nuclear power stations generate radioactive waste and spent fuel. Spent fuel may either be disposed of or recycled to separate out the useful uranium and plutonium. In some cases reprocessing can help to manage safety and environmental risks, for example there is no proven alternative to reprocessing fuel from the early Magnox reactors in the UK, which cannot be stored long-term in water. However, reprocessing also raises particular concerns about the creation of separated plutonium which would require the long-term storage, the management of associated waste streams, which in the UK include regulated radioactive discharges to the Irish Sea, and the transport of spent fuel and nuclear materials.

117. The private sector has made no proposals to reprocess spent fuel from any new nuclear power stations.

118. **The Government has concluded that any nuclear power stations that might be built in the UK should proceed on the basis that spent fuel will not be reprocessed and that accordingly waste management plans and financing should proceed on this basis.**

Question 14
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?

### Other considerations

119. We recognise that making a decision on the potential role of nuclear power is a complex issue, and that there are many issues that need to be considered.

Question 15
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?

## Our proposals on nuclear power

120. The Government is not itself proposing to build nuclear power stations. We have, however, reached the preliminary view that private sector energy companies should have the option of investing in new nuclear power stations, subject to the following conditions:

- the developer preparing an environmental Impact Assessment[54] and securing development consent;
- the developer securing the necessary permissions from the independent regulators to ensure that the nuclear power station could be operated safely, securely and without detriment to public health;
- a decision by the Secretary of State, that the proposed design is Justified (in accordance with the Justification of Practices Involving Ionising Radiation Regulations 2004)[55];

54 in accordance with the "EIA Directive" 85/337/EEC
55 Justification is a high-level assessment to determine the benefits and detriments associated with a particular class or type of nuclear practice. Before a new class or type of practice can be introduced into the UK, it must be justified.

- the proposal being in a site that meets the suitability criteria as identified through a Strategic Siting Assessment. This Assessment would also meet the requirements for a Strategic Environmental Assessment (in accordance with EC Directive 2001/42);
- the establishment, in legislation, of arrangements to protect the taxpayer and ensure that energy companies meet their full decommissioning costs and full share of waste management costs. These would need to be agreed before proposals for new nuclear power stations could proceed. As with the existing nuclear power stations, there is a potential Government liability in accordance with international Conventions to cover third party damages in the unlikely event of a major accident;
- a decision that the management of waste arising from new nuclear power stations would be explored through the Managing Radioactive Waste Safely (MRWS) process.

121. Within this framework, we think it is likely that energy companies will come forward with proposals for new nuclear power stations, although we cannot predict this with certainty. Their decisions will be affected by their view on the underlying costs of new investments, their expectations of future electricity, fuel and carbon prices, expected closures of existing power stations and the development time for new power stations. We cannot know all of these things today and believe we should reflect this uncertainty by having a diversified approach in our energy policy. This will reduce the risks associated with this uncertainty, for example, by preventing over-reliance on a limited number of technologies.

122. The Government believes that, given the many uncertainties in the energy market over the coming decades, not allowing energy companies the option of investing in new nuclear power stations would increase the risks of not achieving our long-term climate change and energy security goals, and if we were to achieve them, it would be at higher costs.

123. Having reviewed the evidence, the Government's preliminary view is that the advantages of giving the private sector the widest choice of investment options, including nuclear power stations, outweigh the disadvantages. Moreover, we believe that through the regulatory protections already in place, and other risk mitigation approaches described in this document, the risks can be effectively managed.

## Question 16
## 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?

## Question 17
## Are there other conditions that you believe should be put in place before giving energy companies the option of investing in new nuclear power stations? (for example, restricting build to the vicinity of existing sites, or restricting build to approximately replacing the existing capacity)

**Our proposals for facilitative action**

124. If we conclude that energy companies should be allowed to invest in new nuclear power stations, the Government would carry out a package of facilitative action designed to reduce the regulatory and planning risks associated with investing in nuclear power stations.

125. The package of measures is designed to reduce the uncertainties in the pre-construction period for new nuclear power stations through improvements to the regulatory and planning processes. The measures will also set out arrangements for the funding of decommissioning and waste management and disposal. The proposed package of measures covers:

- taking steps to improve the process for granting planning consent for electricity developments by ensuring it gives full weight to national, strategic and regulatory issues that have already been the subject of discussion and consultation. This could take the form of a National Policy Statement, consistent with the reforms proposed in the 2007 Planning White Paper[56]. We would:
  - develop criteria for suitable sites for new nuclear power stations through a Strategic Siting Assessment, subject to relevant European and domestic legislative requirements; and
  - continue our consideration of the high-level environmental impacts through a formal Strategic Environmental Assessment in accordance with the SEA Directive[57]. Applicants for specific proposals would still need to carry out a full Environmental Impact Assessment;

- running a process of "Justification" (in accordance with the Justification of Practices Involving Ionising Radiation Regulations 2004);

- the nuclear regulators pursuing a process of Generic Design Assessment[58] of industry preferred designs of nuclear power stations to complement the existing licensing processes. This would consist of an assessment of the safety and security of power station designs and their radiological discharges to the environment; and

- developing arrangements that would protect the taxpayer by ensuring that private sector operators of nuclear power stations securely accumulate the funds needed to meet the full costs of decommissioning and full share of waste management costs. This would need to be agreed before proposals for new nuclear power stations could proceed.

56 *Planning for a Sustainable Future*, May 2007, http://www.communities.gov.uk/planningwhitepaper
57 European Directive 2001/42/EC.
58 This is sometimes referred to generically as "pre-licensing".

126. The power to consent to the construction of power stations greater than 50MW capacity has been executively devolved to Scottish Ministers and is also devolved in Northern Ireland. In developing the proposals above we will need to take account of any areas in which the Devolved Administrations have competence.

### Question 18
### Do you think these are the right facilitative actions to reduce the regulatory and planning risks associated with such investments? Are there any other measures that you think the Government should consider?

127. The Government has previously consulted on a similar package of proposals, through the July 2006 consultation on a Nuclear Policy Framework. Because the proposal has been refined, we are consulting again on this issue. If respondents would like us to reconsider their responses to that consultation, then they should indicate this in their response to this consultation.

128. Alongside this in-principle consultation, there is a linked technical consultation on the details of running a Justification process and a Strategic Siting Assessment. Respondents to this consultation may wish to consider the information brought forward in this consultation[59].

129. If after these consultations, we confirm our preliminary view that energy companies should be allowed to invest in new nuclear power stations, we will set this out in a further Energy White Paper later this year.

130. In summer 2007, the Government will also be launching a consultation on proposals for implementing the Committee on Radioactive Waste Management's recommendations for geological disposal of higher activity radioactive wastes as part of the Managing Radioactive Waste Safely (MRWS) programme. This consultation will specifically consider the geological repository development programme and site selection process. The consultation is expected to launch in June 2007. Respondents to this consultation may want to see the more detailed information on geological disposal that will be published in the MRWS consultation before responding to this consultation.

## Proceeding with facilitative action on a contingent basis

131. There is a limited window for replacing a significant amount of our existing electricity generating capacity. Energy companies will need to invest in around 30-35GW of new electricity generating capacity – as coal and nuclear plants retire – over the next two decades, with around two-thirds needed by 2020. This is equivalent to about one third of our existing capacity. We know that there is an urgent need to tackle climate change.

59 http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

132. New nuclear power stations have long lead times. This time is necessary to secure the relevant regulatory and development consents which must be obtained before construction can begin, but there is also a long construction period compared to other generating technologies[60].

133. New nuclear power stations are therefore unlikely to make a significant contribution to the need for new capacity before 2020. Even with our expectation that the share of renewables will grow, it is likely that fossil fuel generation will meet some of this need.

134. However, beyond that date there are still significant amounts of new capacity needed; for example in 2023 one third or 3GW of our nuclear capacity will still be operational, based on published lifetimes. Given the likely increase in fossil fuel generation before this date, it is important that as much of this capacity as possible is replaced with low carbon technologies. Nuclear power stations could make an important contribution to this need and make a contribution to our energy security.

135. However, without early clarity on the Government's policy, we will foreclose the opportunity for nuclear power because of the long lead times. There will not be a time when climate change and energy policy will stop evolving and adapting. Meeting our energy challenges will require changes to the UK energy system, it is important that we make progress now.

136. We therefore believe it is prudent to start working on this facilitative action now, on a contingent basis, so that no time is wasted if we do conclude that nuclear power has a role to play. We will therefore be starting work on some of these activities, in particular on the Generic Design Assessment process and the arrangements for waste and decommissioning funding, on a contingent basis alongside this consultation. We will review whether to continue with this work in the light of the consultation responses.

# RESPONDING TO THIS CONSULTATION

## Consultation Questions

This document sets out a summary of the key challenges of tackling climate change and ensuring energy security that the UK faces:

### 1. 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?

The document also sets out the evidence and information that we have considered and the preliminary conclusions that we have reached following our assessment of this evidence. We invite respondents to consider the evidence we have presented, and to comment on the following questions:

60 Our conservative assumption is that for the first new nuclear plant the pre-construction period would last around 8 years (to secure the necessary consents) and the construction period would last around 5 years. For subsequent plants this is assumed to be 5 and 5 years respectively.

2. 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?

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

4. 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?

5. 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?

6. 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?

7. 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?

8. 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?

9. 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?

10. 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?

11. 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?

12. 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?

### 13. 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?

### 14. 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?

The purpose of this major consultation exercise is to provide interested parties with information on nuclear power, and to assist parties to reach an informed view on the future of nuclear power in the UK. Based on the responses and evidence gathered during this consultation, we will consider whether it is appropriate to confirm our preliminary view as Government policy, and to allow energy companies to invest in new nuclear power stations.

### 15. 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?

In their responses to the consultation, we encourage parties to include the reasoning behind their conclusions and any evidence that supports their views. In reaching a conclusion on the future of nuclear power, we will assess the responses to this consultation and the evidence and information that it brings forward.

## 16. 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?

### 17. Are there other conditions that you believe should be put in place before giving energy companies the option of investing in new nuclear power stations? (for example, restricting build to the vicinity of existing sites, or restricting build to approximately replacing the existing capacity)

Alongside this in-principle consultation, there is a linked technical consultation on the details of running a Justification process and a Strategic Siting Assessment. Respondents to this consultation may wish to consider the information brought forward in these consultations[61].

### 18. Do you think these are the right facilitative actions to reduce the regulatory and planning risks associated with such investments? Are there any other measures that you think the Government should consider?

61 http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

# How to respond

This consultation seeks views on the information and arguments set out on whether the private sector should be allowed the option of building new nuclear power stations.

We want to hear from members of the public, industry, non-Governmental organisations (NGOs) or any other organisation or public body.

We are seeking views on whether the Government has considered the relevant arguments; whether we have considered the arguments reasonably and whether there are other important arguments we have overlooked. Your views will contribute to the shaping of the policy on the future of civil nuclear power in the UK. They will help Government assess the arguments before it reaches its final decision on the future of new nuclear build.

We will consider carefully the responses we get and this will enable us to take a decision on nuclear power later in the year.

The Government will give greater consideration to the arguments and evidence than to simple expressions of support or opposition to new nuclear power stations when considering responses to this consultation and whether to confirm our preliminary view.

The consultation began on 23 May 2007 and will close on 10 October 2007.

There are a number of ways to let us know your view.

## Online

Visit our website at http://www.direct.gov.uk/nuclearpower2007. The online consultation has been designed to make it easy to submit responses to the questions. On registration you will be provided with a user name and password to enable you to edit or update your submission as many times as you wish whilst the consultation is open.

## By letter, fax or email

A response can also be submitted by letter, fax or email to:

Response – Nuclear Power Consultation 2007
FREEPOST SEA 12430
Thornton Heath
CR7 7XT

Tel: 020 7215 3331
Fax: 020 8683 6601
Email: response@nuclearpower2007.org.uk

If you are responding on paper you can use the response form which is available on request by contacting the DTI Publications Orderline (the address is on page 37).

## Additional points about this consultation

When responding please state whether you are responding as an individual or representing the views of an organisation. If you are responding on behalf of an organisation, please make it clear who the organisation represents and, where applicable, how you assembled the views of members. The website registration form provides space to do this.

After the consultation has closed, all responses (including respondents' names) will be published unless respondents specifically request that their responses be kept confidential. This will apply to all responses whether submitted online, posted, faxed or emailed. Please indicate on your response if you want us to treat it as confidential. You should also read the section on confidentiality and data protection.

The deadline for responses is 10 October 2007.

## Consultation events

In addition, over the next few months we want to meet with representatives from NGOs, industry, local authorities and many other organisations. These meetings will enable us to explore in more detail the views of interested parties.

We will also be hosting a number of regional deliberative events across the UK for members of the public. These events provide an opportunity for the public to input their considered and informed views. They will enable us to understand the views of the public after they have heard the key facts and arguments in the consultation. Discussion at the events will address the same key questions in the consultation document. The public will be recruited to be demographically representative of the UK population. Recruitment will be through direct invitation of randomly selected households on selected electoral registers.

Summaries of the events will be published on our website when available during the consultation.

## Confidentiality and Data Protection

Information provided in response to this consultation, including personal information, may be subject to publication or disclosure in accordance with the access to information regimes (these are primarily the Freedom of Information Act 2000 (FOIA), the Data Protection Act 1998 (DPA) and the Environmental Information Regulations 2004).

If you want other information that you provide to be treated as confidential, please be aware that, under the FOIA, there is a statutory Code of Practice with which public authorities must comply and which deals, amongst other things, with obligations of confidence.

In view of this it would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded as binding on the Department.

The Department will process your personal data in accordance with the DPA and in the majority of circumstances this will mean that your personal data will not be disclosed to third parties.

## Additional copies

You may make copies of this document without seeking permission. Further printed copies of the consultation document or copies of the response form can be obtained from:

DTI Publications Orderline
ADMAIL 528
London SW1W 8YT

Tel: 0845 015 0010
Fax: 0845 015 0020
Minicom: 0845 015 0030
http://www.dti.gov.uk/publications

Copies of the document in Welsh, Braille, large print and audio are also available on request from the Orderline. An electronic version can be found at http://www.direct.gov.uk/nuclearpower2007. A Welsh version of the document will be available at the same address.

## Help with queries

Questions about the policy issues raised in the document can be addressed to:

Query – Nuclear Power Consultation 2007
FREEPOST SEA 12430
Thornton Heath
CR7 7XT

Tel: 020 7215 3331
Fax: 020 8683 6601
Email: query@nuclearpower2007.org.uk

## Taking part in other related consultations

As we explain in the Executive Summary, there are a number of other consultations which you may want to find out more about:

- Alongside this in-principle consultation, there are linked technical consultations on the proposed Justification and Strategic Siting Assessment processes. You can take part in these by visiting the website http://www.direct.gov.uk/nuclearpower2007. Alternatively you can request a copy of the document by contacting the DTI Publications Orderline.
- Managing Radioactive Waste Safely (MRWS) Consultation. This consultation will specifically consider the proposed implementation framework for the geological disposal of the UK's higher activity radioactive waste including the approach to site selection. The consultation is expected to launch in June 2007. Respondents to this consultation may want to see the more detailed information on geological disposal that will be published in the MRWS consultation before responding to this consultation. You can take part in this by visiting http://www.defra.gov.uk or by phoning the Defra Helpline on 08459 33 55 77 or emailing radioactivewaste@defra.gsi.gov.uk.

CHAPTER 1

# How nuclear power works

## Introduction

**A half a century ago the UK's first civil nuclear power stations started to feed electricity into the grid. Since then, nuclear power has played an important part in meeting the country's energy needs, providing electricity that has low carbon emissions and that uses a fuel that has proven and reliable international sources of supply.**

1.1 Nuclear power stations generate electricity from energy produced by the fission, or splitting, of uranium atoms, which takes place in a nuclear reactor. This process creates very large amounts of energy: per atom the energy released is about 50 million times more than that released from the combustion of carbon. This process needs to be carefully managed because of the energy released in the process. The process is controlled by the use of a "moderator". All reactors have sufficient moderators to shut them down completely and fail-safes to ensure that this occurs in the event of any potential incidents.

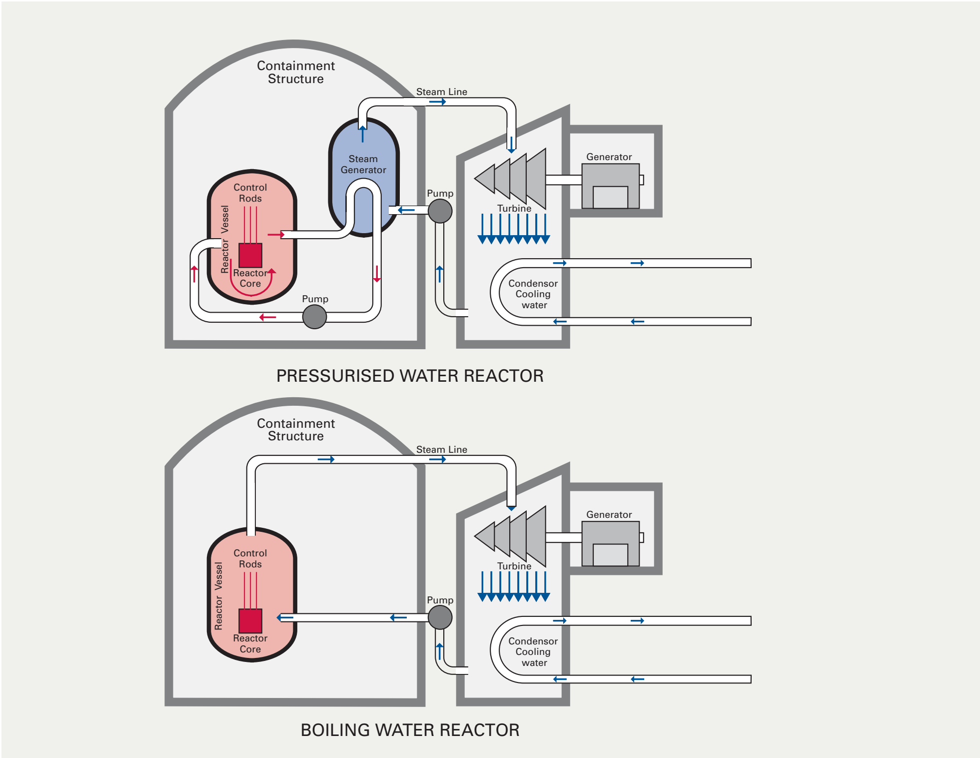
1.2 The early designs of nuclear power stations in the UK use graphite as a moderator. Later designs of nuclear power stations use water as a moderator. There are two main types of water-moderated reactors: those using normal water, often called "light water reactors" or LWRs; and those using "heavy water," a form of water usually made artificially with deuterium, a form of hydrogen[62].

1.3 The energy released from the fission process needs to be removed from the reactor and turned into electricity. In the early designs of power stations in the UK, this was achieved by circulating carbon dioxide through the reactor, which heated up and was used to boil water and create steam which in turn was used to drive the electricity turbines. In water reactors, the water used as a moderator is also used as the heat transfer medium to create steam to drive the turbines.

1.4 There are currently more than 430 nuclear power stations in operation worldwide, with a total net installed capacity of approximately 370GW. Of these, more than 400 are water moderated[63]. In the UK, there is only one light-water reactor in operation at Sizewell in Suffolk. It is likely that any new nuclear power stations that might be built in the UK would be water moderated[64].

62 Deuterium is an isotope of hydrogen with a proton and a neutron in its nucleus.
63 International Atomic Energy Agency (IAEA) – www.iaea.org/programmes/a2/index.
64 Based on discussions with industry during 2006 Energy Review and responses to the Energy Review consultation, http://www.dti.gov.uk/energy/review/consultation-submissions/page27883.html

**FIGURE 1.1. DIAGRAM OF LIGHT WATER REACTORS**



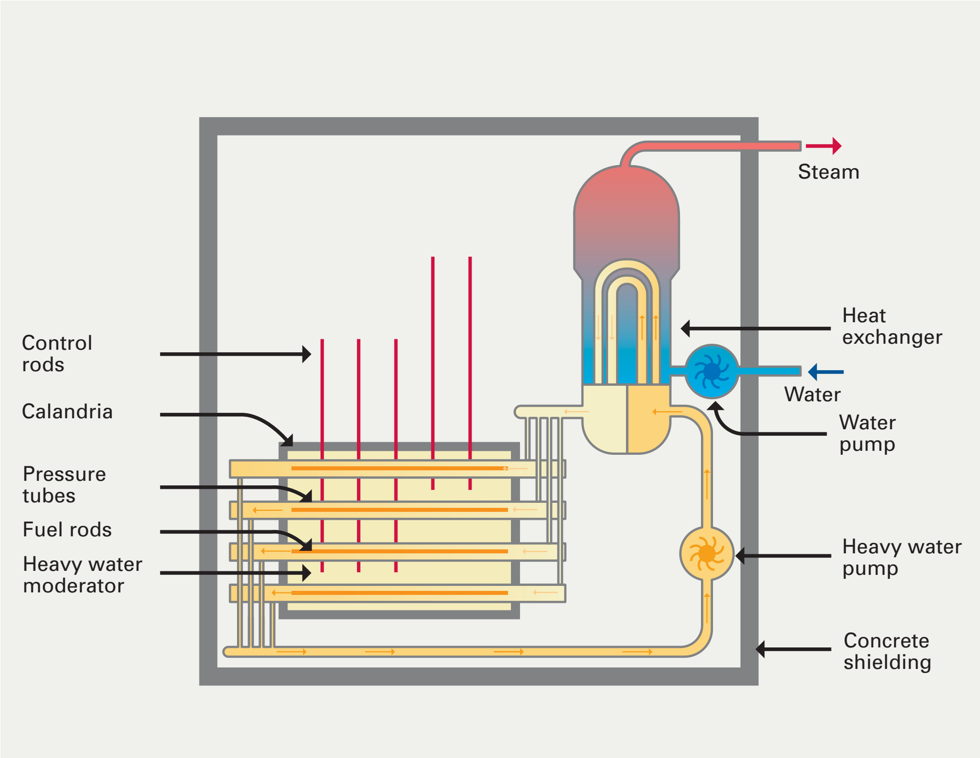

*Source: DTI*

Figure 1.1 The Pressurised Water Reactor (PWR) (top), is one of the more widely used designs for nuclear power stations. The PWR maintains water under pressure in a containment vessel. Nuclear reactions in the core heat water flowing through the reactor. The pressure prevents the water from boiling. The hot pressurised water then travels to a steam generator, transfers its heat to a second low-pressure circuit where water turns into steam that powers the turbine and electricity generator. In a Boiling Water Reactor (BWR) (bottom), water boils in the "primary circuit," and feeds the steam turbine directly.

1.5 There are two main types of LWR, Pressurised Water Reactors (PWRs) and Boiling Water Reactors (BWRs). A number of manufacturers produce different variations of these designs. In both PWRs and BWRs, heat from nuclear reactions turns water to steam which then powers a turbine (see Figure 1.1). The main difference between the two reactor designs is that the water in a PWR is under pressure and does not boil. The heat from this pressurised water heats a secondary un-pressurised circuit which creates steam to power the turbine and generator.

1.6 The most common type of heavy water reactor is the Pressurised Heavy Water Reactor (PHWR), of which there is one pre-dominant design, the CANDU, or Canadian-Deuterium Reactor. Like the PWR, the PHWR has two coolant circuits, one of which is under pressure. The main difference between these designs is that instead of a single pressurised reactor vessel, the PHWR has a number of smaller pressure tubes for each fuel assembly (see Figure 1.2).

**FIGURE 1.2 DIAGRAM OF PRESSURISED HEAVY WATER REACTOR**




*Source: DTI*

Figure 1.2 Like PWRs, the PHWR has two coolant circuits, one of which is under pressure, instead of having a single pressurised reactor vessel, the PHWR has an array of smaller pressure tubes, one for each fuel assembly.

1.7 After extraction from the ground, raw uranium ore is refined and "enriched" in a process that increases the percentage of fissile material in the fuel. Most designs of nuclear power require the amount of fissile uranium to be increased from the amounts occurring naturally. Enriched uranium is then converted to uranium dioxide for fabrication into fuel rods for the reactor. Fuel is periodically removed from reactors to maintain performance. Operators can refuel PHWRs while they are generating electricity but LWRs have to be shut-down every 12 to 18 months for refuelling.

1.8 Technological improvements have increased how much energy a reactor can extract from fuel, the burn-up. The early nuclear power stations achieved an energy output of about 120GWh per tonne (GWh/t) of fuel. This has now risen to over 1200GWh/t, reducing the amount of fuel required and waste produced for each unit of electricity[65]. This has been achieved by developments in reactor designs that maximise fuel utilisation and by increased thermal efficiency of the whole power station.

65 "Nuclear Reactor Fuel – the current situation." Royal Society (1999).

## Oversight of nuclear power stations in the UK

1.9 The nuclear reactions that take place in nuclear power stations create a high level of radioactivity in the reactor. Radioactivity occurs naturally and is a normal part of our environment, but nuclear power stations create much higher intensities that require careful management while operating and after they have finished generating electricity.

1.10 In the UK, the Nuclear Installations Inspectorate (NII), a division of the Health and Safety Executive, and the environment Agencies (The Environment Agency in England and Wales and Scottish Environment Protection Agency in Scotland) regulate radioactive discharges from nuclear power stations. These agencies are also responsible for ensuring that workers, the general public and the environment are protected against exposure to radioactivity. This is discussed further in chapter six.

1.11 Generating electricity by nuclear power creates radioactive waste, some of which remains potentially hazardous for thousands of years. The storage and disposal of this waste is an important part of the nuclear fuel cycle and needs careful long-term management. Waste is categorised into three types, according to its degree of radioactivity and whether it generates heat; high level (HLW), intermediate level (ILW), low level (LLW)[66]. The different classifications define how the waste is dealt with. For example, LLW is sealed in steel containers and placed in shallow repositories. HLW is stored in storage ponds or cooled, dry storage facilities. This is discussed further in chapter eight.

1.12 When a nuclear power station reaches the end of its life, it has to be dismantled (normally referred to as decommissioned). This process also needs careful management. While many parts of the power station are easily decommissioned, some parts will be radioactive because they were exposed to high levels of radiation. In the UK, the Nuclear Decommissioning Authority (NDA) is responsible for the existing nuclear legacy and is decommissioning 20 civil public sector nuclear sites. This is discussed further in chapter eight.

66 Committee on Radioactive Waste Management – www.corwm.org.uk/content-657

## History of nuclear power station development in the UK

1.13 The UK's first commercial nuclear power station, a Magnox gas-cooled design, came on line at Calder Hall in Cumbria in 1956, following a White Paper in 1955 entitled *A Programme for Nuclear Power.* In the next 10-year programme, the UK built a total of 11 Magnox stations, containing 26 reactors, and exported one each to Japan and Italy.

1.14 In 1964, a further White Paper, *The Second Nuclear Power Programme*, proposed a new generation of Advanced Gas cooled Reactors (AGRs). Between 1976 and 1988, the Central Electricity Generating Board (CEGB) and the South of Scotland Electricity Board (SSEB) commissioned seven AGRs in the UK. The CEGB and SSEB, which were also responsible for the UK's oil, gas and coal-fired power stations, were broken up and privatised in the 1990s. The Government transferred ownership of the AGR power stations to what has become British Energy.

1.15 In 1981, the Government published a third White Paper on nuclear power. This announced plans to build five PWR power stations in the UK. The first of these, at Sizewell in Suffolk alongside an existing Magnox station, began generating electricity in 1995. The Government granted planning permission for a second power station based on the same design at Hinkley Point in Somerset, which already has an AGR power station. This was never constructed. There were also plans, later abandoned, for a second PWR at Sizewell. The decisions not to proceed with new construction were taken because, at that time, in the newly privatised electricity market, the Government ruled out providing public sector support for new nuclear power stations. In the then prevailing financial climate, it was unlikely that the private sector would fund such projects. In the UK there have not been any nuclear power stations built since Sizewell B.

**FIGURE 1.3. NUCLEAR POWER STATIONS IN THE UK**


Figure 1.3 There are currently ten nuclear power stations operating in the UK. These provide around 18% of our electricity. Source: DTI.

## Nuclear power in our generation mix

1.16 Electricity demand is highly variable. It varies depending on the time of day, for example it is greater during the day than during the night, and depending on the time of year, for example it is greater during the winter than the summer. The constant part of this demand is known as the baseload. Nuclear power stations are relatively inflexible in their output, and their cost profile (see chapter 4) means that it is economic to run nuclear power stations continually for every hour of the day. Therefore, they are best suited to meeting baseload demand. There are also technical factors which limits flexibility to respond quickly to changes in demand.

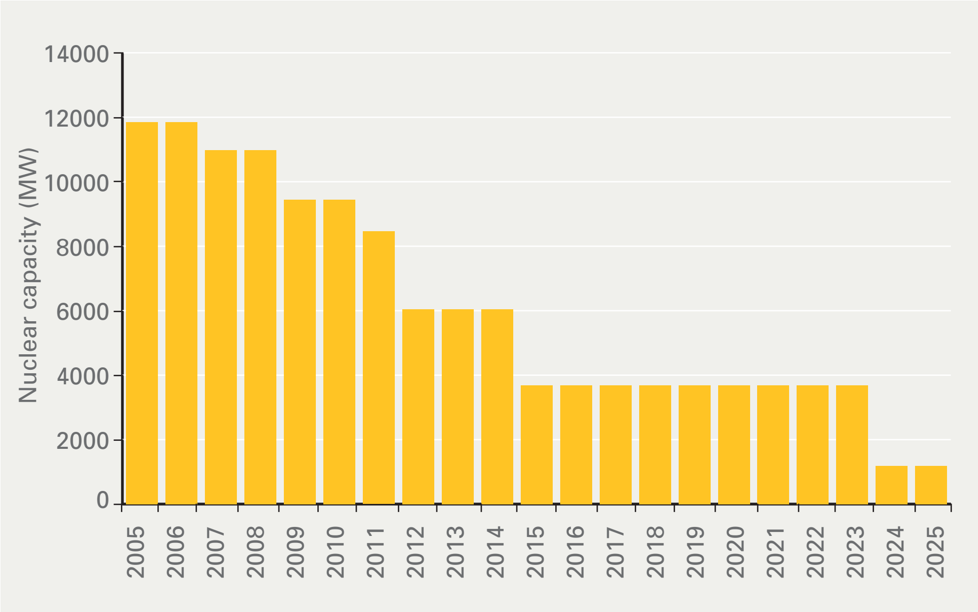
1.17 There are currently ten nuclear power stations operating in the UK. These provide around 18% of our electricity and a significant proportion of our baseload capacity (see Figure 1.3). The Energy White Paper[67] recognised that nuclear power makes an important contribution to electricity supplies and is a major source of low-carbon energy. The Energy Review Report recognised the contribution new nuclear could make to reducing carbon emissions and to security of our energy supplies.

1.18 Many of the UK's nuclear power stations are currently expected to close over the next two decades. By 2025, 10.2GW of nuclear generation capacity is likely to close (see Figure 1.4) based on published lifetimes. However, it is possible that the lives of the existing nuclear power stations could be extended and this would help mitigate the decline in low-carbon generation in the period towards the end of the next decade. Any life extensions would require the operator to establish a safety case with the NII and review their waste and decommissioning arrangements with the Nuclear Decommissioning Authority.

1.19 By 2016, around 8GW of coal-fired and 3GW of oil-fired generation are also likely to close to meet EU environmental legislation. Based on our expectations of demand growth, energy companies will need to invest in around 30-35GW of new electricity generating capacity over the next two decades, with around two-thirds needed by 2020. This is equivalent to about one-third of our existing capacity.

67 Energy White Paper "Our Energy Future – creating a low carbon economy", HMG Cm 5761, 2003.

**FIGURE 1.4. EXPECTED DECLINE IN NUCLEAR GENERATING CAPACITY IN THE UK**




*Source: DTI*

Figure 1.4 The UK's nuclear generating capacity is likely to decline over the next two decades, as many existing power stations come to the end of their published lifetimes.

**This chapter has set the scene for this report's discussion of the role that nuclear power could play in the UK's electricity supply. The following chapters will look in greater detail at some of the topics raised here as well as many of the issues that the UK has to consider when planning for secure and safe energy supplies.**

CHAPTER 2

# Nuclear power and carbon emissions

## Introduction

**This chapter brings together information on full lifecycle emissions of carbon dioxide from the generation of electricity by nuclear power. It compares the carbon emissions from nuclear power to other types of electricity generation and then considers how new nuclear power stations could reduce carbon emissions in the UK electricity generation sector.**

2.1 Growing concern about climate change has put pressure on the electricity supply industry to adopt technologies that do not add to the world's emissions of carbon dioxide. Nuclear power is one option, alongside renewable energy technologies such as wind power and solar energy, combined heat and power and distributed generation, and burning fossil fuels but with the carbon dioxide captured and stored underground.

2.2 Nuclear is a low carbon energy source[68]. This would potentially help us to tackle climate change. There are no carbon emissions from modern nuclear power stations at the point of electricity generation, unlike coal, gas and oil which emit large quantities of carbon as they generate power. Like all electricity generating technologies, carbon is given off over the total lifecycle of the facilities. For example, making steel and concrete for power stations of all types: coal, gas, nuclear or wind releases carbon dioxide into the atmosphere.

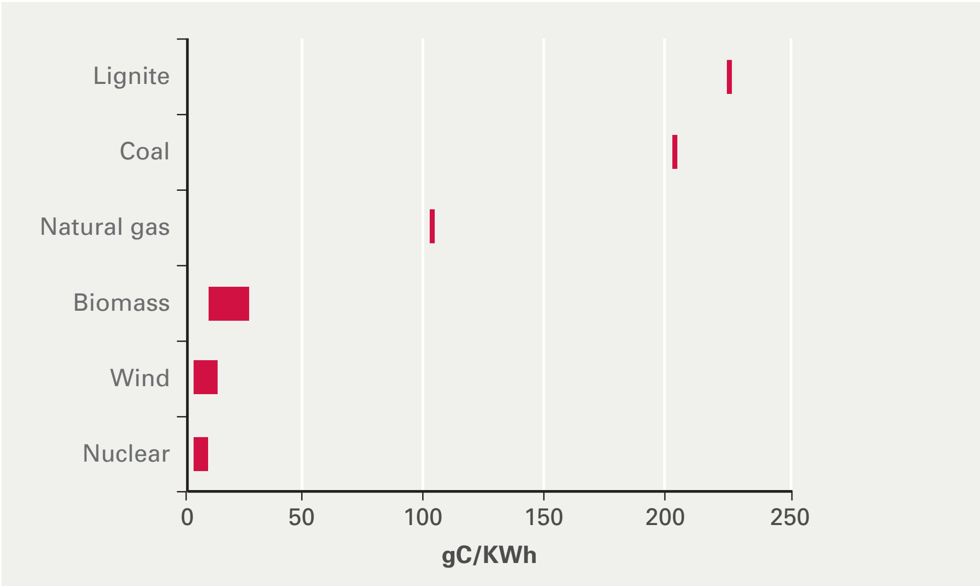
2.3 Carbon emissions specific to nuclear power arise when we mine, refine and enrich uranium, during construction of new power stations, during the disposal of spent fuel and its by-products, and when we finally decommission nuclear power stations and manage the waste created. For example, uranium mining primarily uses plant powered by diesel engines, which emit carbon dioxide. Processing and enriching the uranium draws electricity from the grid and therefore a proportion of it would result in carbon emissions from conventional power stations.

2.4 Studies of the lifecycle carbon emissions from nuclear generation suggest that emissions can be between $6gCO_2/KWh$ (grams of carbon dioxide per kilowatt hour) and $26gCO_2/KWh$[69]. This spread reflects the different assumptions and approaches adopted in analysing carbon outputs, for example there are different estimates of how much electricity is used in the enrichment process and the proportion of that electricity which is generated from low carbon sources.

68 Sustainable Development Commission, The Role of Nuclear Power in a Low Carbon Economy, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives, March 2006.
69 Energy Analysis of Power Systems, Uranium Information Centre, March 2006 http://www.uic.com.au/nip57.htm

2.5 Research by the Organisation for Economic Co-Operation and Development (OECD) Nuclear Energy Agency, the European Atomic Forum and the IAEA identify a range of carbon dioxide emissions from nuclear power between 2 and 6gC/KWh (grams of carbon per kilowatt hour) which is equivalent to between 7 and 22g$CO_2$/KWh[70]. This means that the lifecycle carbon emissions from nuclear power stations is similar to that from wind generation but just a few per cent of the carbon emissions from fossil fuel power stations[71].

**FIGURE 2.1. RELATIVE CARBON EMISSIONS OF GENERATING TECHNOLOGIES**




*Source: OECD Nuclear Energy Agency*

Figure 2.1 The lifecycle carbon emissions from nuclear power stations are low and comparable to those from wind generation. They are significantly lower than emissions from fossil fuel power stations.

2.6 In its analysis for the 2006 Energy Review, the Government assumed that carbon emissions from nuclear power were approximately 3gC/KWh, which is equivalent to 10g$CO_2$/KWh. Under this assumption, our analysis gives annual lifecycle carbon dioxide emissions from nuclear power stations of 87,000 tonnes per GWh (25,000 tonnes of carbon)[72]. We considered it reasonable to make a prudent judgement, above the OECD Energy Agency and roughly halfway between the extremes highlighted in the studies identified by the Uranium Information Centre. This is because the high end estimates assume that coal fired power stations provide most of the electricity used during the lifecycle, and the low-estimates assume low carbon forms of generation predominate. However, in the UK, we expect, even with the anticipated growth in renewables, that gas-fired generation will continue to play an important role in the future energy mix alongside new more efficient coal power stations.

70 Sustainable Development Commission, The Role of Nuclear Power in a Low Carbon Economy, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives, March 2006.
71 Sustainable Development Commission, The Role of Nuclear Power in a Low Carbon Economy, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives, March 2006.
72 DTI analysis: http://www.dti.gov.uk/energy/whitepaper

2.7 We can expect carbon emissions from nuclear power to fall further as new reactor technologies lead to more efficient power stations with fewer components, with the ability to extract more energy from their fuel[73]. Carbon emissions will also decline as we switch to generating technologies that produce less carbon, so that the electricity used in fuel enrichment and construction of power stations, for example, is itself generated in a way that produces less carbon.

2.8 However, as with wind power, the production of materials such as cement and steel for nuclear power stations is carbon intensive. Steel and cement manufacture is likely to remain a carbon intensive process because some of their emissions arise from the chemistry of the process. Emissions could, however, be reduced by more resource efficient designs and construction techniques[74].

## Carbon savings from nuclear power

2.9 To estimate the contribution new nuclear power stations could make to reducing carbon emissions, we have to make some assumptions about carbon emissions from nuclear power. We also have to make some assumptions of the generating technology, and its associated carbon emissions, that nuclear power stations are likely to displace.

2.10 We can estimate how much carbon we save from our existing nuclear power stations by comparing their carbon emissions with those that might come from power stations using different fuels. When the Sustainable Development Commission made this comparison in 2004, it estimated that existing nuclear power stations saved 5% to 12.6% of the UK's total carbon emissions each year, depending on whether gas or coal were to provide the electricity that now comes from nuclear power.

2.11 When considering investment in new electricity generation, the private sector is likely to choose gas-fired power stations to provide much of the expected need in new and replacement capacity. Historically, gas has been the new-build plant of choice by private investors, because of its relatively low capital costs, and the relative ease of securing development consent, which makes it a lower risk investment[75]. While generators have recently been showing a revived interest in coal, in our analysis we use gas-fired generation as a reference plant.

2.12 When we came to assess the potential carbon savings of building nuclear power stations rather than gas-fired power stations, we made some prudent assumptions about the efficiency of gas-fired generation[76]. In our central case, we assumed that carbon dioxide emissions from a 1GW gas-fired power station would be 2.6 million tonnes a year (712,500 tonnes of carbon). If a 1GW nuclear

73 For example, the AP1000 has 50 per cent fewer valves, 83 per cent less piping, 87 per cent less control cable, 35 per cent fewer pumps and 50 per cent less seismic building volume than a similarly-sized conventional plant; http://www.ap1000.westinghousenuclear.com.

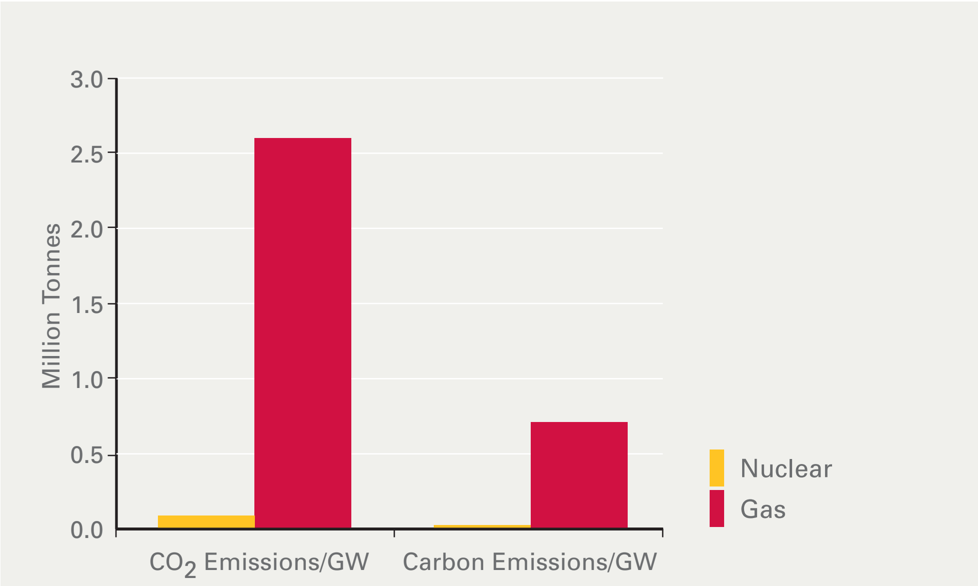
74 Sustainable Development Commission, The Role of Nuclear Power in a Low Carbon Economy, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives, March 2006.

75 Sustainable Development Commission – Paper 4: The Economics of Nuclear Power, 2006.

76 See Cost Benefit Analysis of Nuclear Power available from the DTI website: http://www.dti.gov.uk/energy/whitepaper

power station were built instead, there would be a net annual saving of 2.53 million tonnes of carbon dioxide a year (689,000 tonnes of carbon)[77]. This may even underestimate nuclear power's carbon savings. This is because estimates of emissions from gas-fired generation do not include the full lifecycle. In other words, the gas fuel cycle creates carbon emissions, for example during recovery of gas from the sea bed and from construction of power stations, but we do not have sufficient data to be able to form a reliable view of these emissions (see Figure 2.2).

**FIGURE 2.2. COMPARING CARBON EMISSIONS FROM NUCLEAR AND GAS-FIRED GENERATION**




*Source: DTI Analysis*

Figure 2.2 Using gas-fired power stations as a benchmark, nuclear power has much lower carbon emissions. The difference could be even bigger because, unlike our calculations for nuclear power, the estimates of carbon emissions from gas-fired power stations does not include some of the outputs produced at the "front end" of the lifecycle. Some analysis uses carbon as the reference point, while other research papers base calculations on carbon dioxide. This chart gives the calculation in both forms.

77 DTI Analysis for Energy Review, http://www.dti.gov.uk/energy/whitepaper

**The Government believes that, based on the significant evidence available, the lifecycle carbon emissions from nuclear power stations are about the same as wind generated electricity with significantly lower carbon emissions than fossil fuel fired generation. As an illustration, if our existing nuclear power stations were all replaced with fossil fuel fired power stations, our emissions would be between 8 and 16MtC (million tonnes of carbon) a year higher as a result (depending on the mix of gas and coal-fired power stations). This would be equivalent to about 30-60% of the total carbon savings we project to achieve under our central scenario from all the measures we are bringing forward in the Energy White Paper. Therefore, the Government believes that new nuclear power stations could make a significant contribution to tackling climate change. We recognise that nuclear power alone cannot tackle climate change, but these figures show that it could make an important contribution as part of a balanced energy policy.**

## Question 2

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?

CHAPTER 3

# Security of supply impacts of nuclear power

**This chapter sets out the key drivers of electricity security of supply and explores the potential contribution that nuclear power could make in delivering secure supplies of electricity in the UK.**

3.1 A key objective of the Government's energy policy is to achieve secure, reliable, supplies of energy. In respect of electricity, this requires sufficient power stations to generate electricity, sufficient supplies of input fuel and associated infrastructure. It also means avoiding socially unacceptable levels of interruption to consumers' electricity supplies and avoiding costs to the economy from the unexpectedly high or volatile prices, which can be associated with limited supplies of electricity.

3.2 This chapter sets out information on:

- the key features of security of electricity supply;
- the role that nuclear could play in contributing to the security of our electricity supplies; and
- the security of supply risks associated with nuclear power.

## What are the key features of security of electricity supply?

3.3 The unique characteristics of electricity mean that at any point in time the demand for electricity has to be met simultaneously by electricity supplies.

3.4 This means that at any point in time, we need:

- **Sufficient capacity to generate electricity** – Given that it is technically difficult and not commercially feasible to store electricity on a large scale, electricity cannot be "stockpiled" in one period of time for use in the future. Additionally, the transmission grid has limited flexibility to cope with imbalances in supply and demand. This means that the electricity system is vulnerable to the risk that there may be insufficient capacity to meet demand at a particular point in time, for example in the event of an unexpected outage of a power station or if demand levels rise above normal. Such risks can be managed by maintaining a level of spare generation capacity that is in excess of the expected level of peak electricity demand (commonly referred to as a capacity margin).
- **A range of different electricity generation technologies** – The individual characteristics of different electricity generation technologies each contribute to the ability of the generation mix to generate sufficient electricity supplies. For example, some generation capacity needs to be flexible to accommodate variations in the demand for electricity during the day – i.e. at peak vs. non-peak times and during the year i.e. summer vs. winter. Additionally, if a technology specific problem forces the outage of a number of power stations, the availability

of alternative technologies reduces the risk of a supply interruption. An alternative way of providing diversity and managing the risk of not having sufficient supply to meet demand is through demand-side flexibility. This means that when the supply/demand balance gets tight, prices rise and cause consumers who are not prepared to pay the resulting higher prices to reduce their demand. Reducing demand in this way is common practice amongst some industrial customers.

- **Reliable supply chain** – The generation of electricity also requires the supply chain for producing electricity to be reliable. This includes reliable access to input fuels such as gas, coal and uranium (if new nuclear is to be an investment option), and reliable pipeline and import terminals and storage facilities, to transport primary input fuels to power stations. Finally, it includes reliable facilities for the generation of electricity and an adequate transmission and distribution network infrastructure to transport electricity to final customers.

3.5 While each of these elements is necessary to manage the risks of supply interruptions, they are not on their own sufficient to ensure secure supplies of electricity are available. For example, the intermittent nature of wind generation means you cannot guarantee that sufficient supplies of electricity are available at any point in time, regardless of the amount of installed wind generation capacity.

3.6 The security of the electricity system as a whole needs to be consistently maintained over time in order to accommodate fluctuations in the conditions that affect the supply and demand of electricity throughout the electricity supply chain. This means that sufficient timely investment is required to accommodate growth in demand, replace retiring power stations and to maintain the reliability of infrastructure throughout the supply chain.

## Future risks to security of supply

3.7 The Energy White Paper[78] highlights the risks to security of supply that the UK will need to manage over the next two decades and beyond. We face increasing reliance on imported energy and need timely investment in new generation capacity both to meet increasing demand and replace closing and ageing existing power stations.

3.8 There are a number of uncertainties related to how fossil-fuel and carbon prices and technology costs will evolve over the long term (this is discussed further in chapter five). These are important factors in determining the costs and attractiveness of investing in the different available and developing generation technologies. It is also difficult to predict with accuracy the level and pattern of future electricity demand and consequently, difficult to predict the amount of electricity supplies that will be required. For instance, the development of low carbon technologies in other sectors of the economy could potentially have a significant impact on the demand for electricity.

78 Energy White Paper, *Meeting Our Energy Challenge*, 2007, http://www.dti.gov.uk/energy/whitepaper

## Creating diversity

3.9 The range of uncertainties about possible developments in the energy and electricity sectors highlights that we cannot know today which mix of generation technologies is the most appropriate for ensuring future electricity security of supply, while making the long-term transition to a low-carbon economy.

3.10 We believe that the risks to security of supply and costs of future electricity generation are best managed by creating a diverse portfolio of technology options for generating electricity. The Government's role is to set a market framework that encourages diversity. We believe that private sector energy companies should have the widest choice of technologies in which to invest.

3.11 The different characteristics of the range of available and developing technologies contribute to the flexibility necessary to be able to respond to future developments that we cannot yet envisage. We believe this is the most appropriate way to manage the risks to security of supply in the electricity generation sector.

## Harnessing diversity through markets

3.12 Market participants are best placed to manage the complex range of interrelated factors affecting the profitability of electricity generation investments and how these might evolve over time. We therefore believe that a market-based approach is the best way to decide which combination of these options is invested in, determining our future electricity generation mix.

3.13 However, in order to make investment decisions that support the achievement of the Government's energy goals, market participants need effective price signals that reflect the true costs (including the costs of carbon emissions) to companies of generating electricity and the value consumers attach to buying electricity. This enables the market to:

- balance electricity supply and demand in the short term;
- ensure timely investment in new capacity over the long term; and
- help reduce the UK's carbon emissions.

## How can nuclear affect security of supply?

3.14 Diversity of electricity supplies is maximised where the mix of technologies that energy companies can choose to invest in have different characteristics. The characteristics of nuclear power are very different to those of conventional fossil-fuel based or renewables generation. Allowing nuclear to be an investment option therefore brings the potential for added value in managing the risks to the security of electricity supplies. The chapter sets out below the specific characteristics of nuclear power that can affect the security of the UK's electricity supplies.

### Fuel supplies

3.15 The UK is increasingly reliant on imports for electricity generation fuels. For example by 2020, 80% of the UK's gas requirements will be sourced from imports[79]. Additionally, long term global reserves of fossil-fuels are declining and the International Energy Agency (IEA) has highlighted uncertainty over whether energy suppliers will make sufficient investments to extract these reserves[80].

79 DTI, Energy and Carbon Emissions Projections, 2007, http://www.dti.gov.uk/energy/whitepaper
80 IEA, *Natural Gas Market Review 2007, Security in a globalising market to 2015.*

3.16 Nuclear fuel supply is a stable and mature industry[81]. Based on the levels of global nuclear generation in 2004, the known available reserves of uranium that can be mined for less than $130/kg (approximately the uranium price in 2006[82]) would last for the next 85 years[83]. Moreover, the IEA have concluded that world uranium resources are more than adequate to supply the expected global expansion of nuclear power. It is currently mined in 19 different countries and resources of economic interest have been identified in at least 25 other countries. The largest reserves are in Australia and Canada[84]. Therefore including new nuclear power as an option for private sector investment would spread the supply risks that could be associated with a particular fuel or region of the world, thus making the electricity system less vulnerable to supply interruptions. The availability of fuel is discussed in more detail in chapter ten.

3.17 Including nuclear power in the generation mix may result in a reduced need for gas-fired power stations, and consequently, reduce gas import requirements; gas supplies are more heavily concentrated in countries at greater risk of political instability. Moreover, the supply chains of nuclear fuel, gas and coal are not interdependent and an interruption in the supply of gas or coal is unlikely to affect the supply of uranium. Consequently, the option of including new nuclear in a diverse mix increases the diversity of input fuels that we are reliant on and spreads the risks of fuel supply interruptions.

**Construction and operation**

3.18 The operation of a nuclear power station has limited flexibility because of certain technological factors. This means that nuclear power is suited to operating continuously and providing baseload generation. Conversely it cannot meet the need for flexible power stations to respond quickly to changes in demand. It is also technically feasible for coal and gas-fired generation to be used for baseload generation. However, given the carbon emissions associated with fossil-fuel fired generation and in the absence of carbon capture and storage, nuclear power emits significantly less carbon (see chapter two).

3.19 Technical faults in a nuclear power station could result in one station being out of operation for long periods of time – as has occurred with some of the existing UK fleet – or an entire fleet being out of operation (if the nature of the problem affected all stations of a particular design). Clearly the greater proportion of nuclear in the mix, the greater the potential impact on electricity security of supply associated with any technical fault. However, we believe the probability of such an event in the case of any new nuclear power stations is low because the designs of power stations that might be proposed in the UK are evolutions of significantly more reliable designs.

3.20 Nuclear power stations have long lead times. By contrast the construction period for gas-fired power stations is only approximately four years. This means that new nuclear power stations cannot be built in time to address the potential capacity tightness that we could see around the middle of the next decade and other technologies would have to be employed to deal with this possible shortfall. But new nuclear power stations could begin to

81 Sustainable Development Commission, *Paper 4: The Economics of Nuclear Power*, 2006.
82 http://www.cameco.com/investor_relations/ux_history
83 NEA and IAEA, *Uranium 2005: Resources, Production and Demand*, 2006 (The "Red Book")
84 NEA and IAEA, *Uranium 2005: Resources, Production and Demand*, 2006 (The "Red Book")

make an important contribution in meeting the expected demand growth and expected power station closures by around 2020 and beyond.

3.21 If announcements of new nuclear power stations deterred other investors from building other generation capacity, and there were then delays in the commissioning of a nuclear power station, it could exacerbate security of supply risks and require the provision of alternative generation capacity and/or demand side response[85].

**Costs**

3.22 Nuclear power is a proven, mature technology that can be deployed on a large scale. Over the lifetime of a nuclear plant, and we believe that at any positive carbon price, it has lower costs per unit of electricity output (known as levelised costs) than gas-fired generation (see chapter four).

3.23 The input fuel costs of nuclear power are lower as a proportion of total cost than coal and gas-fired generation[86]. The input fuel costs are also more stable[87]. According to analysis prepared for the Energy Review and updated for this consultation, fuel costs make up 11% of total costs for nuclear power[88], and of total fuel costs only 10% is the cost of uranium ore[89]. Therefore it only accounts for 1% of overall generating costs. By contrast, fuel costs are the largest component of total costs for gas-fired generation, estimated to be 71% according to the Government's analysis[90]. This means that gas-fired generation costs are susceptible to fluctuations in fossil-fuel prices.

3.24 Historically, gas-fired power stations have been seen as the marginal generation plant which sets the wholesale price of electricity. However, the cost profile of nuclear power with low operating costs and low long-run marginal costs, means that including new nuclear power stations as an option can effectively place a cap on long-run wholesale prices. This means that while gas-fired power stations are the marginal generation power station, wholesale prices are also susceptible to fluctuations in fossil-fuel prices.

3.25 If future gas prices continue to be high and available fossil-fuel resources become increasingly constrained, the costs of conventional fossil-fuel based generation could increase, putting upward pressure on electricity prices. Similarly, higher carbon prices would undermine the economics of fossil-fuel fired power stations raising their generating costs. Nuclear power can therefore be beneficial in providing a hedge against these risks of higher generation costs.

3.26 Additionally, nuclear power does not require the same amount of fuel infrastructure as other generating technologies. For example, gas transport and

85 Note that nuclear should not crowd out investment in electricity generated from renewables because the Renewables Obligation effectively segments the renewables market from the rest of the electricity generation market, thereby "protecting" investments in renewables.
86 DTI analysis 2006.
87 IMF, Summary volatility statistics, March 2007.
88 DTI analysis 2006.
89 IEA/NEA, *Projected Costs of Generating Electricity*, 2005 Update.
90 DTI analysis 2006.

storage facilities are necessary to maintain reliable gas-fired power stations. Therefore, the overall costs of producing the same amount of electricity by nuclear power can be lower because the supporting infrastructure is less expensive. The economics of nuclear power is discussed further in chapter four.

## Conclusion

3.27 Nuclear power has some particular characteristics that can contribute to achieving the objective of secure electricity supplies. Whilst there are some limitations to the contribution that nuclear power can make to security of supply, all technologies have limitations. Security of supply cannot be achieved via a reliance on a single technology or fuel given the uncertainties around how future events (particularly prices, costs and demand) may unfold over time and how these affect the ability of the electricity system to meet our energy needs. It is clear therefore, that nuclear power can offer benefits in ensuring future security of electricity supplies as part of a diversified generation mix.

**The Government believes that the best way to achieve secure energy supplies is by encouraging a diversified mix of generating technologies, and that energy companies should have the widest choice of technologies in which to invest. We know that our nuclear power stations are coming to the end of their lives; not allowing energy companies to invest in new nuclear power stations would increase our dependence on fewer technologies and expose the UK to risks to the security of our energy supplies.**

**The Government believes that allowing energy companies the option of investing in nuclear power stations would make a contribution to maintaining a diverse generating mix, with the flexibility to respond to future developments that we cannot yet envisage. Allowing energy companies the option of investing would therefore make an important contribution to the security of our energy supplies.**

## Question 3

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

CHAPTER 4

# Economics of nuclear power

## Introduction

**This chapter reviews the high-level economics of nuclear power in order to assess the competitiveness of nuclear power compared to other forms of electricity generation. It discusses the cost elements of nuclear power and the uncertainties on costs estimates. It also makes an assessment of the benefits to the UK, taking account of the benefits of reduced carbon emissions and the estimated quantification of the benefits of security of energy supplies which was used for the nuclear cost benefit analysis.**

4.1 As for any type of power station, energy companies would decide whether to propose, develop, construct and fund any new nuclear power stations. Private sector financing would also need to cover the full costs of decommissioning and full share of waste management costs. Therefore, it would be for the private sector to ultimately take a view on the financial viability of any proposal for a new nuclear power station.

4.2 The costs and economics of any new nuclear power station will depend on, among other things, the contracts into which developers enter for the construction of the power station, the cost of capital and ultimately the electricity generated. Under this framework, energy companies would not bring forward any proposals for a nuclear power station if they did not think it would be economic.

4.3 This high-level assessment aims to identify whether nuclear power could be a competitive form of electricity generation for the UK. It also takes into account the potential impact of valuing the low carbon emissions from nuclear generation, and the wider benefits for the UK of improved security of energy supplies that nuclear power would bring through reducing the need to import fossil fuels for power generation. In making their assessments, energy companies will have to take into the account the uncertainties in the energy market over the coming decades, for example such as how the 20% EU renewables target will be implemented across Europe.

4.4 In the light of such uncertainties our analysis is based on a number of different scenarios for nuclear costs, and for gas and carbon prices, rather than a single forecast. These projections reflect the uncertainties in the energy market, for example on the estimates of nuclear costs, differing views on fossil fuel prices and the extent of the commitment to reduce carbon emissions through the introduction of a carbon price. Our cost estimates include the costs of decommissioning of nuclear power stations and long-term waste management (commonly called back-end costs). The analysis in this chapter is based on the comprehensive cost benefit analysis of nuclear generation prepared for the 2006 Energy Review. A copy of the cost benefit analysis is available from the DTI website[91].

4.5 This chapter sets out information and evidence on:

- the cost components of nuclear power;
- uncertainties in cost estimates for nuclear power;
- Government estimates of the costs of nuclear power;
- cost-effectiveness of power generation in the UK; and
- valuing the benefits of reduced carbon emissions and security of energy supply.

## Cost profile of nuclear power

4.6 There are four major components in the costs of nuclear power; capital, operations and maintenance, fuel and back-end costs. A recognised way of estimating the costs of electricity-generating technologies is to add the capital costs, and, in the case of nuclear power, the back-end costs, onto the operating costs, and to divide this by the amount of electricity that the plant is expected to generate during its lifetime. This calculation yields a measure known as "levelised costs". These are usually expressed in terms of costs per kWh or MWh.

4.7 *Capital costs* – also referred to as construction costs – are those incurred during the planning, preparation and construction of a new power station. These include the costs of physical materials and labour, as well as financing costs during preparation and construction. However they usually exclude the costs of connection to the electricity transmission network or the initial fuel stock.

4.8 Nuclear power stations are large facilities that take years to plan, build and commission. Thus, capital represents the largest cost component and is the biggest influence on the levelised cost of nuclear power.

4.9 Three variables drive the cost of financing the capital component of a nuclear power station:

- the length of the pre-construction period;
- how long it takes to construct the plant; and
- the cost of the capital[92].

4.10 The development period before construction reflects how long it takes to secure consent and planning approvals. This process can take up to eight years and bears a cost (estimated to be in the region of £250 million[93]). Estimates of how long it takes to construct a nuclear power station, after the planning phase, vary from five to ten years[94]. Longer construction times increase financing costs as interest charges accumulate. The capital costs of

91 http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007
92 Cost of capital is sometimes known as the discount rate. Broadly speaking, it reflects the cost of obtaining capital for a project, for example the return that an investor would require on their investment.
93 Environmental Audit Committee, *Keeping the lights on: Nuclear, Renewables and Climate Change,* March 2006.
94 See Cost Benefit Analysis of Nuclear Power at http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

any large construction project depend on the discount rate. Figures from the IEA/NEA show that differing discount rates can increase levelised cost by between 50% and almost 70%[95]. A recent report by Greenpeace applied a 15% discount rate to the cost benefit analysis assumptions which resulted in an almost 40% increase in the levelised cost[96].

4.11 *Operations and maintenance costs* – also referred to as O&M costs – relate to the management and upkeep of a power station during its lifetime. O&M costs exclude fuel costs but include labour, insurance, security, spares, planned maintenance and corporate overhead costs. Existing nuclear power stations provide an extensive source of data on O&M costs. The range in O&M costs, between £3.5/MWh and £11.5/MWh, (see Table 2 in the cost benefit analysis) could reflect, among other things, labour costs in different countries.

4.12 O&M costs also include the cost of insurance. There is a special regime regulating liability for third-party injury and property damage caused by occurrences and activities at nuclear power stations or by occurrences involving nuclear material in transit. Operators are liable regardless of fault, and others (for example contractors) are relieved of potential liability. The liabilities of operators are limited (geographically, in monetary amount and time). Operators must maintain insurance or other financial security covering their liabilities. This system results from the Paris Convention on third-party nuclear liability and the Brussels Supplementary Convention, which provide for a special liability regime for loss caused by nuclear activities, taking into account the unique circumstances of the nuclear industry. In the UK the main implementing provisions are section 7 onwards of the Nuclear Installations Act 1965.

4.13 It would be for operators of existing and any future new build power stations to bear the cost of insurance[97]. Under the Brussels Convention, the Government steps in to provide compensation when (broadly speaking) the operator's liability limit is exceeded, though Government liability is itself limited in principle, and in certain circumstances contributions would be due from other signatories to the Conventions.

4.14 Operators' costs under these arrangements are likely to rise in future. The Paris and Brussels Conventions[98] were revised in 2004, among other things substantially increasing the minimum cap on operator liability per major incident to €700 million (and therefore the amount which must be covered by insurance or other financial security) and introducing liability for certain kinds of loss other than injury or property damage – for example the cost of measures to reinstate impaired environment. When the revised Conventions are implemented in the UK there will be an increase in the liability amount and the cost of insurance for UK nuclear operators (present ones and any future ones). To the extent that commercial cover cannot be secured for all aspects of the new operator liabilities, the Government will explore the alternative

95 IEA/NEA, *Projected Costs of Generating Electricity*, 2005 Update. The study uses discount rates of 5% and 10%. See Cost Benefit Analysis of Nuclear Power at http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

96 http://www.greenpeace.org.uk/files/pdfs/nuclear/nuclear_economics_report.pdf

97 Arrangements are different for the Magnox power stations, only two of which are still operational. These are owned by the Nuclear Decommissioning Authority but operated on their behalf by contractors and the NDA pays for the insurance.

98 For further details refer to: http://www.nea.fr/html/law/nlparis_conv.html and http://www.nea.fr/html/law/nlbrussels.html

options available – including providing cover from public funds in return for a charge. In addition, in the event of a major accident, the amount of compensation required to be provided by the Government from public funds under the Brussels Convention will substantially increase because of the amendments to that Convention and there will be a requirement for the Government to step in where an operator's financial security proves to be insufficient or unavailable. The Energy Act 2004 gave powers to the Government to amend the Nuclear Installations Act 1965 to implement the amendments to the Paris and Brussels Conventions and we would expect to consult on this in due course.

4.15 Operators may also be affected by certain other industry specific legislation. For example it is intended to implement Articles 48 and 53 of the Euratom Basic Safety Standards Directive by providing for action to be taken where land (and in Scotland water) has been radioactively contaminated as a result of nuclear activities or a nuclear incident. We intend to legislate in a way which has regard to the liability principles of the Paris Convention as implemented in the UK and which does not impose liability on operators for which financial security is not available.

4.16 *Fuel costs* reflect the cost of fuel for the power station. A light-water reactor (LWR) requires new fuel every 12 to 18 months. Fuel represents a small component of the costs of nuclear power, even at IEA's upper estimate of £6.5/MWh[99]. Although the cost of uranium has risen in recent years (see chapter 10), uranium itself accounts for only some 10% of the cost of nuclear fuel[100]. Uranium conversion, enrichment and fuel fabrication are the biggest cost components. Nuclear fuel supply is a stable and mature industry whose costs have been broadly stable or falling for some years[101].

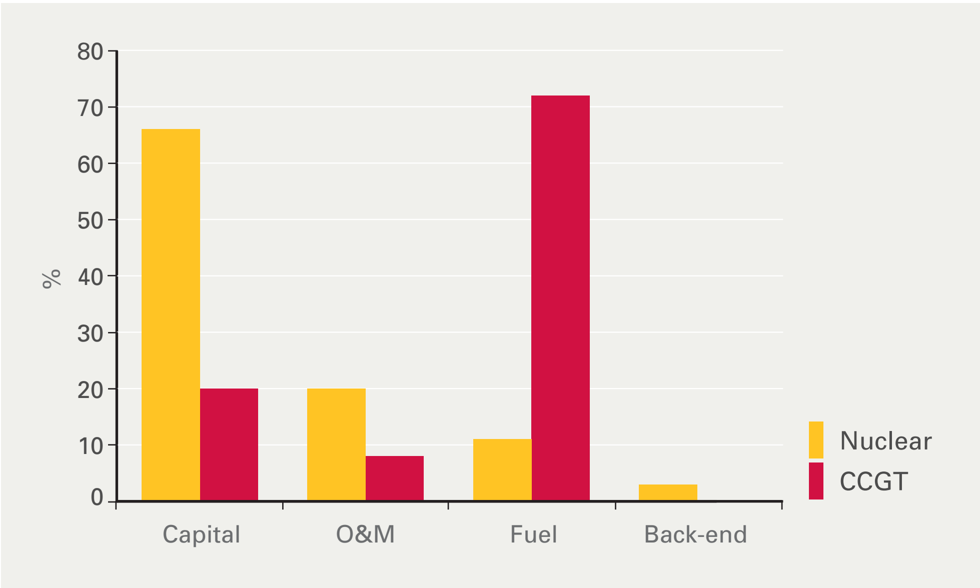
4.17 *Back-end costs* are those incurred in dismantling a nuclear power station at the end of its operating life, a cost common to all generating technologies. Nuclear power also has to bear the unique costs of long-term management and disposal of radioactive waste (see chapter eight). Back-end costs are potentially significant and subject to much uncertainty. For waste in particular, it is difficult to accurately state the additional costs of new build waste on the costs of geological disposal at this stage. As discussed in chapters 8 and 13, further work will be undertaken to establish the costs of any new build waste, and the range of likely uncertainty. The illustrative figure included in the cost benefit analysis is drawn from the example scenario from the CoRWM inventory and 2003 cost estimates prepared by Nirex[102]. Both decommissioning and waste management costs will not be incurred for many years and developers could have a long period over which to accrue funds to cover these back-end costs. As a result, the levelised cost for new nuclear is not particularly sensitive to the cost of waste disposal, given the time period over which waste disposal costs are discounted. For example, if the £276m figure used in the central case were doubled to £550m, the levelised cost of nuclear would increase by £0.3/MWh to £38.0/MWh. If the figure were trebled to

99 IEA/NEA, *Projected Costs of Generating Electricity*, 2005 Update.
100 IEA/NEA, *Projected Costs of Generating Electricity*, 2005 Update.
101 Sustainable Development Commission, *Paper 4: The Economics of Nuclear Power,* 2006.
102 Cost Profiles for CoRWM Option 7 (Deep Geological Storage) and Option 9 (Phased Deep Geological Storage), June 2006. Paper provided by Nirex (now NDA) to CoRWM in 2005/6

£825m, the impact is less than £1/MWh (£0.7/MWh over the base figure), giving a levelised cost of £38.4/MWh. Chapter eight includes a more detailed discussion of waste management and decommissioning.

4.18 For nuclear power, construction accounts for most of the costs, whereas for gas-fired generation (Combined Cycle Gas Turbine (CCGT)) fuel is the largest component (see Figure 6.1). In the UK, the electricity mix is such that gas-fired generation has historically been and is currently the marginal generation power station; the power station is flexible which means it can be operated in line with electricity demand (it can be started and shut-down relatively quickly) and therefore it sets the price of wholesale electricity. Although energy companies have recently been showing a revived interest in coal, they have historically seen gas-fired generation as the new-build power station of choice, based on its economics and the lower risk associated with such an investment[103]. For these reasons, we use gas-fired generation as a reference power station in our analysis in this document.

**FIGURE 4.1. COST PROFILE OF NUCLEAR AND GAS-FIRED GENERATION**




*Source: DTI Analysis 2006*

Figure 4.1 Cost Profile of Nuclear and Gas Fired Generation. In contrast to gas-fired generation, the levelised cost of nuclear generation is insensitive to fluctuations in fuel prices because it makes up a small percentage of total costs, and is particularly sensitive to the capital cost used.

## Uncertainties in cost estimates

4.19 Forecast and studies of the future costs of nuclear generation vary widely[104]. It is therefore important to consider a number of issues and uncertainties when analysing the evidence and reaching a conclusion. These uncertainties include:

103 Sustainable Development Commission, *Paper 4: The Economics of Nuclear Power,* 2006.
104 See Cost Benefit Analysis of Nuclear Power available at http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

- variables relating to estimates of capital costs;
- sources of data relied upon in forecasts;
- comparing international evidence;
- lack of operational plant of the kind likely to be built in the future;
- risks of delay before and during construction; and
- negative externalities of nuclear power with regards to safety and non-proliferation.

4.20 However, uncertainties in estimating the costs of nuclear generation do not preclude analysis of high-level economics. They do mean that any analysis must reflect this uncertainty and should take a prudent approach when reaching conclusions.

## Variables relating to capital costs

4.21 There are potential complications in making direct comparisons between cost assessments. These arise from the assumptions that they include. There is no internationally agreed definition of capital costs for nuclear power stations. For example, assumptions on capital costs may include the engineering costs associated with establishing a new programme of nuclear build, or the fuel for the initial commissioning, as well as assumptions on interest rates during construction and the cost of capital, all of which can have a significant impact on estimates.

## Sources of data

4.22 Most of the studies that provide the basis for estimating the potential costs of nuclear generation take their information from industry sources. This is inevitable when discussing not-yet-constructed power stations[105] and does not, necessarily undermine the evidence. Vendors of nuclear power stations have a legitimate interest in presenting costs in a way that maximises their chances of commercial success. Many of the studies that we have considered augment these estimates from industry, such as the Massachusetts Institute of Technology (MIT) study, to take account of this potential of industry estimates to present an optimistic assessment[106].

4.23 We need to be similarly cautious when considering the estimated costs of nuclear power stations that are already under construction. These are being constructed under commercially sensitive "turnkey" contracts with only limited information available. A turnkey contract is one offered at fixed price by the vendor for the construction of the power station. An alternative is for a cost-plus, where the vendor would receive a fixed margin over and above the cost of the plant. Vendors may also enter into early contracts as "loss-leaders" in the expectation that they will be able to recoup costs on subsequent projects.

## Comparing international evidence

4.24 Few reports exist that set out to assess the economics of building new nuclear power stations in the UK context. While we can draw on assessments from abroad, cost components can differ significantly between countries, in, for example, the costs of labour and / or capital. This variation is reflected in the range of estimates in the IEA/NEA study[107].

105 Sustainable Development Commission, *Paper 4: The Economics of Nuclear Power,* 2006.
106 See Cost Benefit Analysis of Nuclear Power at http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007.
107 IEA/NEA, *Projected Costs of Generating Electricity,* 2005 Update.

## Lack of operational plant

4.25 While a European Pressurised water Reactor (EPR) power station is under construction in Finland, with construction expected to start on an EPR in France in December 2007, and China plans to construct four AP1000 nuclear power stations, there is as yet no evidence on the operational performance of this next generation of nuclear power stations. There are examples of the next generation Advanced Boiling Water Reactor (ABWR) in operation. Another potential candidate for new nuclear build in the UK, these ABWRs allow us to compare the operational performance and estimates of this design. However, these reactors are in Taiwan and Japan rather than in the European Union, so it is difficult to make direct comparisons because of national differences, for example in the cost of labour or capital as discussed above.

4.26 The absence of recent direct experience of new nuclear build in the UK is an obstacle to detailed economic assessment. However, any new projects are likely to be modifications of earlier international power stations, with simplified designs and requiring fewer components. Therefore, it is fair to say that there is some experience of the costs of building and operating designs that the UK might build.

## Risk of delay before and during construction

4.27 The UK has not had a good record in constructing nuclear power stations to time and on budget. For example, Sizewell B, the most recent power station built between 1988 and 1995 in the UK by the Central Electricity Generating Board (CEGB) – the nationalised industry responsible for power generation, experienced 35% cost over-runs. However, we do not consider this to be the best indicator of the potential for new nuclear power construction in the UK. Electricity markets are now liberalised and competitive, creating greater incentives to keep costs down.

4.28 Moreover, the Government can influence the extent to which nuclear power stations might be delayed during the pre-construction period through improvements to the planning and licensing regimes. For example, the introduction of a Generic Design Assessment process, to identify the "licensibility" of designs before large capital commitments need to be made, could reduce the risk and uncertainty associated with regulatory delay. The commitment made in the 2007 Planning White Paper to reform the planning system for major infrastructure projects should lead to shorter and more predictable planning processes.

## Negative externalities not usually considered as costs

4.29 Nuclear generation can have wider negative impacts on society and the environment that are not addressed in the studies that form the basis for this economic analysis. Two potential negative effects that we should consider are:

- the risk of radiation release, either from the plant or from the resulting waste, following an accident or intentional damage; and
- the potential transfer of technology or nuclear material to nuclear weapons production.

4.30 These are important issues in reaching a considered view on whether nuclear has a role to play alongside other low-carbon technologies for electricity generation (see chapter five). However, we do not consider that the most appropriate approach is to monetise these negative externalities as part of an economic analysis.

4.31 The extremely low estimated probabilities associated with a major accident[108] mean that if an accident did occur, with significant costs of damage to people and the environment, it would still not have a material impact in monetised terms on the estimates. A purely economic approach to these issues would downplay important risks that go beyond pure economic and financial analysis. The Sustainable Development Commission, in reviewing its policy on nuclear power in 2005, reached the same conclusion[109]. Similarly, we cannot sensibly monetise the risk of diversion of nuclear materials to weapons production.

4.32 As we have mentioned earlier in this chapter, the compensation of third-party loss arising from the operation of nuclear power stations and transport of nuclear material will continue to involve potential government liability, in particular pursuant to the international regimes relating to such loss. Also as mentioned above we expect to implement Articles 48 and 53 of the Euratom Basic Safety Standards Directive for the nuclear industry in a way which will involve at least some degree of government liability.

## Government estimates of the costs of nuclear power[110]

4.33 The Government examined estimates made by the private sector on the potential costs of nuclear generation[111]. The average of these estimates was £30/MWh (see Figure 4.2). Our costs are at the higher end-of-market estimates, reflecting the prudent assumptions we used in our own analysis, as set out in Figure 4.2.

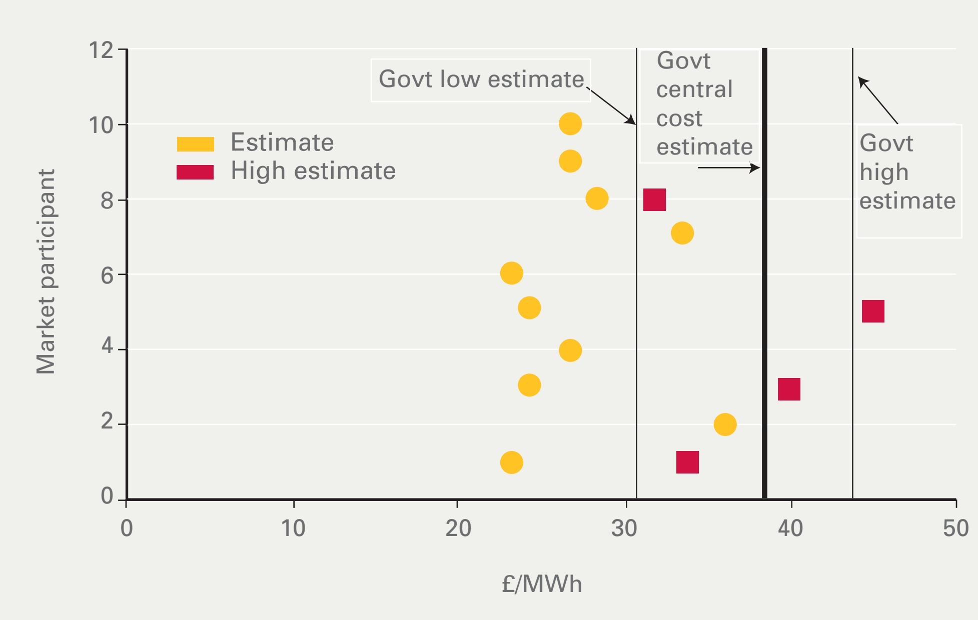
108 The literature suggests the probability of major accidents (core meltdown plus containment failure) is $4X10^{-9}$ in the UK. The associated expected cost is estimated to be of the order of £0.03/MWh to £0.30/MWh depending on the assumptions about discount rate and the value of life; using the figure at the top end of this range would not change the DTI cost benefit analysis. Introducing risk aversion, the results of the DTI cost benefit analysis in the central case would be robust for a risk aversion factor of 20 at the highest estimated value for the expected accident cost. For a summary of relevant literature, see *Externalities of Energy (ExternE), Methodology 2005 Update*, European Commission.

109 Sustainable Development Commission, *Paper 4: The Economics of Nuclear Power,* 2006.

110 These costs are taken from the cost benefit analysis used for the 2006 Energy Review. They are not indicative of the cost estimates that the Government would develop to assist in the development of arrangements to require developers of nuclear power stations to accumulate funds to meet their full decommissioning costs and full share of waste management costs. This is discussed in more detail in chapter eight.

111 See Cost Benefit Analysis of Nuclear Power available at http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

**FIGURE 4.2. ESTIMATES OF THE COSTS OF NUCLEAR POWER**




*Source: Data from Cost Benefit Analysis*

Figure 4.2 Estimates of the costs of nuclear power. Market estimates compared to the Government's cost estimates, show that the Government has taken a prudent approach in its cost estimates.

4.34 Based on the evidence explored in this chapter, the Government considered a range of nuclear costs:

- a central-cost case of £38/MWh;
- a low case of £31/MWh;
- a central-high case of £40/MWh; and
- a high case of £44/MWh.

4.35 The tables below set out the assumptions that were made for each of the cost components in each of these scenarios. We consider the high-cost case unlikely. Should the Government conclude that nuclear power has a role to play, we propose to undertake steps to reduce the risks of delays during the planning and licensing phases. More generally, we consider it unlikely because of the extreme caution in the estimates within this case. As discussed in chapters 8 and 13, further work will be undertaken to establish the costs of any new build waste, and the range of likely uncertainty.

| TABLE 4.1. ASSUMPTIONS FOR CENTRAL CASE NUCLEAR COSTS. | | |
|---|---|---|
| Key Item | Assumption | Source/Comment |
| Pre-development cost | £250 million | Environmental Audit Committee report "Keeping the Lights on: Nuclear, Renewables and Climate Change", March 2006 |
| Pre-development period | 8 Years | 5 years to obtain technical and site licence with 3-year public inquiry period. Sizewell B pre-development period was 7 years |
| Construction cost | £1,250/kW plus £500 million IDC[112] and £10/kW onsite waste storage every ten years over life | Total build cost is £2.8bn. Compares to estimates of £2.7bn for Finland EPR (based on recent press which suggest the final cost might be €4bn) |
| Construction period | 6 Years | Vendors estimates from 5 to 5.5 years. Sizewell B construction period was 7 years |
| Load factor | 80% rising to 85% after five years | Vendors expect 90% and over |
| Operational life | 40 Years | Vendors expect 60 year life |
| O&M cost | £7.7MWh (or £90 million per annum) | Within range provided by Sustainable Development Commission. Vendors expect O&M to be around £40 million per annum |
| Fuel supply cost | £4.4/MWh | Based on raw uranium price of $80/lb, which with enrichment and fabrication costs as published by Uranium Information Centre gives £2,400/kg all in cost. PB power notes that most studies assume a fuel cost of around £4/MWh |
| Waste disposal cost | Fund size of £276 million at end of 40 year life or £0.4/MWh | Assumes higher level waste is disposed in a national deep geological repository together with legacy waste. Fund growth is assumed to be 2.2% in real terms |
| Decommissioning cost | Fund size of £636 million at end of 40 years or £0.7/MWh | Cost is assumed to be £400 million/GW. Vendors estimates are from £325 million/GW for the EPR and £400 million for the AP 1000. Fund growth is assumed to be 2.2% in real terms |
| Cost of capital | 10% | Post-tax real discount rate, used in a number of studies and widely accepted by industry |

112 (IDC) Interest During Construction

Table 4.1. Assumptions for central case nuclear costs. The resultant levelised cost based on these assumptions is £38/MWh, which is a conservative estimate based on other studies and the industry estimates set out in figure 4.2.

| TABLE 4.2. ASSUMPTIONS FOR LOWER COST NUCLEAR SENSITIVITIES. | | |
|---|---|---|
| | Data | Levelised cost (£/MWh) |
| CENTRAL CASE | | **38** |
| Pre-development cost | £100 million (decrease of £150 million) | 36 |
| Pre-development period | 7 Years (12 month decrease) | 38 |
| Operation period | 60 years (20 year increase) | 37 |
| Construction cost | £850/kW (10% decrease) | 31 |
| Availability first five years | 90% (10% increase) | 37 |
| O&M cost | £35/kW | 35 |
| Fuel cost | £2,000/kg (£400/kg decrease) | 37 |
| Cost of capital | 7% (3% decrease) | 31 |

Table 4.2. Assumptions for lower cost nuclear sensitivities. This is analogous to the forecasts of the General Directorate for Energy and Raw Materials (DGEMP) of the French Ministry of the Economy, Finance and Industry for a programme of 10 reactors, or a 7% cost of capital or a combination of other factors. The resulting levelised cost ranges from £31/MWh to £37/MWh. The scenario with the assumption of low construction cost or low cost of capital results in a levelised cost of £31/MWh.

| TABLE 4.3. ASSUMPTIONS FOR HIGHER COST NUCLEAR SENSITIVITIES | | |
|---|---|---|
| | Data | Levelised cost (£/MWh) |
| CENTRAL CASE | | **38** |
| Pre-development cost | £300 million (increase of £50 million) | 38 |
| Pre-development period | 9 Years (12 month increase) | 38 |
| Construction period | 10 Years (4 year increase) | 41 |
| Operation period | 30 years (10 year decrease) | 39 |
| Construction cost | £1400/kW (10% increase) | 40 |
| | £1625/kW (30% increase) | 44 |
| Availability first five years | 60% (20% decrease) | 39 |
| Fuel cost | £3,000/kg (£600/kg increase) | 39 |
| Cost of capital | 12% (2% increase) | 42 |
| Decommissioning cost | £950 million fund after 40 years (50% increase) | 38 |
| Waste disposal cost | £320 million fund after 40 years (15% increase)[113] | 38 |

Table 4.3 Assumptions for higher cost nuclear sensitivities. In line with our prudent approach, we have considered a number of higher-cost estimates. Using these estimates we have created a number of scenarios to create a high-case (£44/MWh) and central-high case (£40/MWh), which could be considered as extreme given the conservative central case.

The evidence we discussed earlier in this chapter suggest that construction costs and the cost of capital are the greater areas of uncertainty. The high-case reflects a 30% overrun in construction costs or an increased cost of capital of 12%, considering these events together would give a levelised cost of £50/MWh.

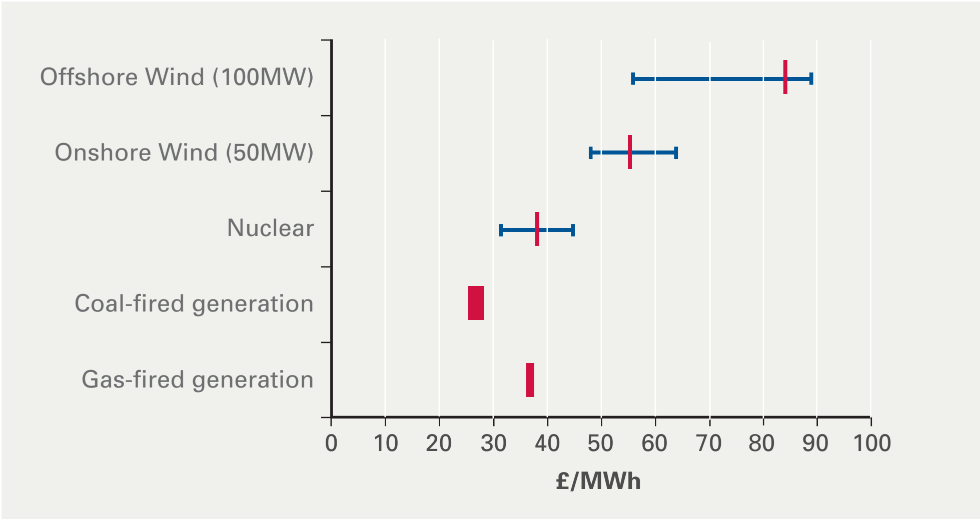
The central-high case reflects a number of different scenarios, for example it encompasses longer periods for pre-development and construction, lower load factors and operating life, and higher costs for decommissioning and waste management.

113 The levelised cost for new nuclear is not particularly sensitive to the cost of waste disposal, given the time period over which waste disposal costs are discounted. If the £276m figure used in the central case were doubled to £550m, the levelised cost of nuclear would increase by £0.3/MWh to £38.0/MWh. If the figure were trebled to £825m, the impact is less than £1/MWh (£0.7/MWh over the base figure), giving a levelised cost of £38.4/MWh.

## The cost-effectiveness of power generation in the UK

4.36 Using the same methodology to consider a range of plausible scenarios of generation costs, we have calculated levelised costs for electricity generation based on gas, coal and renewable resources[114] and using different scenarios for fuel and carbon prices (see Figure 4.3).

**FIGURE 4.3. LEVELISED COST OF ELECTRICITY GENERATION – BASED ON NOVEMBER 2006 FUEL PRICES AND NO CARBON PRICE**



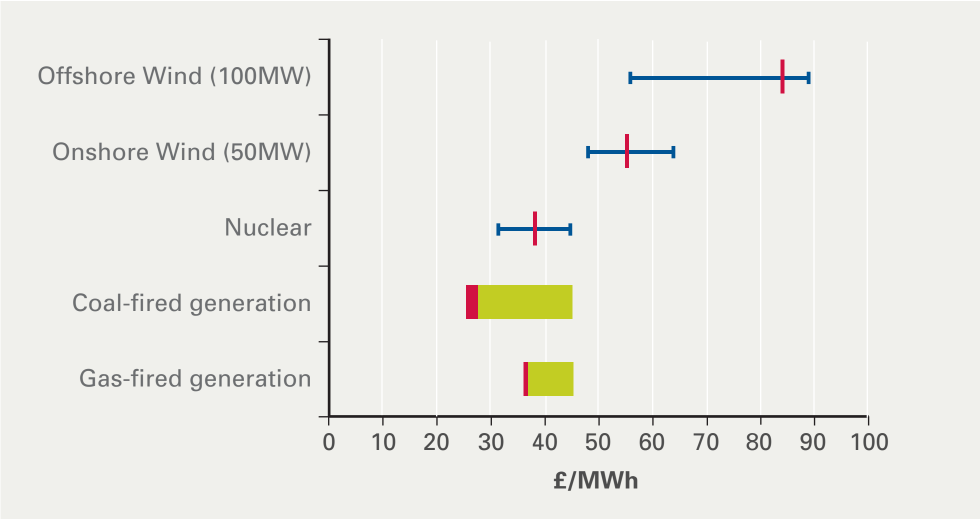

*Source: DTI analysis*

Figure 4.3 Levelised cost of electricity generation – based on November 2006 fuel prices and no carbon price. The wider range on coal-fired generation reflects the differing cost of pulverised-fuel technology and integrated gasification technology. The wider lines on nuclear and renewable technologies represent uncertainties in capital costs.

4.37 Where a price is attributed to carbon emissions, it gives a cost advantage to low-carbon technologies. If we assume an average carbon price of €25/t$CO_2$, nuclear power becomes the lowest cost form of generation (see Figure 4.4). This is because nuclear generation, along with renewable technologies, generates low emissions of carbon dioxide (see chapter two).

114 DTI Analysis, 2007

**FIGURE 4.4. LEVELISED COST OF ELECTRICITY GENERATION – BASED ON NOVEMBER 2006 FUEL PRICES AND A CARBON PRICE OF €25t$CO_2$**




*Source: DTI analysis*

Figure 4.4 Levelised cost of electricity generation – based on November 2006 fuel prices and a carbon price of €25/t$CO_2$. The green bars represent the additional cost of carbon emissions and show a cost of £44/MWh for gas-fired and coal-fired generation.

## Assessments of benefits to the UK

4.38 In considering the economics of nuclear electricity generation, we believe it is important to also take into account benefits that it offers in terms of climate change and energy security. Only then can we see whether nuclear generation offers economic benefits for the UK in general (see Table 4.4). Our analysis, which shows whether nuclear generation would provide economic benefits to the UK in a number of different scenarios, takes into account:

- estimates of nuclear costs (in low, central and high-cost cases);
- estimates of gas-fired generation (in low, central and high-cost cases)[115];
- estimates of carbon prices;
- the difference in carbon dioxide emissions between nuclear and gas-fired generation (see chapter two) to calculate the value of carbon saved according to a number of different carbon prices; and
- the security of supply benefits of nuclear over gas-fired generation (see chapter three).

A qualitative analysis on the alternative technologies to nuclear power is detailed in chapter five.

115 As mentioned in the Cost Profile section in this chapter, the electricity mix in the UK is such that gas-fired generation has historically been and is currently the marginal generation power station. Energy companies have also historically seen gas-fired generation as the new build power station of choice. For these reasons, we use gas-fired generation as a reference power station in our analysis in this document.

4.39 Where numbers are positive (see Table 4.4), they show that benefits in carbon emissions reductions and security of supply of nuclear outweigh the cost disadvantage against gas-fired generation. The welfare balance is the security of supply benefit (as discussed in chapter three) plus the environmental benefit of reduced carbon emissions, net of any cost penalty.

**TABLE 4.4: WELFARE BALANCE OF NUCLEAR GENERATION IN £MILLION/GW**

| | Low gas price, central nuclear cost | Central gas price, high nuclear cost | Central gas price, central nuclear cost | Central gas price, low nuclear cost | High gas price, central nuclear cost |
|---|---|---|---|---|---|
| Carbon price = €0/t$CO_2$ | -2000 | -1000 | 40 | 1100 | 1800 |
| Carbon price = €10/t$CO_2$ | -1600 | -600 | 500 | 1600 | 2200 |
| Carbon price = €15/t$CO_2$ | -1500 | -500 | 600 | 1800 | 2400 |
| Carbon price = €25/t$CO_2$ | -1000 | -50 | 1000 | 2200 | 2800 |
| Carbon price = €36/t$CO_2$ | -600 | 400 | 1500 | 2600 | 3300 |

*Source: Cost Benefit Analysis*

4.40 Expectations of future carbon prices depend on assumptions about our commitment to tackle climate change and reduce emissions through putting a price on carbon. The proposals in the Energy White Paper, published alongside this consultation are designed to embed the principle of an effective carbon price signal into our market framework. The Government is committed to strengthening the EU ETS which will build investor confidence in the existence of a multi-lateral long term carbon price signal.

4.41 However, there are uncertainties in the future carbon price. If the commitment to putting a price on carbon fell away, then the targets for reductions in emissions would be less onerous. This would lead to a lower market price for carbon, because it would be cheaper and easier to meet these lower targets. This would affect the economics of non-renewable low carbon technologies such as nuclear power and carbon capture and storage. It will be for energy companies to make assessments of these uncertainties in making their investment decisions.

4.42 However, given the scale of investment in new generation assets required in the UK over the next two decades, UK investors need such clarity over carbon price fundamentals in good time if they are to make investment decisions consistent with Government's energy policy goals. The EU ETS will remain the key carbon pricing mechanism, and the Government is confident that it can provide a continuing price signal, however, the Government is keeping open the option of further measures to reinforce the operation of the EU ETS in the UK should this be necessary to provide greater certainty to investors. The proposals in the Energy White Paper are designed to provide certainty to business that the founding principles of our framework – competitive markets and an effective carbon price – will not change so they should seek to invest in a range of low-carbon technologies.

4.43 Our assumptions on the costs of gas-fired generation equate to a levelised cost of £37/MWh. Varying the fuel price results in a low-cost case of £25/MWh and a high-cost case of £47/MWh – based on gas prices of 20p/therm and 56p/therm respectively, compared to a central case of 39.9p/therm.

4.44 Under our modelling, gas-fired generation has a narrow cost advantage over nuclear generation in the central-cost case. This advantage increases as gas prices fall. However, with a high gas-price, nuclear generation has a cost-advantage over gas-fired generation. In fact, assuming a central-cost nuclear case, nuclear generation has a cost advantage for any gas price exceeding 43p/therm. This analysis also shows that, in the absence of a carbon price, nuclear is more expensive than power generation from fossil fuels and is less expensive than renewable technologies.

4.45 Our analysis of the influence of carbon prices on the economics of power generation (see Table 4.4) shows that:

- with low case for gas prices, nuclear power would provide no economic benefit to the UK under any scenario for carbon prices;
- with central case for gas prices and high nuclear costs, nuclear power provides economic benefit only at a carbon price of €36/t$CO_2$; and
- with central case and high case for gas prices and a central case for nuclear costs, nuclear power provides economic benefit regardless of the carbon price.

**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 in terms of reduced carbon emissions and security of supply benefits under likely scenarios for gas and carbon prices. As an illustration, under central gas and nuclear cases, and with a future carbon price of €36/t$CO_2$, the net present value over 40 years of adding 10GW of nuclear capacity would be of the order of £15 billion.**

## Question 4
## 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?

CHAPTER 5

# The value of having low carbon electricity generation options: nuclear power and the alternatives

## Introduction

**This chapter considers the value to the UK of giving energy companies the option of building new nuclear power stations. It is difficult to predict the future need for energy and electricity, because there is a wide range of uncertainties. Markets are well placed to deal with this uncertainty, because they provide the flexibility needed to respond to developments that we cannot predict today. They are also well placed to determine the "least-cost" combination of technologies that will ensure secure electricity supplies, while we make the transition to a low-carbon economy. Through measures announced in the Energy White Paper, published alongside this consultation, the Government is taking a number of actions to facilitate a wide range of technology options, and to strengthen the existing market framework so that it provides the appropriate incentives to invest in technologies consistent with our goals for tacking climate change and ensuring security of supply.**

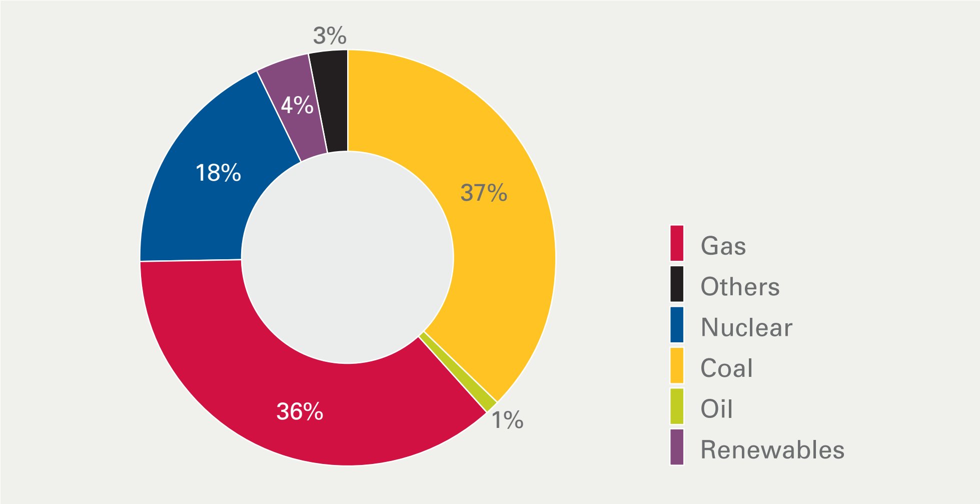
5.1 This chapter sets out information on:

- the evolution of the UK's energy mix and the uncertainties in the future;
- the options available to reduce carbon emissions from the electricity generation sector;
- the role that markets can play in managing this uncertainty; and
- how we can examine possible future scenarios using economic modelling, including the impacts on our energy goals of not allowing energy companies to invest in new nuclear power stations.

## The evolution of the energy mix

5.2 Our energy policy objectives are to tackle climate change by reducing carbon emissions and to ensure secure, clean and affordable energy as we become increasingly dependent on imported fuel. As set out in chapters 1 to 3 of this document, nuclear is a low carbon electricity generation technology that already plays a role in diversifying our electricity generation mix, supplying 18% of the UK's electricity in 2006 (see chart 5.1)

## CHART 5.1 UK ELECTRICITY GENERATION MIX (2006)




*Source: DTI, 2007*

Chart 5.1 The UK already has a diverse electricity generating mix, with nuclear making an important contribution to this diversity.

5.3 However, we will see significant changes in energy and electricity markets in the period to 2050. A significant number of fossil fuel power stations will close over the next two decades, in response to European emissions legislation,[116] and as existing power stations reach the end of their expected lives. Even with a concerted effort to increase the efficiency of our energy use, if we are to deliver our energy policy goals, we will need new low carbon power stations to enable the UK to make the transition to a low carbon economy.

5.4 In the period to 2050, we could see substantial technological as well as social and behavioural change. Few would have predicted the substantial improvements in standards of living and the technological developments we have experienced over the last 40 years. These changes have brought a wide range of appliances within the reach of the average household. They have also massively increased individuals' mobility, for example through more affordable air travel, with major impacts on energy demand and use.

5.5 Technological change in the future could make the achievement of our goals easier, for example through breakthroughs in low carbon technologies. However, we could also see a considerable increase in demand for energy and electricity, as we make the transition to a low carbon economy and / or adapt to the impacts of climate change. For example, if electric or hydrogen fuelled cars were to become more widespread, electricity demand per capita could be significantly higher than its current level. As an illustration, work by E4tech for the Department for Transport suggests that completely replacing the UK's passenger car fleet with electric vehicles could increase demand by around 16% of 2005 levels, and if they were replaced by hydrogen power vehicles from grid electrolysis, demand could increase by 24%[117]. Equally we could see increased use of air conditioning if global temperatures rise or we could see new waves of technologies entering every day

116 Most of the oil and coal power station closures over the next decade are being driven by the EU's Large Combustion Plant Directive (LCPD aimed at reducing sulphur dioxide and nitrogen oxide emissions).
117 More details are available in chapter nine of the Low Carbon Transport Innovation Strategy http://www.dft.gov.uk/pgr/scienceresearch/technology

use, as we have seen with the advent of digital technology in the last decade or so. Similarly, demand could be increased as a result of faster than expected increases in economic growth. Such developments could put the UK under even greater pressure in trying to reduce our carbon emissions by 60% by 2050.

5.6 The availability and cost of energy supplies are also uncertain. As well as the long-term decline of fossil-fuel reserves, the International Energy Agency (IEA) highlights the uncertainty over whether energy suppliers will make sufficient investments to extract these reserves[118]. This could see fossil fuels become expensive for use in electricity generation, even more so if gas-to-liquids and coal-to-liquids technologies made further advances, increasing the potential uses of and demand for fossil fuels.

5.7 How such developments play out will fundamentally affect the demand for and cost of electricity generation technologies. For example, sustained high fossil fuel prices would make it attractive to invest in energy efficiency and less attractive to invest in fossil-fuel fired generation. Conversely, if storing electricity became technically feasible, the effective costs of intermittent power sources such as wind could drop significantly.

5.8 Furthermore, international and domestic policy will affect the development of electricity generation technologies, influencing the level of effort, speed of adjustment and policies employed to tackle climate change. How much effort we will need to make depends on both the science of climate change, which is still evolving, and political will. The draft Climate Change Bill creates a new legal framework for the UK achieving through domestic and international action, at least a 60% reduction in carbon emissions by 2050. It includes provisions for the target to be amended in light of significant developments in climate science or international law or policy.

## There is no single solution to meeting the UK's energy goals

5.9 Uncertainty about future electricity generating technologies and about future energy demand is a reminder that we cannot know today which technology or mix of technologies would be the most appropriate for delivering our energy policy goals over the medium to long term. Moreover, we recognise that such uncertainty is inevitable as climate change and energy policy continue to evolve.

5.10 Over the next two decades it is likely that gas and coal-fired power stations will continue to constitute a large share in the generation mix[119], However we also expect an increase in the share of renewable generation: the UK has an aspiration for 20% of electricity supplies to come from renewables and the EU has also recently agreed that renewables should provide 20% of its energy needs by 2020. The Commission has been asked to bring forward detailed proposals – including for each Member States' contribution to the EU 2020 targets on renewables and greenhouse gases – by the end of this year. This means there is some uncertainty as to the size of the UK's contribution.

5.11 We must also now prepare for our climate change strategy beyond 2020. Renewables are a key part of our long-term strategy, but we will also need

118 IEA World Energy Outlook 2006.
119 DTI, *Updated Emissions Projections,* July 2006, http://ww.dti.gov.uk/files/file31861.pdf

substantial deployment of low carbon non-renewable technologies, including in electricity generation, if we are to make the transition to a low carbon economy.

5.12 Therefore, if the UK is to meet our energy goals over the longer term and protect ourselves against the risks associated with uncertainty, we need to create a framework that supports a range of investment options that are consistent with our carbon and security goals. Single solutions on their own will not allow us to meet our goals under all circumstances. By having a diverse range of options, the UK will be better placed to deal with the range of possible futures that could unfold. For this reason, Government policy is aimed at ensuring a framework that develops and deploys a wide range of electricity generation technologies and to drive improvements in energy efficiency. The Energy White Paper "Meeting the Energy Challenge" sets out the Government's policies to achieve this including measures to:

- incentivise the take up of energy efficiency measures and to set tough environmental standards for buildings and products;
- strengthen the existing regulatory and investment framework, for example by removing barriers to planning and strengthening incentives to invest in and deploy low carbon technologies;
- promote Research Development & Demonstration (RD&D) into low carbon technologies through the Energy Technologies Institute;
- support the development of CCS by launching a competition for a full-scale demonstration in the UK;
- improve and strengthen support for renewables, including through banding[120] the Renewables Obligation to better support a range of renewable technologies; and
- remove barriers to the deployment of distributed generation technologies including combined heat and power.

5.13 It is within this context that we are also considering and consulting on the issue of whether new nuclear power stations should be an investment option for private sector companies.

## Options for reducing carbon emissions from the electricity generation sector

5.14 It is possible to reduce carbon emissions from the electricity sector through action on both the demand and supply side.

## Energy efficiency and demand reduction

5.15 The starting point for reducing emissions is to save energy. Businesses and individuals can undertake a number of measures to use their energy more efficiently. Government analysis prepared for the Energy White Paper "Meeting the Energy Challenge"shows that energy efficiency measures such as improved billing for businesses and improved insulation in homes are amongst the most cost effective ways of reducing electricity demand and hence carbon emissions[121]. These measures also improve the productivity of the economy as a whole, by improving the efficiency with which we use our energy resources.

5.16 However, there are limitations to the potential contribution that energy efficiency measures can make in delivering our energy goals. For example, as

120 The Goverment's proposals for "banding" would give different levels of subsidies to different renewable technologies according to their technological development

121 See chapter ten Energy White Paper "Meeting the Energy Challenge" http://www.dti.gov.uk/energy/whitepaper

we have already seen in the UK, households may use the financial rewards from improving energy efficiency to increase their use of energy, a phenomenon described as the rebound effect[122]. For example, people might opt to improve their level of comfort, by increasing the temperature at which they heat their home, or by purchasing more energy-consuming products, thereby increasing carbon emissions.

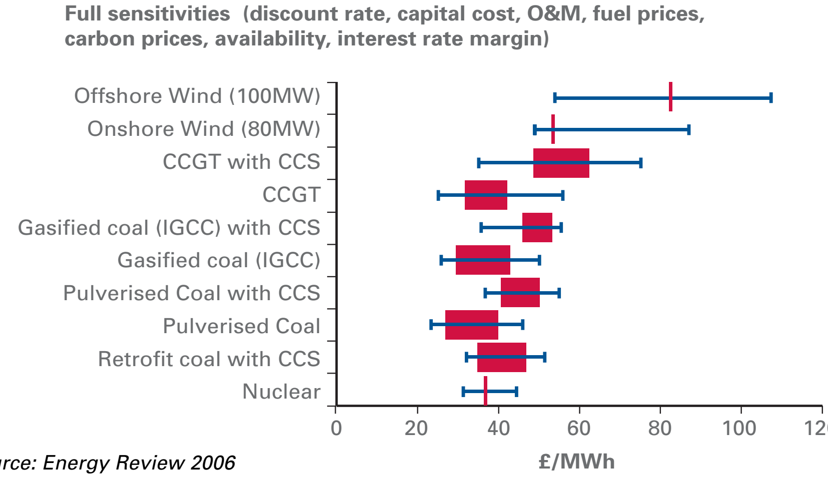
5.17 As Government policies such as the Carbon Emissions Reduction Target (previously known as the Energy Efficiency Commitment) deliver more savings, many of the most cost effective opportunities to improve energy efficiency will be exhausted. Realising energy efficiency savings will therefore become increasingly expensive and difficult, requiring significant changes in individuals' behaviour in using energy and the adoption of more expensive and less convenient energy saving measures.

5.18 Energy efficiency must play an important role in making our economy more efficient, getting more out of the energy supplies that we use. However, as our economy is expected to continue to grow over the next forty years, such actions will only slow the growth in energy demand[123]. If we are to provide the energy needed for economic growth while reducing carbon emissions in line with our goals we will also need to reduce the carbon emissions associated with the generation of electricity.

## Low-carbon electricity generation technologies

5.19 There are a number of low carbon technologies that energy companies could invest in that could help reduce the UK's carbon emissions from the electricity generation sector – chart 5.2 below summarises the economic cost of the different technologies expressed as a range to highlight the uncertainty surrounding some of the key assumptions, for example in fossil-fuel prices. These estimates do not represent a Government view on the future relative costs of generating technologies. The purpose of this work is to provide an estimate of the relative generating costs under a number of different scenarios which might arise because of the many uncertainties discussed above.

**CHART 5.2 CENTRAL GAS PRICE WITH CENTRAL CARBON PRICE (£17/t$CO_2$) AS BASE - SHOWING FULL SENSITIVITIES**




*Source: Energy Review 2006*

122 http://www2.defra.gov.uk/research/Project_Data/More.asp?I=EE01015&M=CFO&V=USC
123 For example, the IEA World Energy Outlook 2006 estimates that global energy demand will increase by about 50% by 2030. Even under the alternative policy scenario, which assumes all current policies are successfully implemented, energy demand is expected to increase by around 40% by 2030.

Chart 5.2 The chart shows the impact on the generation costs when a number of variables are considered (discount rate, capital cost, O&M, fuel prices, carbon prices, availability, and interest rate margin). The red ranges represent the impact of altering carbon prices. The blue ranges represent the impact of varying all assumptions to derive the lower and upper range of generating costs.

5.20 Nuclear power and fossil fuel generation tend to be less expensive than renewables in most of the scenarios considered (see chart 5.2). However, each of these technologies have other benefits and limitations that are not fully captured by the financial costs expressed in this analysis.

5.21 If we were to limit the technologies available to help the UK meet its goals we would be more heavily reliant on the remaining technologies. In a mix of fewer options, any disadvantages of the remaining technologies would become more significant, because the diversity of the UK's generating mix would be decreased. Chapter Three discusses in more detail the value of diversity in contributing to the security of energy supplies.

5.22 There is a range of low carbon technology options for generating electricity that are currently available or are being developed. The section below discusses some of the characteristics of each of the available options to the market, their benefits, and their limitations, including for example uncertainties surrounding their deployment.

**Renewables**

5.23 Renewable technologies can make a significant contribution to reducing the UK's carbon emissions. Today, they make up around 4% of the electricity mix. The Government is committed to increasing the share of electricity met by renewable technologies. Since 2002, the Government has set a target to generate a growing percentage of electricity by renewable technologies and has provided financial support through the Renewables Obligation (RO). The RO effectively segments the renewables market from the rest of the electricity market, ensuring continued investment in renewables. This "ring-fenced" financial support is driving investment in renewables, and would continue regardless of a decision on whether to allow energy companies to invest in new nuclear power stations.

5.24 In the Energy White Paper, "Meeting the Energy Challenge" the Government sets out its proposals to strengthen and modify the Renewables Obligation. These proposals, to be implemented in 2009, will increase the level of renewables investment and deployment (see chapter 5.3 of the Energy White Paper and the renewables consultation document launched alongside the White Paper for more details[124]).

5.25 At a European level, the European Council has agreed a binding target for the share of energy from renewables of 20% by 2020. The 20% target is an ambitious goal. After a decision has been reached on each Member States' contribution, we will bring forward the appropriate measures beyond those set out in the Energy White Paper published alongside this consultation[125]. Beyond 2020 the UK will need to deploy a wider range of low-carbon generation technologies if we are to deliver our 2050 goal of reducing carbon emissions by 60%.

124 DTI, Energy White Paper, *Meeting the Energy Challenge,* 2007, http://www.dti.gov.uk/energy/whitepaper
125 DTI, Energy White Paper, *Meeting the Energy Challenge*, 2007, http://www.dti.gov.uk/energy/whitepaper

5.26 The main limitation for renewables is its cost relative to other forms of electricity generation. With the exception of large-scale hydroelectric power stations – which as a technology has limited potential for further capacity increases as many suitable sites in the UK have been exploited – renewable technologies are relatively immature and are in the early stages of deployment. They are still more expensive than coal- and gas-fired generation. For example, the levelised cost of onshore wind, one of the most competitive forms of renewable generation today is between £60/MWh and £83/MWh compared to £37/MWh for gas-fired generation[126]. However, it is expected that, the cost of renewable generation should fall as the technologies are deployed more widely.

5.27 There are potential limitations, and risks of relying on renewables to deliver the UK's climate change and security of supply objectives alone:

- many forms of renewable generation are intermittent, they depend on external forces, such as wind, that are not available at all times. Therefore, they cannot respond to increases in demand during peak times of the day. As a result, backup generation is required to maintain secure energy supplies. If the low-carbon benefits of adding renewable capacity are not to be eroded, then this back-up capacity also needs to be low carbon. Without appropriate back up, the greater the percentage of renewables in the generating mix, the greater the risk to security of supply;
- the provision of back-up generation also has implications for the cost of building this new generation capacity and for strengthening networks to accommodate the new capacity. Given the intermittency of many of the more cost effective forms of renewable generation, for example wind, very high proportions of renewables could create difficulties for system operation and load balancing[127];
- there are uncertainties over the speed with which some renewable technologies such as wave and tidal power will develop. These uncertainties affect estimates of the likely cost and feasibility of their deployment on a much larger scale.
- the UK has a limited number of suitable locations for renewables. Important considerations of local acceptability could significantly hinder the deployment of such technologies. In March 2006, 24 projects with a combined capacity of 1.2GW had been under consideration in the planning system for more than 21 months[128]. Delays are often caused by objections from local communities and/or other interest groups. The visual impact of such developments would have to be compared to other electricity generation technologies: one modern nuclear power station with a capacity of at least 1GW and an estimated land-take of 25 to 75 hectares[129] - would have to be weighed against around 500 to 800 average sized wind turbines, potentially spread across a range of sites. The British Wind Energy Association estimate that a 1GW onshore windfarm would spread over an area of 10,000 hectares, although the majority of this land would not be used for foundations and access roads, so could also be used for limited activities like farming[130]. However it is likely that offshore windfarms, like the London Array project, will also be proposed.

126 Ernst & Young Report on renewables costs; and Nuclear CBA for gas-fired plants costs.
127 DTI, Energy White Paper, *Meeting the Energy Challenge,* http://www.dti.gov.uk/energy/whitepaper
128 DTI, *The Energy Challenge,* Cmd 6887, http://www.dti.gov.uk/energy
129 Westinghouse AP1000 Advanced Passive Plant, Westinghouse Electric Company, http://nuclearinfo.net/twiki/pub/Nuclearpower/WebHomeCostOfNuclearPower/AP1000Reactor.pdf
130 http://www.bwea.com/ref/faq/html

**BOX 5.1: Investment in renewables**

Companies will invest in new power stations on the basis of expected profitability of investments. The discussions we had with energy and investment companies during the Energy Review process has confirmed that there is significant financial capacity available to fund investment projects and that access to capital is not a barrier to investment in profitable projects.

Developing technologies, such as renewables, need support to ensure they can offer sufficiently attractive investment opportunities. The Renewables Obligation provides financial support to renewables by placing an obligation on energy suppliers to source a growing proportion of their electricity supplies from renewable sources. Our analysis indicates that the Renewables Obligation (together with the exemption of renewables from the Climate Change Levy) will provide an annual level of financial support of around £1bn in 2010 and around £2bn in 2020. The Renewables Obligation effectively segments the renewables electricity market from the rest of the electricity generation market, thereby ensuring continued investment in renewables in the UK. In addition, factors that contribute to higher electricity prices but which do not affect the costs of renewables, e.g. higher carbon prices or gas prices, will further improve the economics of electricity generation from renewable sources.

We have undertaken a range of analysis and modelling for the purposes of the Energy White Paper and this nuclear consultation[131]. Our analysis of future new investment in electricity generation shows in all scenarios that there is substantial new investment in renewables over the coming years. The renewable proposals in the Energy White Paper will also help us to make further progress to increase the penetration of renewable generation in the UK.

## Carbon Capture and Storage

5.28 Carbon capture and storage (CCS), involves "capturing" carbon dioxide emitted from burning fossil fuels, transporting and storing it in secure spaces, such as geological formations, including under the seabed. CCS can be applied to either coal-fired or gas-fired generation, reducing $CO_2$ emissions by as much as 90%[132]. The Stern Review of the economic impacts of climate change highlighted the strategic role that CCS technology could play globally in reducing carbon emissions, with the potential to contribute up to 28%[133] of global carbon dioxide mitigation by 2050[134].

5.29 The Government is committed to exploring the option of CCS. The 2007 Budget announced a competition in the UK that aims to establish the world's first commercial scale CCS demonstration on power generation.

131 UK MARKAL Model, DTI energy model, Redpoint Energy analysis. See Box 5.3 for more details on the models
132 Intergovernmental Panel on Climate Change (IPCC).
133 International Energy Agency, *Energy Technologies Perspectives*, 2006.
134 Sir Nicholas Stern, *The Stern Review – The Economics of Climate Change*, 2006.

A demonstration will help provide a better understanding of the likely costs, practicalities and timing of the wider deployment of this technology. Chapter 5.4 of the Energy White Paper includes further details on CCS, including Government actions to address regulatory uncertainty and the competition[135].

5.30 However, CCS represents a major technological challenge. No commercial scale power station using CCS technology has yet been developed anywhere in the world, although some key elements of the individual stages of the process have been demonstrated. There would be high risks attached to relying solely on CCS to reduce carbon emissions. Inevitably, given the early stage of development of CCS, there are a number of uncertainties related to its ability to contribute to meeting our carbon emissions reduction goal:

- practical uncertainties related to applying the technology to electricity generation;
- the technology costs and the reduced energy efficiency of power stations fitted with CCS technology;
- technical uncertainties related to the construction of a carbon dioxide transportation and storage system, including the long-term liability for the integrity of the storage site, after injection has ceased; and
- regulatory uncertainties related to the development of an internationally accepted regime for the storage of carbon dioxide under the seabed.

## Nuclear

5.31 Nuclear power is a mature technology. It has met almost one fifth of the UK's electricity demand since the first nuclear power station became operational in the 1950s. Although nuclear power stations generate 18% of the UK's electricity today, based on published lifetimes, all of our existing power stations will have closed by 2035. However, generators have indicated they will seek life extensions, so it is possible that some of the existing capacity could continue operating.

5.32 As discussed in chapter two of this document, the lifecycle carbon emissions from generating nuclear power are similar to those from wind generation[136], therefore the Government believes that it can reliably be considered a low carbon technology.

5.33 In a balanced energy mix, nuclear power stations can make some specific contributions to the security of the UK's energy supplies (as discussed in chapter three). Their cost profile - with large upfront capital costs, but relatively low ongoing fuel and operating costs - mean that nuclear power is relatively insensitive to fluctuations in uranium fuel prices. This cost profile, and the technical characteristics of the technology mean that nuclear power stations are highly suitable for providing baseload electricity generation. They are less suited to providing the short run flexibility required to meet changes in peak demand.

5.34 However, given the long lead times in constructing and commissioning new nuclear power stations[137], electricity generation from new nuclear power

135 http://www.dti.gov.uk/energy/whitepaper

136 Sustainable Development Commission, *The Role of Nuclear Power in a Low Carbon Economy, Paper 2: Reducing $CO_2$ Emissions – Nuclear and the Alternatives,* March 2006.

137 Our conservative assumption is that for the first new nuclear plant the pre-construction period would last around 8 years (to secure the necessary consents) and the construction period would last around 5 years. For subsequent plants this is assumed to fall to 5 and 5 years respectively.

stations would be unlikely to be able to contribute significantly to reducing our carbon emissions before 2020.

5.35 In addition, even though nuclear is a mature and proven technology, and new designs are less subject to technical failure[138], there are still regulatory issues that would need to be addressed before new nuclear power stations could be deployed, notably in relation to:

- the requirement to secure consents from the nuclear regulators to ensure that the safety, security and health risks can be adequately managed. These processes can be lengthy and unpredictable;
- the designs of nuclear power stations that might be built. Although the most likely designs are evolutions of existing powerstations, they are relatively new technologies without significant experience of construction. For example, the project to build a new reactor in Finland is currently one year behind the planned construction schedule; and
- Arrangements need to be in place to ensure that operators of nuclear power stations meet their full decommissioning costs and full share of waste management costs before new nuclear power stations could be built. These arrangements have not yet been finalised.

5.36 Nuclear power stations also require large capital investments, with a long payback period across its 40 to 60 year life. Uncertainty over this time period, for example in the carbon price, makes it harder for energy companies to make financial appraisals.

### Distributed Generation

5.37 Distributed generation (DG) is made up of a number of technologies - that connect directly to the distribution network - each with different costs and potential for take-up (for more information about DG and its costs see Box 5.1). DG would reduce carbon emissions through the use of small scale renewable technologies or more efficient fossil fuel technologies, such as CHP (combined heat and power) which can offer efficiencies in fuel use by capturing waste heat that is a by-product of electricity generation. DG technologies can also avoid some of the electricity losses in transmission and distribution. There is also some evidence that DG can have behavioural benefits where consumers who identify more closely with the source of their energy supply tend to value their energy inputs more highly and reduce waste[139].

5.38 As with renewables, the future penetration of DG will likely be limited by the relatively high costs of many DG technologies, many of which are at an early stage of development[140].

5.39 One of the most cost-effective technologies is large-scale CHP[141]. Any increase in the contribution of DG to our overall generation mix is likely to be dominated by gas-fired CHP generation, although there is a growing role for

138 For example, over the last seven years the load factor of Sizewell B has been on average around 86%.
139 Research by the Sustainable Development Commission and the National Consumer Council shows that people moving into homes with built-in renewable energy technologies report far greater awareness of what they can do to reduce their climate impact, and their energy use: *I Will If You Will* (Sustainable Consumption Roundtable, May 2006) – http://www.ncc.org.uk/responsibleconsumption/iwill-summary.pdf
140 Review of Distributed Generation, DTI/OFGEM, http://www.dti.gov.uk/energy/whitepaper
141 The Digest of Energy Statistics (DTI, March 2006) defines large-scale CHP as schemes >10MWe. Although in 2006, such schemes represented 83% of total electricity capacity of CHP schemes, they made up <5% of the number of schemes.

renewable CHP in the UK. Gas-fired CHP has up to 30% lower emissions relative to new conventional gas-fired generation, but it still emits at least around 60 tonnes of carbon per GWh more than wind[142].

5.40 However, large scale CHP projects are site specific. They require a significant customer base for the waste heat, this could be for an industrial process or community heating. Like large-scale hydroelectric power stations, many of the sites suitable for CHP have already been exploited in the UK.

5.41 This suggests that DG's potential contribution to the generation mix will be limited, complementing rather than replacing centralised alternatives in the medium term. Nevertheless, efforts by the Government and Ofgem are aimed at maximising the potential for DG by removing the barriers to its uptake[143].

**BOX 5.2: MODELLING THE COSTS OF DISTRIBUTED GENERATION (DG)**

'Distributed generation' is not a single technology, but instead encompasses a wide range of technologies including CHP, microgeneration and renewables connected directly into the distribution grid. To reach conclusions about the costs of an increased share of DG in the UK generation mix it is necessary to take into account the costs of each individual DG technology, as well as the likely share of each technology within the total DG sector.

Modelling the costs of the DG sector is highly uncertain. Costs are evolving for less mature technologies such as renewables, and can be site-specific, especially for CHP where costs depend on the nature of the heat load. Equally, we do not know what the future take-up of each technology will be. Instead, we must work with 'what if' scenarios, considering what the costs of DG could be if take-up were to follow a given pattern.

The WADE model[144] compares the total cost of meeting a country's need for new electricity generating capacity using alternative mixes of centralised and distributed generating capacity. DTI has worked with WADE to develop an initial understanding of the relative costs of meeting the UK's need for new generation capacity over the coming 20 years, comparing a centralised scenario to one with a higher proportion of DG. This overall cost comparison incorporates a wide range of input information provided by the DTI, including capital costs of building plant and transmission and distribution infrastructure, fuel costs and carbon costs. However, the WADE approach does not explicitly model the heat component of CHP. Given the importance of CHP within any likely DG scenario – it is anticipated that CHP will account for over 50% of new DG capacity – the

142 Energy White Paper, DTI 2007, http://www.dti.gov.uk/energy/whitepaper
143 *DTI/Ofgem Review of Barriers and Incentives to Distributed Generation, Including Combined Heat and Power,* Review Report May 2007.
144 World Alliance for Decentralised Energy, http://www.localpower.com

**BOX 5.2: continued**

findings generated by the WADE model can only offer a starting point on DG costs rather than a robust conclusion.

The work undertaken by WADE for DTI suggests that the costs to the UK of meeting additional energy demand over the coming 20 years using DG would be higher than if a centralised approach were taken. In the distributed and centralised scenarios modelled, the fuel, carbon and transmission and distribution infrastructure costs are lower in the DG case. However this is more than out-weighed by the lower capital and operation and maintenance costs in the centralised case. More detail about this work is provided in "Using the WADE model to investigate the relative costs of DG" at http://www.dti.gov.uk/energy/whitepaper/consultations.

To be confident of these preliminary results would require a model capable of explicitly considering heat. Further work is needed to model the heat and electricity aspects of a distributed energy system to enable more robust conclusions about the relative costs of DG to be drawn. This work would still be subject to great uncertainty surrounding the potential for each technology, the likely take-up and the evolution of costs. However, the overall framework within which this uncertainty was modelled would be robust.

## The role of markets in managing uncertainty

5.42 Given the risks and uncertainties associated with each of these technologies, as well as the risks and uncertainties about the way the world and energy markets may develop, the Government's intention is to provide a market framework that facilitates as diverse a portfolio as possible of available technologies (see chapter three) if we are to minimise the risks and costs associated with achieving our energy goals.

5.43 It is because of these uncertainties and risks that we do not believe the Government should decide the composition of the fuel mix or the share of each technology in the mix. Instead, we believe that a market based approach is the best way to manage these uncertainties, providing the UK with the flexibility to respond to developments we can't yet envisage. Operating within this framework, investors are best placed to weigh up the complex range of interrelated factors affecting the profitability of investing in electricity generation and how these might evolve over time.

5.44 We recognise, however, that on their own, markets will not deliver the Government's wider social and environmental goals. The Stern Review[145] highlighted the role for governments in developing low carbon technologies; for example, by ensuring a strong carbon price signal, and by supporting the research, development and demonstration of early stage technologies. For this reason, the Government needs to set a policy framework that provides

145 The Stern Review, *The Economics of Climate Change,* October 2006

incentives to companies to produce environmentally sustainable electricity as well as delivering secure and reliable supplies at affordable prices.

5.45 This chapter has already mentioned some of the steps that the Government has announced in the Energy White Paper "Meeting the energy Challenge" to improve the electricity investment framework and to influence investment behaviour, for example by removing barriers to planning and strengthening the Renewables Obligation. We will also keep open the option to further strengthen and improve the framework if we are not making sufficient progress against our goals.

## Modelling future energy market scenarios

5.46 Analytical modelling allows us to study possible scenarios of the future mix of electricity generation and to analyse the role nuclear power could play in the future as well as the impacts of excluding the option for energy companies to invest in new nuclear power stations.

5.47 We have conducted this analytical work as part of the preparation for the Energy White Paper. The full reports for these studies are published on the DTI website[146]. To reflect the uncertainty over the way we could use energy in the future, we have used different models, and a range of assumptions covering different time periods, to generate a series of scenarios both for the medium and the longer term future.

5.48 For the period up to 2030 we have used a model of the electricity market which simulates the decision making process of investors on the basis of:

- the underlying costs of new investment;
- investors' expectations of electricity prices, fuel prices and carbon prices; and
- the lead times associated with bringing new generation capacity on-stream.

However, in the long-term to 2050, as the range of uncertainties increases, we have used a model of the entire UK energy system to explore the changes to the energy system required if we are to deliver our goal of reducing carbon emissions by 60% by 2050 at least cost (see Box 5.3).

### BOX 5.3: APPROACHES TO ECONOMIC MODELLING IN THE ENERGY SECTOR

#### Modelling scenarios of developments in the energy sector

We have used a number of different modelling approaches to inform our understanding of the energy system in general. In the context of understanding the role that nuclear power might play, and the impacts of excluding it, we have used two models, As with all models, the results that they produce are shaped by the data and input assumptions. To ensure the analysis is as robust as possible, both models and their use in the Energy White Paper "Meeting the Energy Challenge" have been peer reviewed by a group of Government and external experts.

146 http://www.dti.gov.uk/energy/whitepaper/nuclearpower2007

**BOX 5.3: continued**

**Dynamics of GB Electricity Generation Investment: Prices, Security of Supply, $CO_2$ Emissions and Policy Options** – *a modelling report by Redpoint Energy on projecting electricity supply in the period to 2030*

We have examined the potential investment decisions made by firms in the electricity generation sector in the period up to 2030. This dynamic investment modelling simulates the decision making process of investors on the basis of:

- the underlying costs of new investment;
- investors' expectations of electricity prices given uncertain future demand and supply scenarios, fuel prices and $CO_2$ prices; and
- the lead times associated with bringing new generation capacity on-stream.

The modelling captures the uncertainty investors face over the fundamentals that determine the profitability of investment decisions, such as fossil-fuel prices, which affect the amount and type of capacity built as well as energy prices.

Note that this model does not impose any requirement that the Government's or the EU's targets, such as those for greenhouse gases, renewable-energy, or efficiency, are fully met, though it does assume improvements in energy efficiency or the level of renewables generation.

**The UK MARKAL-Macro model** – *Exploring carbon abatement and the implications of the energy system beyond 2030*

Beyond 2030, there is even greater uncertainty over fossil-fuel prices, technology costs and energy demand. We have used the UK MARKAL-Macro (M-M) model, to explore the technical and macroeconomic implications of reducing carbon emissions by 60% by 2050 under a number of scenarios.

The modelling shows that it is likely that a rich mix of technologies will be required if we are to meet our carbon goals at least cost. In contrast to the Redpoint model, which concentrates on the power sector, the M-M model covers the entire energy system, including electricity, heat and transport. The M-M model is one of the few models that is able to explore the energy system in the long term. However, it does not fully capture all costs and risks. In deriving a path to 2050, it assumes that over the entire period there is perfect foresight of all available technologies and their costs, i.e. at any point in time the model knows when and at what costs different technologies will become available. The model therefore does not capture

**BOX 5.3: continued**

the full range of uncertainty around the development of new technologies, thus it is likely to underestimate the full costs of less developed technologies and the potential risks (for example, to security of supply) of excluding a particular generation technology. As part of the White Paper "Meeting the Energy Challenge", we have used a number of scenarios to capture the wide range of costs that might materialise under different fuel prices and technology costs.

## Modelling to 2030 – Dynamic investment modelling (Redpoint model)

5.49 This model simulates the decision making process of investors in electricity generation to 2030[147]. The modelling results are based on the DTI's central assumptions for fossil fuel prices[148]. The modelling assumes a gradual upward trend in the carbon price over time, so that low carbon generation technologies become more attractive relative to fossil fuel fired generation. This is because the carbon price increases the cost of fossil fuel generation by placing an additional cost for each tonne of carbon emitted in electricity production. The modelling also takes account of the financial support which is made available to renewable investors through the Renewables Obligation.

5.50 We have modelled two scenarios in analysing the potential role of nuclear: a scenario in which companies can invest in the full suite of electricity generation options including new nuclear, and one which explicitly excludes nuclear.

5.51 The modelling suggests that we could see around 30-35GW of new electricity generation capacity being built over the next two decades, with around two-thirds of this by 2020. The key drivers of new capacity requirements to 2020 are:

- coal and oil-fired power station closures: we know that around 8GW of existing coal fired stations and around 3GW of oil fired power stations are due to close by 2016 under the requirements of the Large Combustion Plant Directive[150]. This Directive also restricts the operation after 2016 of the remaining 20GW of coal stations that are not required to close by the Directive;
- nuclear power station closures: on currently published lifetimes, around 7GW of nuclear power stations are due to close between now and 2020; and
- higher electricity demand – due to continued economic growth, annual electricity demand is expected to grow by around 50TWh by 2020 despite expected improvements in energy efficiency[151].

147 Redpoint Energy, *Dynamics of GB Electricity Generation Investment: Prices, Security of Supply, $CO_2$ Emissions and Policy Options*, 2007.

148 These inputs are consistent across the modelling, analysis and cost benefit used as part of the development of the Energy White Paper. We are publishing the detail of other input assumptions, for example on the possible evolution of the carbon price, as part of the full consultancy report published alongside the Energy White Paper.

150 This EU environmental legislation is aimed at reducing sulphur dioxide, nitrogen oxide and particulate matter emissions from large combustion plants above 50MW, including power stations.

151 The assumptions behind the Redpoint model do not take into account the impact on energy demand from the policies and measures set out in the Energy White Paper 2007.

5.52 In the period between 2020 and 2030, the modelling suggests that around 2GW of the remaining older coal plants and around 2.5GW of some of the older CCGT gas-fired power stations will also close. In addition, based on currently published closure dates, 2.5GW of existing nuclear capacity will also close.

## Scenario with nuclear included as an investment option

5.53 Due to the long lead[152] times, we expect that new nuclear power stations could make only a limited contribution to new electricity generation capacity in the period up to 2020. The range of modelling conducted for the Energy White Paper "Meeting the Energy Challenge" shows new nuclear power stations coming on-stream from 2020 at the earliest. However, some see this as a conservative estimate. For example, one potential developer of new nuclear power in the UK has offered a more optimistic perspective and suggested that it would be possible to develop the first new nuclear power station by 2017.

5.54 Between 2020 and 2030, the modelling suggests that we would see around 10GW of new electricity generation capacity coming on-stream. The model also suggests that of this, around 5GW would be new nuclear power stations, contributing around 10% of electricity output by 2030, with the remainder being made up by renewables, coal and gas-fired generation (see chart 5.3).

5.55 The modelling shows that no CCS plant is built throughout the period. This is based on the assumptions made about the cost of CCS technology and the electricity price, even incorporating an assumed carbon price, the electricity price is insufficient to incentivise the building of new CCS plant because there are less expensive alternative investment options available[153].

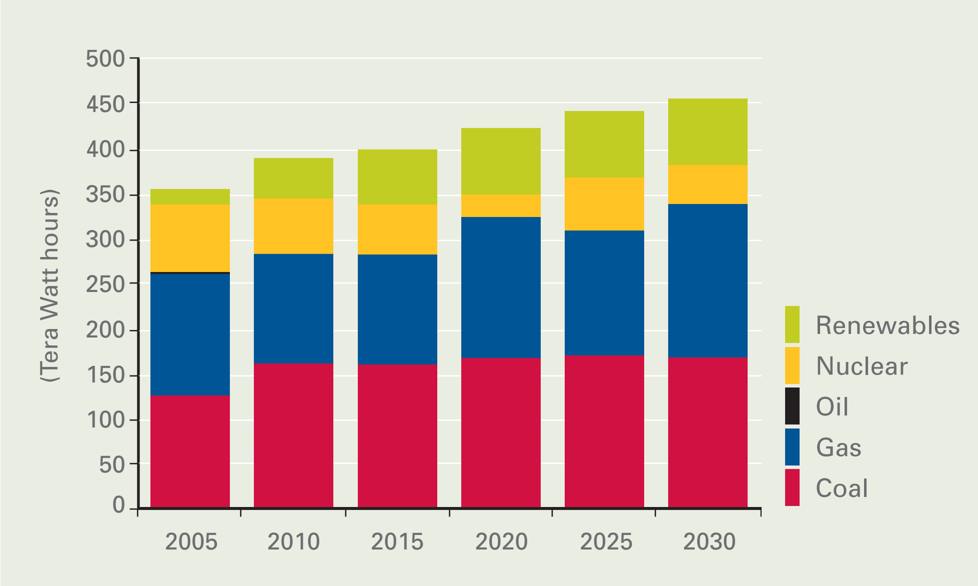
5.56 Some commentators have been concerned that proposals to bring forward new nuclear power stations would deter investment in renewables. However, the modelling shows substantial new investment in renewables over the coming years, under all scenarios[154]. This is because the Renewables Obligation effectively "ring-fences" the renewables market from the rest of the electricity generation market, thereby "protecting" investments in renewables. See Box 5.1.

152 Our conservative assumption is that for the first new nuclear plant the pre-construction period would last around 8 years (to secure the necessary consents) and the construction period would last around 5 years. For subsequent plants this is assumed to fall to 5 and 5 years respectively.

153 In the Redpoint modelling, carbon price is assumed to increase steadily from around €12/t$CO_2$ in 2007 to around €44/t$CO_2$ in 2030.

154 Redpoint Energy, *Dynamics of GB Electricity Generation Investment: Prices, Security of Supply, $CO_2$ emissions and Policy Options,* 2007

**CHART 5.3: ELECTRICITY GENERATION MIX INCLUDING NEW NUCLEAR (2005-2030)**




*Source: Redpoint Energy, 2007*

Chart 5.3: If energy companies are allowed to construct new nuclear power stations, in 2030, nuclear could provide about 10% of total electricity output Note: 2005 are actual output figures (DTI, 2007). This chart excludes electricity output from imports and storage.

## Scenario with nuclear excluded as an investment option

### Implications for security of supply

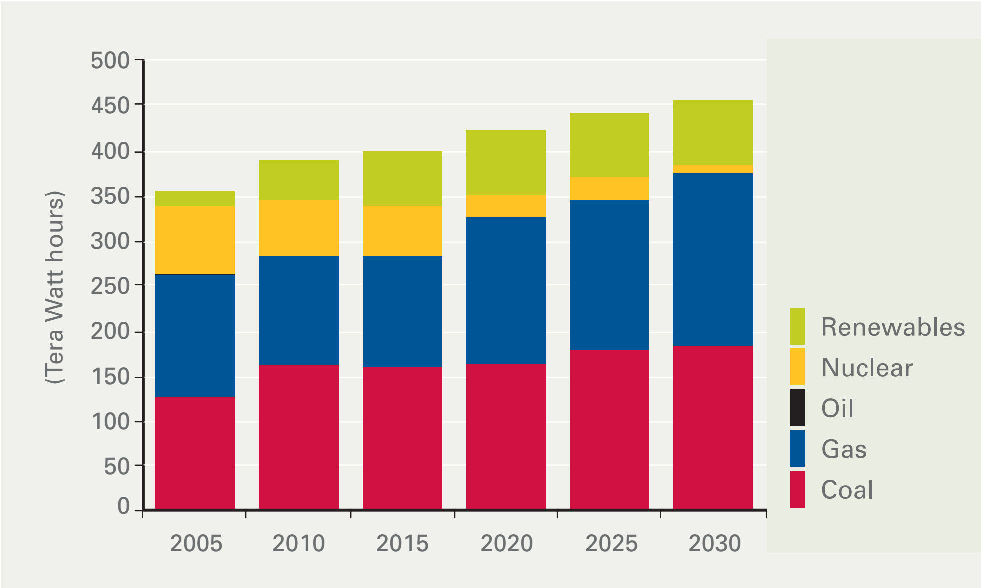
5.57 The modelling shows the UK could see up to 2-4GW less overall new investment in generation capacity in the period to 2030. This is because investors will build new generating capacity only when expected electricity prices are sufficient to stimulate investment in other technologies. Under the carbon price assumptions in the modelling, nuclear becomes the lowest cost electricity generation technology by around 2023 and is cheaper than gas and coal-fired generation as both types of generation incur increasingly higher costs associated with each tonne of carbon emitted[155]. Therefore, the less attractive economics of building and running conventional generation means that investment in non-renewable generation is delayed until later in the 2020s, compared to the scenario where new nuclear is an option.

5.58 The reduced level of investment in this scenario implies that there would be less spare electricity generation capacity to cope with unexpected variations in demand or problems with electricity supply. Under this scenario, we would also see a less diverse mix of technologies, because the private sector has fewer options to consider. This means that the electricity system would be less robust to security of supply shocks, particularly those affecting fossil fuel fired generation which would comprise 82% of the mix in 2030 (see Chart 5.4). The modelling suggests that by 2030 gas-fired plants would represent around 42% of the mix and conventional coal-fired plants 40%, compared to 37% for each fuel in the baseline

155 In the Redpoint modelling, carbon price is assumed to increase steadily from around €12/t$CO_2$ in 2007 to around €44/t$CO_2$ in 2030.

scenario where nuclear is allowed. Even with nuclear excluded as an option, the model does not show any new CCS plants being built, for the same cost reasons as discussed above.

**CHART 5.4: ELECTRICITY GENERATION MIX EXCLUDING NEW NUCLEAR (2005-2030)**




*Source: Redpoint Energy, 2007*

Chart 5.4: If energy companies are not allowed to construct new nuclear power stations, the modelling suggests that the private sector would construct more gas and coal-fired power stations than otherwise because they remain more economic compared to renewables. Note: 2005 are actual output figures (DTI, 2007). This chart excludes electricity output from imports and storage

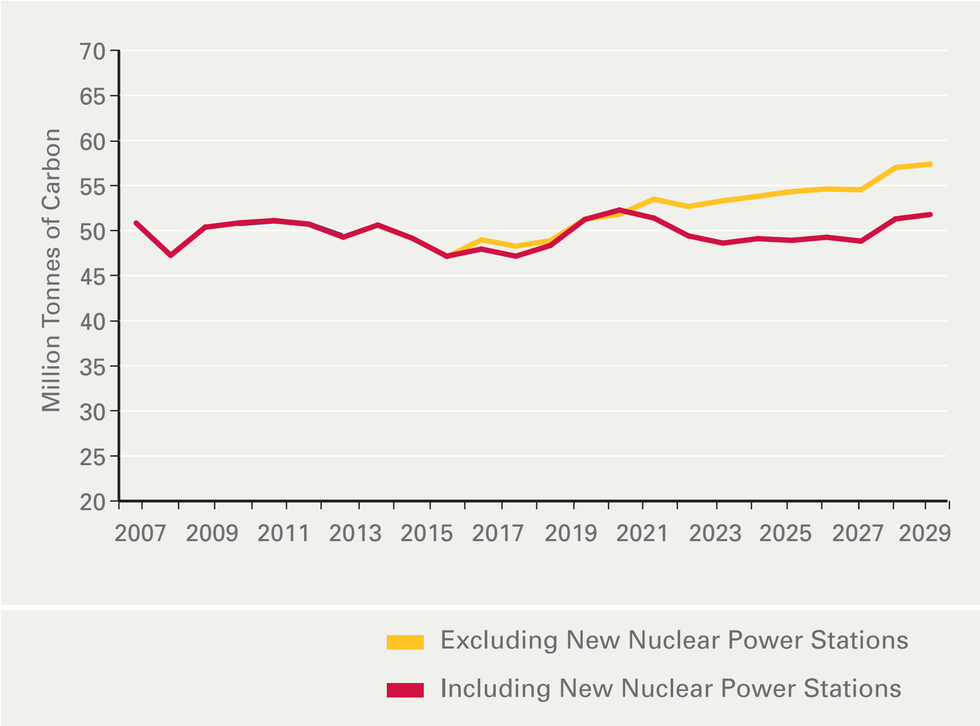
5.59 In addition, the modelling suggests that in this scenario the lower levels of investment in generation capacity and the higher costs of the available generating technologies in the period 2020-2030 increase wholesale electricity prices by, on average, 4% in the 2020-2030 period compared to the scenario where new nuclear is allowed as an option.

## The implications for carbon emissions

5.60 Without the option of new nuclear power stations, we would be more heavily reliant on carbon emitting fossil fuel electricity generation, with negative impacts on carbon emissions. The generation mix in the scenario where energy companies are not allowed to invest in new nuclear power stations shows carbon emissions in the electricity sector being higher by, on average, 4 million tonnes of carbon each year (MtC), in 2030 emissions are almost 6 MtC higher[156]. To put this into context, this average figure of 4 million tonnes of carbon is equivalent to around 16% of the total carbon savings we project to achieve under our central scenario from all the measures we are bringing forward in the Energy White Paper "Meeting the Energy Challenge" (see Chart 5.5).

156 To note that as explained in Box 5.3, the Redpoint Energy modelling does not put any constraints on emissions from the power sector, though it does include a carbon price. This modelling also pre-dates the March 2007 European Spring Council so does not take account of the potential targets we may face in contributing to the EU target that 20% of energy supplies should be from renewable sources.

**CHART 5.5 – CARBON EMISSIONS FROM THE POWER SECTOR INCLUDING AND EXCLUDING NEW NUCLEAR POWER STATIONS**




*Source: Redpoint Energy, 2007*

Chart 5.5 – Carbon emissions under different scenarios where new nuclear power stations are excluded or included.

5.61 As a result, any increase in emissions from the electricity sector, as shown from the modelling, could make it more difficult to achieve our long term target to reduce carbon emissions by 60% by 2050.

## Long term scenarios to 2050

5.62 It is extremely difficult to predict how the energy system will develop in the very long-term – i.e. over the next 40 to 50 years. This is because of the magnitude of uncertainty, in factors such as the cost and availability of fossil fuels; the cost and availability of existing and emerging low carbon technologies; and energy demand growth.

5.63 To help us to examine different possible scenarios in the face of these large uncertainties, as part of the Energy White Paper "Meeting the Energy Challenge", we have used the UK MARKAL-Macro model (M-M model)[157] to help provide insights into the electricity generation technologies that might play a role if we are to reduce carbon emissions by 60% by around 2050. The model provides technological detail on the entire energy system, and is one of very

157 DTI "The UK MARKAL model in the 2007 Energy White Paper" www.dti.gov.uk/energy/whitepaper; Strachan N., R. Kannan and S. Pye (2007), *Final Report on DTI-DEFRA Scenarios and Sensitivities using the UK MARKAL and MARKAL-Macro Energy System Models,* http://www.ukerc.ac.uk/content/view/142/112

few models that allow us to look at how the energy use of the whole UK economy might evolve under a carbon constraint over the next 50 years.

5.64 To reflect the Government's goal, the model is constrained to deliver a 60% reduction in carbon emissions by 2050. The model then chooses the most cost effective combination of technologies across all sectors to deliver this constraint on carbon emissions based on the input data and assumptions on fossil fuel prices and technology costs. As with all models, the M-M model has limitations which we must to take into account in interpreting the results (see Box 5.3 on modelling approaches). However, because it simulates how the UK's energy system might evolve under certain conditions, the model remains a useful tool that we can use to help inform policy making and thinking.

5.65 Chart 5.6 shows the electricity generation mix in 2050 in seven scenarios we have explored, all of them consistent with achieving our goal of reducing carbon emissions by 60% by 2050 at least cost to UK GDP. The chart shows the most cost-efficient generation mix under three broad themes:

- the first three scenarios show the mix under different fuel prices;
- the third and fourth scenarios vary the trajectory of reductions in carbon emissions to 2050[158]; and
- the final three scenarios use a different set of generation cost estimates (all of which are consistent with the DTI financial modelling work published with the Energy Review Report in July 2006)[159]. The detailed assumptions and further results can be found in papers published alongside the Energy White Paper[160].

5.66 Under all of the scenarios analysed for the Energy White Paper, and under two separate sets of generation cost assumptions from the DTI and the UK Energy Research Centre, the model shows energy companies investing in new nuclear power stations, as part of a mix of technologies that delivers our carbon goal at least cost to the economy. This is the case, even in scenarios where we assume that the cost of alternative technologies will fall substantially as industry climbs the learning curve. For example, the average costs of coal-fired CCS generation are assumed to fall by around 15% relative to first of a kind; and the capital costs for offshore and onshore wind are assumed to be successfully reduced by around 30% by 2050.

5.67 If we vary the expected generation costs for key technologies[161], the share of nuclear power in the 2050 electricity generation mix ranges from 28-64% in 2050. Similarly, if we vary the trajectory for achieving emissions savings, the share of nuclear power in the mix can range from 5-36% of the 2050 generation mix. On average across the scenarios in chart 5.5, nuclear power makes up around 32% of the electricity mix in 2050.

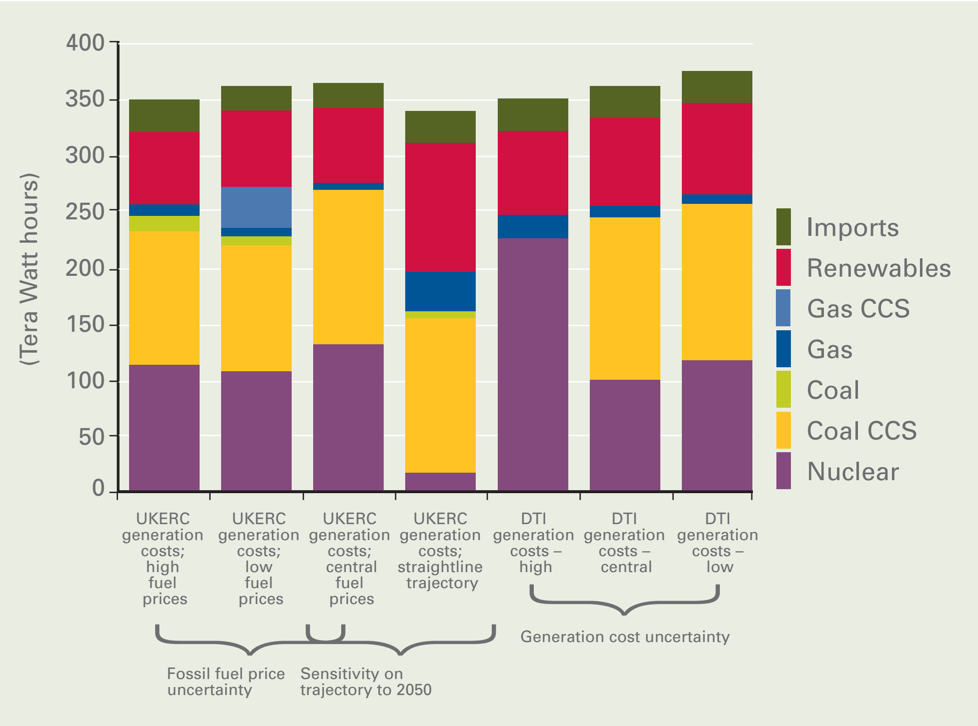
158 Most scenarios in Chart 5.6 follow trajectory of achieving a 30% reduction in emissions by 2030, falling linearly to 60% by 2050. A sensitivity was conducted in which the model was forced to abate earlier in the forecast period, in a "straight line" from 2010 to 2050.

159 To note that all other scenarios use the generation cost estimates from the UK Energy Research Centre (UKERC) database.

160 DTI "The UK MARKAL model in the 2007 Energy White Paper" http://www.dti.gov.uk/energy/whitepaper; Strachan N., R. Kannan and S. Pye (2007), *Final Report on DTI-DEFRA Scenarios and Sensitivities using the UK MARKAL and MARKAL-Macro Energy System Models,* http://www.ukerc.ac.uk/content/view/142/112

161 According to high, central and low ranges published with the Energy Review Report in July 2006.

**CHART 5.6 – ELECTRICITY GENERATION MIX IN 2050 CONSISTENT WITH ACHIEVING A 60% REDUCTION IN EMISSIONS BY 2050 – VARIOUS SCENARIOS IN M-M MODEL**




*Source: UK MARKAL Macro Model*

Chart 5.6 – The M-M model optimises the available technologies to meet the carbon constraint at least cost. In the scenarios in chart 5.6, the cost to GDP in 2050 varies from 0.3%-1.0% of GDP (equivalent to £8-£28 billion) in 2050[162]. In all modelling runs, the model chooses a broad mix of generating technologies to help us meet the 2050 goal[163].

## A scenario with new nuclear excluded as an option

5.68 We have explored a scenario in which the M-M model is prevented from choosing new nuclear power, while still enforcing the requirement to meet a 60% reduction in carbon emissions by 2050. This represents a decision not to allow energy companies the option of investing in new nuclear stations.

5.69 To achieve the 2050 target, the model shows more investment in alternative generation technologies such as wind and coal with CCS. These technologies are currently more expensive than nuclear power even though the model assumes that the costs of these technologies will fall over time, as the technologies become more mature. However, these cost reductions are not guaranteed. Moreover, in the case of CCS, relying on it as a large-scale generation technology will require substantial effort to overcome technical and regulatory barriers (as described earlier in this chapter).

162 This is the annual cost in 2050 (in 2000 prices). This demonstrates that 2050 GDP is lower than it otherwise would be because of the requirement to reduce carbon emissions by 60%.

163 To note the MARKAL model does not model the risk of not being able to achieve our 2050 carbon emissions goal.

5.70 When energy companies are not allowed to invest in new nuclear power stations, in addition to relying more heavily on other more expensive electricity generation technologies, the model also minimises the costs of meeting the 2050 carbon reduction goal by requiring further carbon savings in other sectors of the economy such as transport.

5.71 Even when energy companies have the full range of investment options, including nuclear power stations, the M-M model highlights the profound changes the UK must make to its energy system if it is to meet the 2050 carbon emissions target. These changes become even more radical if a particular technology option, such as nuclear, is excluded. By 2050:

- with no carbon constraint, electricity demand is expected to increase by around 30% compared to today's levels. However, to meet our goals and with all generation technologies available, including nuclear, the M-M model shows that total electricity demand would need to remain at roughly today's levels despite UK GDP being three times as large as today. If nuclear power is excluded, then electricity demand will need to fall by around 6% compared to today's levels. This is a concerted reduction in energy demand, which would have to occur in the context of continued economic growth. This implies a substantial improvement in the energy intensity of the economy, i.e. each unit of output would need to be produced with less and less energy. Although this kind of transformation is not infeasible, the model does not capture the risk that it may not be possible to deliver the technological advances and behavioural changes in energy use required.
- in the scenario that excludes nuclear power, the total contribution of wind power to the overall electricity mix would have to rise significantly relative to today's wind generating capacity – from around 1 to 2% of the generation mix today to around 30% in 2050. This would be equivalent to gaining planning consent for and building more than 15,000 new 2MW wind turbines in the UK in the period to 2050[164]. This represents 10,000 more wind turbines than if energy companies were allowed to invest in new nuclear power stations, and would imply finding appropriate locations with availability of wind and overcoming local objections. Based on the British Wind Energy Association estimates for land take of windfarms, this would require 300,000 hectares devoted to windfarms across the UK. This is about the same amount of space in the UK that is now covered by roads[165]. It is likely that offshore windfarms will also be proposed, although the generating costs are higher than for onshore wind operation and there are regulatory issues to resolve.
- without new nuclear power stations, carbon emissions from electricity generation would be twice what they would have been if we allowed energy companies to invest in new nuclear capacity. In other words, if we were to achieve our target of a 60% reduction in carbon emissions by 2050, we would have to make even greater reductions in emissions from transport and the use of heat.
- in particular, the modelling highlights some of the trade-offs that would occur between sectors. For example to achieve our 2050 goal, car fuel demand will need to fall by around 12% by 2050, compared to what it would have been if no effort is made to reduce emissions. However, when nuclear is excluded fuel demand has to fall by a further 13%.

164 The M-M model does not capture any potential planning constraints on the siting of these required turbines.
165 http://www.bwea.com/ref/faq.html

5.72 As discussed earlier in this chapter, there are many uncertainties and virtually limitless scenarios that can be considered. The scenarios above are just a few examples of the developments we would need to see to deliver the 2050 goal without new nuclear power as an option for the private sector. They highlight how removing nuclear power as an option could increase the challenges and costs of tackling climate change.

5.73 It is difficult to quantify implications for the economy and consumers of energy as a result of the additional constraints on energy use that arise from excluding nuclear power, both in terms of the risks of achieving our carbon goals or securing energy supplies, but also in terms of the effect it will have on individuals in terms of loss of well-being.

### A scenario with new nuclear excluded as an option and where CCS fails to develop

5.74 We have also examined a scenario where nuclear power is excluded as an option, and safe, reliable carbon capture and storage with power generation fails to develop on a sufficient scale in the timeframe available. This scenario could include an outcome where the overall costs of a large scale roll-out of CCS, including the required infrastructure costs, turn out to be too high, or simply that it is found that the carbon dioxide cannot be transported and stored safely in underground aquifers or depleted oil/gas fields over the very long-term. In this scenario, even more substantial changes to the type and amount of energy we use would be required by 2050:

- wind generation would have to rise to over 60% of the UK's electricity mix, requiring planning consent for and construction of at least 30,000 2 MW wind turbines. We do not know if it is technically possible or publicly acceptable to generate such a proportion of our electricity by wind power; and
- electricity demand would have to fall by around 9% relative to today's levels, compared to no change in demand if nuclear is included in the mix. Again, this would need to be delivered against a background of a 200% growth in the UK economy.

### Estimates of costs

5.75 The M-M model provides an indication of the likely costs of different scenarios. In the scenario where nuclear is excluded but all other technologies are available – and are successfully deployed with the associated cost reductions assumed in the modelling – the M-M model estimates that in delivering the 60% goal there would be an additional annual cost to the UK economy by 2050 of around £1bn (a total annual cost of achieving the 60% goal of £21 billion by 2050).

5.76 In the scenario where nuclear is excluded and CCS fails to develop, the M-M model estimates that, by 2050, the additional annual cost to the UK economy would be around £6 billion (so that the overall annual cost of achieving the 60% goal would be £26 billion in 2050). In other words, the modelling estimates that the additional costs of excluding nuclear as an option from the mix is an annual cost of £1 billion in 2050, and an annual cost of £6 billion if CCS technology also fails to develop.

5.77 Although the M-M model is useful in capturing the technical implications of reducing carbon emissions, it cannot capture the full financial (or indeed social implications) that might occur if a particular low carbon technology were excluded.

The model cannot either take account of the security of supply considerations either of relying on a limited number of technologies, for example exposure to a greater risk of technological failure or exposure to the risk of a fuel supply interruption, for example in gas supply. Nor does it capture some of the risks inherent in the modelling assumptions, such as the risk that the costs of alternative low carbon technologies do not fall as much as projected or the risk that we fail to see the behavioural change required to deliver the improvements in energy efficiency necessary to meet our 2050 goal. We believe the cost estimates the M-M model provides are therefore likely to be at the lower end of estimates of the expected costs.

## The implications of excluding nuclear from the mix

5.78 Given the risks and uncertainties associated with the development of new technologies, as well as the risks and uncertainties about the way in which the world and energy markets may develop, we believe it is essential to have as diverse a portfolio as possible of available technologies. On this basis, excluding any one of these options would increase the risks and costs associated with delivering our energy policy goals.

5.79 In particular, excluding the option of new nuclear build from a future energy mix would threaten:

- **Delivery of our 2050 carbon emissions reduction goal** – if nuclear power, a large-scale proven low carbon technology, were excluded we would be principally reliant on renewables and CCS technologies for reducing carbon emissions from electricity generation. The application of CCS to electricity generation is as yet unproven and without a breakthrough in technology for storing electricity, most renewable technologies need to be backed up with non-intermittent technologies. If there were problems or high costs associated with the development or deployment of either technology, more effort to reduce emissions would be needed in other sectors, for example transport. This could increase the risks of failing to meet our carbon goal;
- **Security of supply** – Nuclear power is a proven technology. It already contributes to the diversity of the UK generation mix. Without the option of nuclear power, we will be reliant on a smaller number of technologies to insure us against the range of future developments which could undermine security of supply, for example higher fossil fuel prices or disruption in the fuel supply chain. Some of these technologies – such as CCS and renewables – may not be deployable on a large scale to meet demand. This would expose us, in some scenarios, to a higher risk of electricity supply interruptions or to higher costs for delivering a given level of security of supply; and
- **The cost of delivering our energy policy goals** – Nuclear power is likely to be one of the most cost effective low carbon electricity generation technologies, even when we assume substantial learning in the development and deployment of alternative low-carbon technologies like renewables. We risk incurring a higher cost in meeting our carbon and security of supply goals if there are problems with the availability of alternative technologies, the costs of deploying them do not reduce as expected or we exclude the option of investing in new nuclear power stations. Long run average electricity prices are effectively capped by the long run costs of building a new power station. Therefore, in the absence of the option to build the least expensive available technology, the UK would incur higher costs to deliver the same amount of electricity. Based on our modelling and in a central scenario, in 2030 –

including the assumed carbon price – the cheapest technology would be nuclear at £42/MWh, while the next cheapest technology would be gas at £48/MWh, which is about more 10% higher than the cost of nuclear power[166]. These costs will faced by generators and may be passed through to consumers.

**The Government believes that given the wide range of uncertainties it is difficult to predict with certainty the future need for and use of energy and electricity.**

**We have modelled a number of different future scenarios as part of the analysis to support the Energy White Paper. The modelling indicates that it might be possible under certain assumptions, to reduce the UK's carbon emissions by 60% by 2050 without new nuclear power stations. However, if we were to plan on this basis, we would be in danger of not meeting our policy goals:**

- **Security of supply: we would be reliant on a more limited number of technologies to achieve our goals, some of which (e.g. carbon capture and storage) are yet to be proven on a commercial scale with power generation. This would expose the UK to greater security of supply risks, because our electricity supplies would probably be less diverse as a result of excluding nuclear; and**

- **reducing carbon emissions: by removing one of the currently more cost-effective low carbon options, we would increase the risk of failing to meet our long term carbon reduction goal.**

**By excluding nuclear as an option, our modelling also indicates that meeting our carbon emissions reduction goal would be more expensive.**

**Therefore, the Government believes that giving energy companies the option of investing in new nuclear power stations lowers the costs and risks associated with achieving our energy goals to tackle climate change and ensure energy security.**

### Question 5
### 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?

166 Redpoint Energy, *Dynamics of GB Electricity Generation Investment: Prices, Security of Supply, $CO_2$ Emissions and Policy Options*, 2007.

CHAPTER 6

# Safety and security of nuclear power

## Introduction

**This chapter explores the safety and security risks posed by civil nuclear power facilities in the UK. It also describes the regulatory protections in place to ensure that these risks are managed.**

6.1 The operation of any power station creates safety and security risks. There are also certain risks associated with recovery of fuel for power stations, for example there are safety risks with coal mining and offshore oil and gas platforms that need to be considered and mitigated. It is for this reason that there is a health and safety regulatory framework in place to ensure industry sensibly manages these risks.

6.2 Nuclear power stations create some specific safety and security risks. These can arise from the design and operation of the power station itself, or from external events. The sort of external influences that could affect a reactor might be natural events such as flooding or man-made, such as a terrorist attack.

6.3 This chapter sets out information on:

- the risk of accidents, examining previous events, developments in modern designs of nuclear power stations;
- the flood management protection required for nuclear power stations;
- security issues;
- potential health impacts from exposure to radiation;
- implications for nuclear proliferation and the international safeguards; and
- the UK and international regulatory regime on these issues.

6.4 The UK has an established regulatory framework, enshrined in legislation, that sets out to ensure that the industry effectively manages the risks associated with the operation of civil nuclear power stations. The key regulators are the:

- Nuclear Installations Inspectorate (NII), a part of the Health and Safety Executive's (HSE) Nuclear Directorate;
- Environment Agency (EA) in England and Wales and the Scottish Environment Protection Agency (SEPA) in Scotland; and
- Office for Civil Nuclear Security (OCNS), a part of the Health and Safety Executive's Nuclear Directorate.

6.5 Other bodies that play an important role in managing these risks include the UK Safeguards Office (UKSO), a part of the Nuclear Directorate of the HSE, which works to ensure that our nuclear safeguards obligations are met. Another organisation, the Dangerous Goods Division of the Department for Transport (DGD-DfT), regulates the safety of transportation of nuclear materials (see chapter seven).

## The risk of accidents at nuclear power stations

### The UK regulatory regime

6.6 Any operator of a nuclear power station must comply with the general health and safety requirements of the Health and Safety at Work etc. Act 1974 and related regulations. Operators must also comply with the Nuclear Installations Act 1965, which requires the potential operator to have a licence from the NII before constructing a nuclear power station. Before issuing a licence, the NII must be satisfied that the power station can be built, operated and decommissioned safely, with risks being kept *"as low as reasonably practicable"*[167] at all times. (This is known as the ALARP principle.) The licence will carry conditions that allow NII to ensure that the operator controls risks throughout the life of the installation.

6.7 The NII's Safety Assessment Principles – there are more than 500 in total – reflect the guidance and standards of the International Atomic Energy Agency (IAEA). These principles describe what the NII looks for when it is considering the safety of a nuclear facility.

6.8 Nuclear power stations must be designed to cope with a wide range of potential failures of equipment or of operation. Operators must be able to demonstrate that in all such events off-site radiological doses will not exceed stringent specified limits. Operators must also demonstrate that the predicted frequency of such accidents is low and within acceptable limits. These limits become more onerous the higher the predicted radiological impacts: an accident with a large off-site release of radioactivity must have a very low probability of happening.

### Classification of nuclear incidents

6.9 In 1990, the IAEA introduced the International Nuclear Events Scale (INES)[168] to explain nuclear and radiological events, their significance, and relative importance to the public in simple terms. More than 60 countries, including the UK, now use INES (see Table 6.1). Events are classified against three criteria:

- on-site impact;
- off-site impact; and
- defence-in-depth[169] degradation.

167 In UK law, measures necessary to avert risk are "reasonably practicable" until or unless their cost, whether in money, time or trouble, is grossly disproportionate to the risk that would thereby be averted.

168 IAEA, *The International Nuclear Events Scale: User's Manual (2001 Edition)*, 2001.

169 Power stations are designed, to meet regulatory requirements, with multiple physical barriers between the source of radioactivity (i.e. fuel inside the nuclear reactor) and the environment, or with multiple different safety systems, so that should one fail then a back-up can be brought into use.

| TABLE 6.1 INTERNATIONAL NUCLEAR EVENTS SCALE | | |
|---|---|---|
| Event type | INES Level | Description |
| Deviation | 0 | Event with no safety significance |
| Incident | 1 | Anomaly<br>*On and off-site impact:* nil<br>*Defence-in-depth degradation:* beyond the authorised operating regime |
| | 2 | Incident<br>*Off-site impact:* nil<br>*On-site impact:* significant spread of contamination or over-exposure of worker<br>Defence-in-depth degradation: significant failures in safety provisions |
| | 3 | Serious incident<br>*Off-site impact:* very small release – public exposure at a fraction of prescribed limits<br>*On-site impact:* major contamination or acute health effects to a worker<br>*Defence-in-depth degradation:* near accident – no safety layers remaining |
| Accident | 4 | Accident without significant off-site risk<br>*Off-site impact:* minor release – public exposure of the order of prescribed limits<br>*On-site impact*: significant damage to reactor core or radiological barrier or worker fatality |
| | 5 | Accident with off-site risk<br>*Off-site impact:* limited release – partial implementation of local emergency plans<br>*On-site impact:* severe damage to reactor core or radiological barriers |
| | 6 | Serious accident<br>*Off-site impact:* significant release – full implementation of local emergency plans |
| | 7 | Major accident<br>*Off-site impact:* major release, widespread health and environmental effects |

Table 6.1 The International Nuclear Events Scale, devised by the IAEA, is a sort of “Beaufort” or “Richter” scale for nuclear incidents. It places nuclear incidents on a scale of severity. Since the UK adopted INES in 1990, there have been eight events at UK nuclear power stations that were classified at Level 2.

## Previous incidents at nuclear installations

6.10 Operators of licensed nuclear facilities in the UK have to report all safety-related incidents to the HSE. The Sustainable Development Commission recently described the UK's civil nuclear industry as having an excellent safety record[169a]. There have been no events relating to a civil nuclear power station with off-site consequences or where all the safety barriers that are an inherent part of the design were breached. Since the UK adopted INES in 1990, there have been eight events at UK nuclear power stations that have been classified as Level-2 incidents.

6.11 There has been one "significant event" in the UK which led to an off-site release of radioactivity, although this was not from the civil nuclear industry. The incident, retrospectively classified as INES 5, occurred at an early plutonium producing military reactor known as the Windscale Pile One in 1957[170]. The pile was an air-cooled graphite moderated reactor. The accident caused the reactor core to overheat, releasing radioactivity over the surrounding area in west Cumberland. It resulted in a ban on the consumption of milk in the area around the site for approximately six weeks. The second Windscale reactor was shut-down immediately after the accident and was never restarted. The UKAEA is decommissioning both reactors, a process that provides experience in developing the technologies needed to decommission nuclear power stations.

6.12 The nuclear industry maintains that the Windscale fire resulted in no loss of life outside the plant and that there has been no long-term environmental contamination[171]. Other parties, however, maintain that the accident should have had an INES rating of more than five. It is indisputable, however, that it was the UK's most serious nuclear event. However, it happened in the 1950s, before the UK independent safety regulatory regime was established. The nuclear regulators would not allow such a reactor to be built today, because it would not satisfy their Safety Assessment Principles.

6.13 A number of incidents have occurred at civil nuclear installations that are not power stations, including research reactors and the Sellafield reprocessing facility. Of these incidents, two, both at Sellafield, have been rated at INES 3. They involved the release of radioactive material within the process plant. The design of the plant meant that there was no off-site release of radioactive material. There have been no events at civil nuclear facilities in the UK rated higher than INES 3.

6.14 A small number of significant accidents[172] have happened at nuclear installations elsewhere in the world such as a serious incident at Three Mile Island in Pennsylvania in 1979. Some of these, such as the accident in 1986 at the Chernobyl nuclear power station in the Ukraine, had significant impacts on health and the environment.

169a Sustainable Development Commission, *Paper 6: Safety and Security,* March 2006.

170 A description of the Windscale Pile event can be found at: http://www.ukaea.org.uk/downloads/windscale/pileaw.pdf

171 World Nuclear Association, *Safety of nuclear power reactors,* November 2003, http://www.world-nuclear.org.

172 Sustainable Development Commission, A summary of significant international events is available in the Sustainable Development Commission report: *Paper 6: Safety and Security,* March 2006.

6.15 However, for a number of reasons we must be careful before comparing past accidents that happened abroad with anything that might occur at new civil nuclear power stations in the UK. In particular, regulatory scrutiny of reactor operations in the former USSR was far less rigorous than it is in the UK today. We must also remember that many of these past accidents occurred in power stations with designs that would not be acceptable to regulators in the UK.

## Safety aspects of modern nuclear power stations

6.16 While we can draw on the experience of early generations of nuclear power stations when analysing safety issues, we can expect new reactor designs to be very different. Designers of nuclear power stations have taken this earlier operational experience and learned lessons from previous nuclear events. They have added features to reduce the likelihood of plant failures and to limit the consequences when failures occur. For example, some of the designs of light water reactors (LWRs) of the type that might be built in the UK make greater use of passive safety features. These employ natural forces, such as gravity flow and natural circulation, to maintain essential cooling. This means that they will not have to rely on the continued operation of engineered safety features, such as pumps circulating coolant, to prevent or limit the effects of plant failures. As a result, designers contend that new designs of nuclear power stations have a significantly lower risk of plant failures leading to a damaged reactor core[173], compared with those which are in operation today – which are already acceptable to the nuclear regulators. For example, the US Nuclear Regulatory Commission specifies that reactor designs must meet a 1 in 10,000 year frequency of damage to the reactor core, but modern designs exceed this. US utility requirements are 1 in 100,000 years, the best currently operating plants are about 1 in 1 million and according to industry, those likely to be built in the next decade are almost 1 in 10 million[174].

6.17 Analysis by the European Commission on the potential for nuclear events suggests that in the UK the probability of major accidents – the meltdown of the reactor's core along with failure of the containment structure – is one in 2.4 billion per reactor per year[175]. By comparison to other events with an extremely low probability, it is thought that the risks of a meteorite of roughly two kilometres in diameter hitting the earth, which could have significant global environmental impacts, could be one per 0.5 million years[176]. However, such a nuclear accident could have severe and wide-ranging consequences, so we have to consider very carefully whether it is reasonable to run such a risk.

6.18 Based on its Safety Assessment Principles, the NII expects the use of different safety systems, with multiple back-ups, to assure the safety of new power stations to a high degree of confidence. Under the same principles, the NII will seek assurance that new designs require no operator intervention for at least 30 minutes following any occurrence at the power station that may affect safety.

173 According to Westinghouse, the manufacturer of the AP1000, the risk of core damage (equivalent to an INES 4 event) is nearly 100 times below current plant and 250 times below the risk permitted by the US nuclear regulator.
174 Uranium Information Centre, http://www.uic.com.au/nip14.htm
175 European Commission, *Externalities of Energy (ExternE), Methodology 2005 Update.*
176 NASA Asteroid and Comet Impact Hazards, http://128.102.32.13/impact/intro_faq.cfm

6.19 The NII is not in a position to substantiate safety claims for reactor safety before it has a chance to carry out detailed assessments. However, the NII certainly expects new designs to take account of operational experience worldwide and to reflect modern safety philosophy and safety features. New nuclear power stations should, then, present risks at least as low as those of existing reactors. There is no reason in principle why these could not be operated safely in the UK. The NII will subject applications to construct new power stations to a rigorous, multi-stage assessment and licensing process to ensure that they are safe to operate.

## Flood risk management

6.20 Just as nuclear power could itself be a part of the UK's response to climate change, the design and operation of nuclear facilities must also anticipate the consequences of climate change and put in place any necessary protective measures. While the design of existing power stations already covers many of the risks that are associated with the effects of climate change, such as more severe weather patterns, there may be other risks that we need to consider for new and existing nuclear facilities. For example, rising sea levels may pose risks to nuclear power stations in some coastal locations. The UK's regulatory regime already requires operators to ensure that nuclear installations are kept safe from flood risks throughout their life, including the period of operation and during decommissioning.

6.21 Under the terms of the nuclear site licence, the NII requires operators to provide a high standard of flood risk protection, so that nuclear facilities can withstand predicted sea level rises. The licence also requires protection against other possible effects of global warming, as well as potential extreme weather events, such as a one in 10,000-year flood risk[177]. The NII requires operators to review the level of protection needed against all external hazards, including flooding, as part of the facility's Periodic Safety Review. Such reviews facilitate the identification of any additional measures required to meet any changes in external hazards, for example any increase in estimates of sea level rise.

6.22 For new nuclear power stations, not only would these requirements apply, but flood risk and flood management issues would also need to feature in the selection of appropriate sites. Such factors will feature in the Strategic Siting Assessment process that we propose to carry out after this consultation, should we conclude that energy companies should be allowed to invest in new nuclear power stations.

6.23 A study prepared by the Met Office[178], on behalf of British Energy highlighted that although sea levels are likely to rise, the increase will not be uniform. This is because a number of issues affect sea levels, such as ocean circulation and local patterns of air pressure. The Met Office's study examines the potential impact of increased greenhouse gas emissions on global temperature and sea levels. It estimates a global increase in sea levels of

177 Safety Assessment Principles: EHA.4 EHA.11, EHA.12, EHA.14, EHA.15, ECE.23
178 Met Office, *Review of medium to long-term coastal risks associated with British Energy sites: Climate Change effects – Final Report,* February 2007.

9 to 69 centimetres by 2080, with local sea level rises varying by up to 50% in relation to the global sea level rise. This is comparable to other estimates[179]. Taking account of increasing sea levels and the potential increase in storm surges, the study concluded that in 2080, the potential height of a "1 in 50-year" storm surge at the UK existing coastal nuclear power stations could be in a range of 94 centimetres to 170 centimetres. The risk of such surges would require additional flood defences to protect power stations at those sites in that timeframe. The regulatory framework in the UK would ensure that power stations on those sites at that time would have flood protection that could at least protect against such events.

6.24 Nuclear operators are responsible for funding their own flood risk management and coast protection defences and for ensuring that they are compatible with other defences in the area. In line with the principles on waste management and decommissioning that the Government published in the 2006 Energy Review report, developers would have to provide and pay for flood management after operation has ceased and until any material in interim storage had been removed from the site.

6.25 The Environment Agency, which has a general supervisory duty for flood protection in England and Wales, estimates that the capital cost of providing a high level of protection for a site with high tidal and wave exposure can range from £2,000 to £20,000 per linear metre[180]. The range is based on the height and type of defence which could vary from low earthen embankments at the lower end of the cost scale to more complex and high concrete or steel structures at the upper end. This would represent a small percentage of the overall capital cost of new power stations[181].

## Security issues and potential vulnerability to terrorism

6.26 Since 2001, there has been a review of security following a change in the threat to the UK. We recognise that nuclear power stations could be attractive targets for terrorist attacks because of the potential impacts such an attack could have on public health and the economy, and the publicity it would attract.

### The UK regulatory framework

6.27 The Convention on the Physical Protection of Nuclear Material, as amended in July 2005, obligates signatories to the Convention to maintain an appropriate security regime with the aim of protecting against the theft of civil nuclear material and protecting such material and civil nuclear facilities against sabotage[182]. In implementing this obligation, signatories are required to maintain a legislative/regulatory framework, designate a regulatory authority

179 Greenpeace and Flood Hazard Research Centre, *The Impacts of climate change on nuclear power stations sites: a review of four proposed new-build sites on the UK coastline,* March 2007.
180 Environment Agency data from the National Capital Programme Management Service (NCPMS) database which includes data on flood defences.
181 DTI Analysis, Energy Challenge, July 2006.
182 http://www.unodc.org/unodc/terrorism_convention_nuclear_material.html.

and apply a number of Fundamental Principles. The UK is a signatory to the Convention and expects to ratify the amendment to this Convention during the forthcoming year.

6.28 The UK has a comprehensive legal and regulatory framework[183], enforced by the Office for Civil Nuclear Security (OCNS), which is part of the Health and Safety Executive, to ensure the security of nuclear installations and nuclear materials in transport which fully meets the requirements of this amended Convention.

6.29 The IAEA also issues guidance to states on how to regulate nuclear security matters[184]. The IAEA's guidance deals with how states should protect themselves against the threats of sabotage or theft of nuclear materials during use, storage or transport.

6.30 The OCNS has regulatory and operational independence and is staffed with professional security personnel. It is responsible for approving security arrangements within the civil nuclear industry and enforcing compliance with regulatory requirements. It does this through inspections and by requiring operators of nuclear plant to carry out counter-terrorism exercises. The Director of Civil Nuclear Security publishes an annual report on the current state of security in the civil nuclear industry. The most recent report, published in August 2006, is available on the website of the OCNS[185].

6.31 Since 1999, the IAEA has recommended that, in implementing national physical protection programmes, states create a "Design Basis Threat" (DBT) assessment. The threat assessment defines the characteristics of potential adversaries who might attempt the unauthorised removal of nuclear materials or sabotage, in order to determine the physical protection measures required. The OCNS is actively involved in the propagation of the DBT scheme to IAEA members and has supported the IAEA in providing guidance and seminars explaining the concepts. The UK's threat assessment is a highly sensitive and protected document. For obvious reasons, it cannot be published. However, the threat assessment provides the civil nuclear industry with an assessment and description of current security threats against which it is required to take appropriate security measures.

6.32 The OCNS is a member of the UK's Joint Terrorism Analysis Centre and working with the various intelligence agencies, it monitors the threat levels to the UK's civil nuclear industry[186]. Regular assessments of the threat levels are made and are disseminated to the industry in updates that supplement the existing DBT. These threat assessments include not just the possibility of terrorist attack against a site but also potential theft of nuclear material or sensitive nuclear information and potential manipulation or blackmailing of staff employed in sensitive positions.

183 Principally contained in the Anti-terrorism, Crime and Security Act 2001, the Nuclear Industries Security Regulations 2003, the Energy Act 2004 and the Serious Organised Crime and Police Act 2005 (as amended).
184 INFCIRC 225 r4 http://www.iaea.org/worldatom/Programmes/Protection/inf225rev4/rev4_content.html
185 http://www.dti.gov.uk/files/file33004.pdf
186 http://www.mi5.gov.uk/output/Page421.html

6.33 Each civil licensed nuclear site has a site-specific security plan which must be approved by the OCNS and which is subject to regular review. Licensees are then required to comply with the standards, procedures and arrangements described in this approved plan.

6.34 For any new nuclear power stations, the OCNS would be involved in the generic design assessment stage with a view to security being built-into the design, rather than being retrofitted.

6.35 The OCNS requires site operators to develop security plans according to the "defence in depth" principle, with several layers and methods of protection that have to be overcome or circumvented, thereby providing appropriate detection, assessment, delay and response to malicious acts. The arrangements detailed include physical security measures, policing and guarding, the protection of sensitive nuclear information and the trustworthiness of staff with access to the site, nuclear material and sensitive nuclear information. All security measures, including the Civil Nuclear Constabulary, are wholly funded by the civil nuclear site licensee.

6.36 The physical security features at licensed civil nuclear sites include:
- chicanes and double barriers to prevent vehicle access points being attacked at speed;
- razor-wire fencing;
- CCTV-linked to permanently-manned security buildings;
- turnstile access where entry and exit is only possible with a site-specific pass, supported with intruder detection systems; and
- additional barriers within the site to protect sensitive areas such as the reactor building.

6.37 Systems at the perimeter fence provide delay coupled with a detection and assessment capability, enabling management to assess the threat posed by the intrusion and to activate appropriate contingency arrangements. The response would depend on the nature of the intrusion. For example there would be different responses to an incursion by demonstrators than to a terrorist attack intent on causing harm[187].

6.38 All nuclear power stations are protected by armed officers from the Civil Nuclear Constabulary (CNC), as well as civilian security guard forces. The CNC, a specialist police force, funded by the nuclear industry, protects nuclear sites and material. Officers in the CNC have full police powers within 5 km of a licensed nuclear site, and anywhere else they need to be to protect nuclear material. If needed, the local police force would provide an additional response.

6.39 Sensitive nuclear information includes information about how plants are protected, including the identification and protection of critical safety systems. This information has to be protected. The OCNS provides instructions on how to handle, store or transmit this information, carries out inspections and approves the licensees' IT security arrangements. The OCNS keeps holders of sensitive nuclear information in the UK informed of threat levels.

187 Following such incursions in 2002 and 2003, unauthorised access onto a licensed civil nuclear site is now a criminal offence under the Serious Organised Crime and Police Act 2005 (as amended).

6.40 In accordance with the site security plan, operators must conduct annual counter-terrorist exercises to test response arrangements, including the command and control arrangements. These carefully planned exercises put staff through a number of scenarios. Where possible, these exercises also involve local emergency services.

6.41 To ensure their trustworthiness, the OCNS undertakes vetting of all employees and contractors who have access to nuclear sites, material and sensitive information. The level of vetting depends on the extent of an individual's access at the site.

## Reports on terrorism and nuclear power stations

6.42 Following the House of Commons Defence Committee report on "Defence and Security in the UK"[188], the Parliamentary Office of Science and Technology (POST) was asked to produce a report "examining the physical robustness of nuclear installations against attacks as well as the consequences in terms of the amount of radioactive material liable to be released and its effects". The report, which was published in July 2004, set out to provide a balanced and impartial view of what was publicly known about the issue. The POST report[189] was limited to published material, although operators and regulators provided access to sites and classified briefings.

6.43 The report summarised that existing nuclear power stations were not designed to withstand some forms of terrorist attack, such as a large aircraft impact, but existing safety and security regimes provided some defence. Published reports drew widely different conclusions about the consequences of attacks on nuclear facilities, due to differing assumptions about the size and nature of the release, weather conditions and the efficiency of countermeasures. Reports suggested that, in a worst case scenario, the impact of large aircraft on certain facilities could cause a release of radioactive material, but some analysts questioned the accuracy of these reports, and argued that accurately targeting these facilities would be difficult. The POST report also pointed out that the events of September 2001 had led to additional protection measures being put in place to increase security and to strengthen emergency planning at and around nuclear facilities.

6.44 It is important to note however that the POST report looked primarily at existing nuclear facilities. Many modern nuclear facilities are designed to withstand the impact of an aircraft. Safety measures can include double layered, reinforced reactor buildings and the strategic siting of protection systems[190].

## New nuclear power stations and terrorism

6.45 Any new nuclear power station would be required to have an approved security plan before radioactive material is allowed on site. Government is considering whether to bring this requirement forward such that the security plan must be approved before construction can begin. The site security plan would need to be developed taking into account the malicious capabilities

188 Defence and Security in the UK, *Defence Select Committee, 6th report, session 2001-2002,* July 2002.
189 Parliamentary Office of Science and Technology, *Assessing the risk of terrorist attacks on nuclear facilities, Report 222,* July 2004, http://www.parliament.uk/documents/upload/POSTpr222.pdf
190 Pressurized Water Reactor, 1600 MWe (EPR), Nuclear Power Plant Olkiluoto 3, Finland, Functional Description , AREVA, http://www.areva-np.com/common/liblocal/docs/Brochure/EPRallemand_26p_en.pdf

detailed in the threat assessment and the "Vital Area" study conducted as part of the Generic Design Assessment.

6.46 Increased security arrangements at national and international airports have reduced the likelihood of airborne terrorist attacks[191]. However, Government chooses not to rely solely on such measures to ensure the security of nuclear installations in the UK. The OCNS has worked with operators of nuclear facilities and the NII on measures to mitigate the risk of a deliberate large aircraft crash. For security reasons, it is not possible to release the details. While these measures relate to existing nuclear installations, we can expect them to apply to new power stations that may be built in the UK.

6.47 Operators and the regulator review security measures in line with current threat assessments, and the OCNS inspects sites regularly to ensure that site operators are following the security arrangements detailed in security plans. As such, the OCNS believes that the security risks associated with building new nuclear power stations can be appropriately managed.

## Health impacts from exposure to radiation

6.48 We are all exposed to natural background radiation. Most of our exposure to radiation, around 80% of the total, comes from natural sources[192], such as natural radon gas that emanates from the ground, cosmic rays from outer space and radiation from rocks and soil. Many naturally occurring materials emit ionising radiation. Medical procedures, such as X-rays, are by far the largest source of our exposure man-to-made radiation, accounting for 14% of our total annual exposure[193].

### The UK Regulatory Regime

6.49 The UK has a strict regulatory framework[194] to restrict routine discharges from nuclear power stations and direct radiation exposures to workers and the general public. The aim is to minimise potential health impacts and ensure that radiation doses are well within internationally agreed limits. These limits are underpinned by obligations under the Euratom Treaty[195]. The UK is also a signatory to the North Sea Conference and OSPAR (Oslo-Paris Convention) which both put limits on the discharges of radioactivity to the North Sea, including the UK's coastal waters.

6.50 The NII works alongside the Environment Agency and the Scottish Environment Protection Agency, which regulate liquid or gaseous radioactive discharges and the disposal of solid radioactive waste, to protect against the health impacts of radiation exposure. The regulators require the operators to

191 Large Associates, *Operational Risks and Hazards of the EPR when subject to aircraft crash,* August 2006.
192 National Radiological Protection Board, now part of Health Protection Agency, *Radiation Doses – Maps and Magnitudes Second Edition.*
193 National Radiological Protection Board, now part of Health Protection Agency, *Radiation Doses – Maps and Magnitudes Second Edition.*
194 As laid out in the Ionising Radiations Regulations, 1999, the Radioactive Substances Act 1993 and Environment Act 1995.
195 Council Directive 96/29/Euratom of 13 May 1996, laying down basic safety standards for the health protection of the workforce and general public against the dangers of ionising radiation. Official Journal of the European Communities, (L159 29.6.1996, p.1).

ensure that the exposures of workers and public from radioactivity from nuclear sites are kept not only below stringent legal limits but are as low as is reasonable achievable. Any new nuclear power stations would need authorisation, under the Radioactive Substances Act 1993, from the relevant environment agency before making any discharges of radioactivity into the environment or disposals of radioactive waste.

6.51 The Government and industry have an emergency preparedness framework in place to mitigate health effects in the unlikely event of major accidental releases of radiation into the environment. This framework includes detailed site-specific plans for each nuclear facility. The plans are tested regularly through exercises, some of which involve the Government and simulated media involvement.

6.52 The environment agencies are responsible for ensuring that new nuclear power station designs can meet high environmental standards and use the best available techniques (BAT) to achieve this, as required by the OSPAR Convention. Through the Generic Design Assessment process (see chapter thirteen), the environment agencies ensure that operators consider this requirement at an early stage. This ensures that the most modern techniques to minimise radioactive waste discharges can be incorporated into the designs of the stations. The application of BAT would ensure that discharges from new nuclear power stations constructed in the UK would not exceed the levels of comparable power stations across the world.

## Radiation exposure to the general public from nuclear power industry

6.53 The Health Protection Agency has assessed the average dose to a member of the general public from all sources of radioactivity and calculates that this is 2.6mSv per year, 80% of which is from natural sources[196]. There is a statutory annual dose limit of 1mSv to members of the public from activities covered by the Ionising Radiations Regulations 1999[197] and the Radioactive Substances Direction 2000[198]. According to the Sustainable Development Commission, the average dose to a member of the public due to radioactive discharges from the nuclear power industry is 0.015% of the annual dose from all sources[199].

6.54 The environment agencies in the UK run a number of monitoring programmes to provide an independent check on the impacts of radioactive discharges. According to the results for 2005, no one living in the vicinity of the existing UK nuclear sites exceeded the statutory dose limit of 1mSv[200].

6.55 The individuals most exposed to radiation from the nuclear power industry were people in Cumbria who were assumed to be large consumers of locally caught fish and shellfish. Their annual dose was 0.46mSv in 2005,

196 Sustainable Development Commission, *Paper 6: Safety and Security,* March 2006.
197 This includes all activities carried out under a nuclear site licence issued by the NII under the Nuclear Installations Act 1965. A full list of activities that are covered is at Regulation 6 and Schedule I of the Ironising Radiations Regulations (SI:1999/3232).
198 The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000 for EA, The Radioactive Substances (Basic Safety Standards) (Scotland) 2000 for SEPA.
199 Sustainable Development Commission, *Paper 6: Safety and Security,* March 2006.
200 Radioactivity in Food and the Environment, 2003. RIFE-11, Environment Agency, Scottish Environment Protection Agency, Environment and Heritage Service, Food Standards Agency, October 2005, http://publications.environment-agency.gov.uk/pdf/PMHO1006BLJP-e-e.pdf

with much of this dose attributable to the Sellafield facility (0.22mSv). Most of this dose is due to historic liquid discharges from Sellafield. While these significant discharges have ceased, the legacy remains[201]. Individuals living in the vicinity of the existing nuclear power stations have lower levels of exposure to radiation, with the most exposed group receiving a dose of 0.13mSv[202].

6.56 According to the independent Committee on Medical Aspects of Radiation in the Environment (COMARE), there is no significant impact of these exposures to radiation on the health of populations living near nuclear power stations. COMARE has monitored this issue since 1986, and has published 11 comprehensive reports on the potential implications of exposure to radiation. The most recent COMARE report identified no evidence of adverse health effects in residents within a 25 kilometre radius of UK power stations[203].

## Radiation exposure to workers in the nuclear power industry

6.57 Under UK law, all employers are responsible for protecting their employees against exposure to radiation in accordance with strict dose limits under the Nuclear Installations Act 1965 and Ionising Radiations Regulations 1999. These limits reflect the recommendations of the International Commission for Radiological Protection for an individual dose limit for radiation workers of 100mSv, averaged over five years, giving an annual limit of 20mSv. Doses are minimised by shielding workers from the sources of radiation and operators carry out regular detailed reviews of performance in this area.

6.58 The UK nuclear industry has adopted even stricter dose limits, for example British Energy, which operates the majority of the nuclear power stations in the UK, has imposed its own internal annual dose limit of 10mSv. According to a British Energy report published in 2002, in 2001 no worker exceeded this limit, and more than 97% of the organisation received doses lower than 2.24 mSv[204]. In 2005, a similar report showed the highest annual exposure was to a contractor (7.94mSv) while the highest dose to an employee of British Energy was 7.32mSv, against a collective radiation dose per reactor of 0.071 man-Sieverts per reactor[205].

6.59 Radiation doses to workers in the nuclear power industry continue to fall. Based on the new designs that might be built by energy companies in the UK, we can expect this trend to continue. Worldwide, the average exposure to workers in the nuclear power industry in 2004 was 0.61mSv for PWR power stations and 1.22mSv for BWRs, both significantly below international regulatory limits[206]. Radiation doses from new power stations are likely to be comparable. Based on information submitted to the Nuclear Regulatory Commission (NRC), the US nuclear regulator, Westinghouse estimates that the collective dose to operators of its AP1000 power station would be 0.671

201 Radioactivity in Food and the Environment, 2003. RIFE-11, Environment Agency, Scottish Environment Protection Agency, Environment and Heritage Service, Food Standards Agency, October 2005, http://publications.environment-agency.gov.uk/pdf/PMHO1006BLJP-e-e.pdf

202 This was at Hinkley Point. There are higher levels of exposure in the vicinity of Heysham, but given the proximity to Sellafield, according to the SDC, the exposure levels could be distorted.

203 The incidence of childhood cancer around nuclear installations in Great Britain, *COMARE 11th Report,* July 2006. This report considered the clustering of childhood cancers across the whole of Great Britain rather than just around nuclear installations (which were studies in the 2005 report).

204 British Energy Safety, *Health and Environment Review, 2001-2002.*

205 *British Energy Report 2005-6: Workplace,* http://www.british-energy.com/documents/workplace_0506.pdf

206 World Association of Nuclear Operators.

man-Sieverts per reactor[207]. These doses compare favourably to other workers prone to radiation exposure in their workplace (see Table 6.2).

| TABLE 6.2 RADIATION EXPOSURE BY OCCUPATION | |
|---|---|
| Occupational group | Average annual dose (mSv) |
| Medical, dental and veterinary | 0.1 |
| Industrial radiography | 0.8 |
| Nuclear industry | 1.0 |
| Air crew | 2.0 |
| Workers in radon-prone geographical areas | 5.3 |

*Source: NPRB Maps and Magnitudes*

Table 6.2 Workers in the nuclear industry are not the only people exposed to occupational radiation. In fact they are exposed to lower doses than other groups of workers. All workers are covered by regulations that set limits on this exposure.

## Implications for nuclear proliferation

6.60 The potential for the proliferation of nuclear weapons from civil power stations stems from the fact that the nuclear materials used in and arising from nuclear power, if diverted from peaceful use, can be used in the manufacture of nuclear weapons. To guard against this, the IAEA oversees an international regulatory "safeguards" system, under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)[208]. All non-nuclear weapon states that are signatories of the NPT are required to conclude agreements with the IAEA to implement safeguards to all their nuclear material and make all facilities available for inspection. The UK is recognised as a Nuclear Weapon State under the NPT but has voluntarily made its civil facilities available for inspection by the IAEA[209] – currently the plutonium stores at Sellafield and the enrichment plant at Capenhurst are inspected by the IAEA. The other Nuclear Weapon States – China, France, Russia and the US – also have voluntary agreements in force with the IAEA. These agreements vary in scope and application.

6.61 In addition, in the European Union, nuclear safeguards are also required under the Euratom Treaty[210] and implemented by the European Commission. To avoid unnecessary duplication, safeguards arrangements in the UK are harmonised between the IAEA and European Commission inspectorates.

6.62 This system of safeguards requires operators of nuclear facilities to have a detailed nuclear material accounting and control system and to make regular reports on inventories of nuclear material. Verification inspections of the declared location and quantities of nuclear material by the internal safeguards inspectorates aim to detect any diversion of significant quantities of such material from peaceful use.

207 http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/chapter12.pdf
208 http://www.un.org/Depts/dda/WMD/treaty/
209 http://www.iaea.org/Publications/Documents/Infcircs/other/infcirc2631.pdf
210 http://europa.eu.int/eur-lex/lex/en/treaties/dat/12006A/12006A.htm

6.63 The UK Safeguards Office is a focal point for contact with the inspectorates, to ensure that the UK meets its safeguards obligations in an effective and efficient manner.

6.64 Under the Euratom Treaty safeguards, all civil UK operators are subject to the full reporting and inspection requirements of the European Commission safeguards inspectorates. Through the UK Safeguards Office, they provide information on the relevant features of the design of their facilities and their nuclear material accounting and control systems. An outline programme of activities is set annually for the following two-year period. Regular reports are made on location, inventories, receipts, shipments and other accounting data for nuclear material. The European Commission safeguards inspectorates also makes regular inspections – both pre-arranged and unannounced – to verify this information. In 2006, the European Commission safeguards inspectorates made some 200 such visits.

6.65 Specific safeguards arrangements are in place at all civilian nuclear facilities in the UK, including power stations. These vary from site to site. For example, a power station with onsite storage of spent fuel will be subject to accountancy verification of fresh and spent fuel as well as containment and surveillance measures, for example, with CCTV, seals on the reactor to detect clandestine removal of irradiated fuel and seals on packaging. Any new nuclear power stations would be subject to such safeguards arrangements. These safeguards systems are designed to provide timely detection of the diversion of nuclear material and thus deter any such attempt.

6.66 The UK Safeguards Office considers that attempts by civilian operators of nuclear power stations to divert nuclear materials for clandestine nuclear weapon purposes would be detected by the safeguards in place. The additional proliferation risks arising from the construction and operation of modern nuclear power stations are limited compared to existing nuclear fuel cycle activities, in which the UK and other countries are already active. These activities would continue regardless of a decision to allow new nuclear power stations to be constructed.

6.67 Nevertheless, it is important to maintain accounting for nuclear material at a high standard and that we meet all relevant legal obligations. To this end, the European Commission has powers under the Euratom Treaty to issue directives to Member States and to impose sanctions on operators in the event of any infringements.

6.68 The Sustainable Development Commission highlighted characteristics that would make the designs of power stations likely to be constructed in the UK unattractive as sources of nuclear proliferation[211]:

- fuel used in the designs of nuclear power stations most likely to be constructed in the UK would need considerable further treatment before they could be used in weapons, with the need for substantial facilities to do so;
- it is difficult to access the fuel used in most of these designs. Light water reactors need to be shut-down every 12-18 months for refuelling, it would not be possible to access the fuel without shutting down the reactor;

211 Sustainable Development Commission, *Paper 6: Safety and Security,* March 2006.

- the regulatory oversight in place through the safeguards regime, and their approach to regular and unannounced inspections; and
- unscheduled movements of material would also be apparent to OCNS and DfT-DGD.

**Based on the advice of the independent nuclear regulators, and the advances in the designs of nuclear power stations that might be proposed by energy companies, the Government believes that the safety, security, health and non-proliferation risks of new nuclear power stations are very small and that there is an effective regulatory framework in place that ensures that these risks are minimised and sensibly managed by industry. Therefore, the Government believes that they do not provide a reason to prevent energy companies from investing in new nuclear power stations.**

## Question 6

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?

CHAPTER 7

# Transport of nuclear materials

## Introduction

**This chapter explores safety and security issues that arise from the movement of nuclear materials. A long-established international framework has provided the basis for the UK's regulation of the transport of nuclear fuel and related materials. This will be the basis of any future plans if we decide that it is in the public interest to allow private sector energy companies to invest in new nuclear power stations.**

7.1 Any nuclear power stations require the movement of nuclear materials. Such movements happen at various stages within the nuclear fuel cycle, from the arrival of the raw materials into the UK, through the manufacture of fuel and its transport to power stations, to the removal of spent fuel and its transfer to reprocessing facilities and waste repositories. Figure 1.3 shows the locations of the existing nuclear power stations in the UK.

7.2 There is a significant difference in the types of radioactive material that are moved in connection to the nuclear power industry. Raw and enriched uranium, and even freshly prepared fuel, are not very radioactive and the handling and transport of such materials does not pose significant risks. It is only once the fuel has been "burnt up" by being used in a reactor that it becomes highly radioactive, and that significant risks are created for those handling and transporting the spent fuel. The risks associated with the transport of the material are reflected in the regulatory requirements. For example, the regulatory requirements for flasks used to transport spent fuel are the most stringent. They are designed to withstand severe accidents without releasing their contents.

7.3 This chapter sets out information on:

- the historical record of transporting nuclear materials, covering accidents and occupational and public exposures to radiation; and
- the international and national regulatory framework overseeing safety and security issues.

7.4 The transport of nuclear materials carries with it some small risks for safety and security. However, there is a well established international framework for regulating the transport of nuclear materials. This is underpinned by UK legislation to manage these risks.

## Regulatory framework

7.5 There has been an international regulatory framework for the transport of radioactive material since 1961 when the International Atomic Energy Authority (IAEA) issued its "Regulations for the Safe Transport of Radioactive Material". International requirements were put into place to protect people and the environment during routine transport of nuclear materials and in the event of an accident.

7.6 At an international level, the United Nations issues Model Regulations on the Transport of Dangerous Goods. These set out basic standards for national and international regulations for the transport of dangerous goods. The UN's Model Regulations reflect the IAEA regulations in its framework for regulating the transport of radioactive materials[212]. The IAEA regularly reviews the regulations, presently every two years, to take into account developments in science and technology and any new requirements from industry.

7.7 At the European level, long-standing directives regulate the transport of hazardous material by road, rail, river and inland waterway. These directives reflect the UN's Model Regulation[213]. The EURATOM Treaty also sets out basic safety standards protecting workers and the general public against the potential harm arising from ionising radiation[214]. These standards include public information and emergency measures in case of accidents[215]. International legislation and conventions also cover the exchange of information with neighbouring EU countries[216], the physical protection of nuclear material[217], and early notification of accidents and assistance in the event of a nuclear incident.

7.8 There are a number of pieces of legislation setting out hoe the UK's regulatory framework for the transport of radioactive material reflects these international codes, treaties and regulations[218]. The Nuclear Industries Security Regulations 2003 (NISR) also set out the regulatory framework to ensure the security of the transport of nuclear materials.

7.9 In the UK, the Dangerous Goods Division of the Department for Transport (DfT-DGD) regulates the safety of transport of all radioactive materials. The Office for Civil Nuclear Security (OCNS) regulates the security aspects of movements of nuclear material, such as preventing material from being diverted, as defined by the Nuclear Industries Security Regulations 2003.

212 IAEA, *Regulations for the Safe Transport of Radioactive Material TS-R-1.*

213 Council Directive 94/55/EC of 21 November 1994 on *the approximation of the laws of the Member States with regard to the transport of dangerous goods by road,* sometimes referred to as ADR
Council Directive 96/49/EC of 23 July 1996 on *the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail, sometimes referred to as RID.*

214 OJ L 159, 29/06/96 p.1

215 Under Title IX of Directive 96/29/Euratom of 13 May 1996.

216 Council Decision 87/600/Euratom, *ECURIE arrangements.*

217 *Convention on the Physical Protection of Nuclear Material* (adopted October 1979, Vienna; amended July 2005).

218 *The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004, SI 2004 No 568* (with amendment SI 2005 No 1732).
*The Radioactive Material (Road Transport) Regulations 2002, SI 2002 No 1093* (with amendment 2003, SI 2003 No 1867).
*The Merchant Shipping (Dangerous Goods and Marine Pollutants) Regulations 1997, SI 1997 No 2367. Merchant Shipping Notice No MSN 1791(M), The Carriage of Dangerous Goods and Marine Pollutants in Packaged Form – Amendment 32-04 to the IMDG Code.*
*The Air Navigation Order 2005, SI 2005 No 1970. The Air Navigation (Dangerous Goods) Regulations 2002, SI 2002 No 2786 (with amendment 2004, SI 2004 No 3214).*

7.10 DfT-DGD is the Competent Authority[219] in the UK for the transport of radioactive material. As the Competent Authority, it must certify that all package designs and associated transport arrangements comply with statutory regulations. Transporters of radioactive material must submit a detailed evaluation of the safety case as evidence that their package and proposed safety arrangements meet the required standards. Companies involved in the transport of radioactive material must also have emergency plans and test them on a regular basis.

7.11 DfT-DGD is also responsible for regulating the safety of transport operation. Its remit requires it to:

- monitor transport operations, by visiting suppliers, carriers and users of radioactive materials;
- audit quality assurance systems for the operators of transports;
- examine maintenance and servicing arrangements; and
- witness testing and manufacturing of containers for transport.

7.12 This is complemented by the assessment of emergency planning, investigation of incidents and independent assessment of the radiation and contamination levels of irradiated nuclear fuel flasks. If DfT-DGD is unhappy with any of their findings they can take regulatory action.

7.13 The regulatory requirements for the security aspects of transport of nuclear materials stipulate that a carrier must:

- be approved by OCNS beforehand;
- satisfy OCNS, through the submission of a Transport Security Statement and/or specific Transport Security Plans, that suitably robust measures are in place to ensure the security of nuclear material;
- comply with directions and instructions issued by OCNS;
- report specific security matters to OCNS; and
- notify OCNS in advance of all intended movements of nuclear material.

## Transport of radioactive materials

7.14 Within the EU, about 1.5 to 2 million packages of radioactive materials are transported each year. Most contain radioisotopes for medical, industrial or scientific uses. Fewer than 5% of these movements are related to the nuclear power industry. In total, transport of radioactive materials accounts for about 2% of all movements of dangerous goods in the EU.

7.15 In the UK, in 2001 there were approximately 7,000 movements of packages containing radioactive material related to the nuclear power industry,

219 A Competent Authority is any regulatory body designated or otherwise recognised as such for the purposes of the Regulations.

out of a total of 500,000 movements of radioactive packages[220]. In the future, the type of nuclear power stations that might be constructed in the UK are likely to require fewer shipments than existing nuclear power stations, because they are more fuel efficient (see chapter one). However, the effect on the total number of nuclear material shipments is unclear and would depend on fuel management options. International, regional and national regulatory frameworks are in place to manage the risks associated with such movements.

7.16 As discussed in chapter twelve, the Government believes that the developers of any new nuclear power stations, should proceed on the basis that spent fuel is not reprocessed. Developers would be expected to provide appropriate storage arrangements capable of being maintained safely until the spent fuel is ultimately removed for disposal, perhaps many decades after removal from the reactor. This means that if the Government allows energy companies to invest in new nuclear power stations, there would be no need to transport spent fuel across the country to reprocessing facilities and then subsequently to the geological repository. Instead, spent fuel would be held in interim storage, during which time, the initial fission product activity would decline rapidly as the more active compounds decay, and it may only require a single movement, of lower activity material to the repository.

7.17 After a period of interim storage lasting perhaps several decades, transportation of irradiated fuel to a geological repository would be required. However, it is not possible to specify which transportation routes would be used as the locations of any new nuclear power stations and geological repository are not yet settled.

7.18 Over the past 40 years, many countries that use nuclear power have transported nuclear fuel by rail, road and sea. In this time, there have been no accidents in the EU involving the transport of nuclear materials that have caused death or serious injury to persons or significant radiological harm to the environment[221].

7.19 Flasks used to carry irradiated nuclear fuel are designed to withstand severe accidents without releasing their contents. These flasks are designed to withstand a series of tests as set out in IAEA regulations:

- drop test;
- puncture test;
- thermal test; and
- immersion test.

220 Department for Transport Dangerous Goods Division.

221 *The Resistance to impact of spent Magnox fuel transport flasks.* Papers prepared on 30 April and 1 May 1985, sponsored by the Power Industries Division of the Institution of Mechanical Engineers and the British Nuclear Energy Society and organised by the Nuclear Energy Committee of the Power Industries Division of the Institution of Mechanical Engineers, ISBN 0852985746.

7.20 The tests are intended to ensure that flasks can withstand the extreme conditions that they might experience in an accident. In one public demonstration, a train travelling at 100 mph (160 km/hr) hit a flask, causing no damage to the flask which would have led to a release of radioactivity had it been loaded with spent fuel[222].

7.21 Compliance with the legislation on the transport of radioactive material ensures that workers are not exposed to high levels of radiation[223]. Radiation exposure to any worker in the transport industry from the transport of nuclear fuel cycle materials is less than 0.7 millisieverts (mSv) per year[224]. This is much less than the limit for radiation workers of 20 mSv per year. According to the Health Protection Agency, these doses are extremely low[225].

7.22 Conservative estimates of dose to the general public from the movement of radioactive materials are a hundredth of this level, no more than 0.006 mSv per year[226], compared to an average annual dose from natural background radiation of 2.6 mSv[227]. The European Parliament concluded in 2001, in its resolution on Transport of Radioactive Material, that the risks associated with the transport of radioactive material were low[228].

**Given the safety record for the transport of nuclear materials, the assumption that spent fuel will not be reprocessed and the strict safety and security regulatory framework in place, the Government believes that the risks of transporting nuclear materials are very small and that there is an effective regulatory framework in place that ensures that these risks are minimised and sensibly managed by industry. Therefore, the Government believes that they do not provide a reason to not allow energy companies to invest in new nuclear power stations.**

## Question 7
## 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?

222 *Survey into the radiological impact of the normal transport of radioactive material in the UK by Road and Rail NRPB-W66.*

223 World Nuclear Transport Institute, *Radiation Dose Assessment for the Transport of Nuclear Fuel Cycle Materials,* http://www.wnti.co.uk/UserFiles/File/public/publications/Review_Series_No2.pdf

224 Health Protection Agency, *Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail,* http://www.hpa.org.uk/radiation/publications/w_series_reports/2005/nrpb_w66.pdf

225 Health Protection Agency, *Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail,* http://www.hpa.org.uk/radiation/publications/w_series_reports/2005/nrpb_w66.pdf.

226 Sustainable Development Commission, *Paper 6: Safety and Security.*

227 NRPB Report, *Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail,* March 2005

228 Official Journal of the European Community, *Safe Transport of Radioactive Material,* A5-0040/2001, 2001

CHAPTER 8

# Waste and decommissioning

## Introduction

**The UK currently has a significant legacy of nuclear waste that must be managed in the long-term. Any waste from any new nuclear power stations that might be constructed in the UK would also need to be managed. This chapter explores the practical issues surrounding the impact that any new nuclear power stations, and the waste they create, would have on our current plans for waste management and the ethical issues that this would raise.**

8.1 This chapter sets out information and evidence covering the following issues:

- the UK's existing nuclear waste legacy;
- the Government's strategy for radioactive waste management, covering both long-term disposal and interim arrangements prior to long-term disposal;
- the potential impact of new nuclear waste on this strategy;
- the UK's existing decommissioning strategy;
- the impact of new nuclear power stations on this strategy;
- the proposed safeguards that would be in place for the taxpayer against decomissioning and radioactive waste management liabilities;
- consideration of the ethical issues around creating new nuclear waste; and
- whether it is appropriate to take a decision now on whether to allow new nuclear power stations to play a role in the future energy mix.

## Summary of proposals

8.2 The Government proposes that if this consultation concludes that nuclear power has a role to play in the UK, the waste from any new nuclear power stations should be disposed of in a geological repository and considers, based on evidence from the Nuclear Decommissioning Authority (NDA) and overseas waste management programmes, that this would be technically possible. Government proposes that waste should be stored in safe and secure interim storage facilities prior to a geological repository becoming available. This is in line with the policy the Government is pursuing for disposing of radioactive waste from the UK's legacy nuclear programmes. We consider that it is technically possible and would be desirable to dispose of both new and legacy waste in the same repository facilities. We would pursue this through the Managing Radioactive Waste Safely (MRWS) programme.

8.3 There are important ethical issues to consider around whether to create new nuclear waste. The Government intends that these ethical issues should be considered through this consultation document and respondents are invited to give their views.

## The existing UK nuclear waste legacy

8.4 As one of the pioneers of nuclear technology, the UK has accumulated a substantial legacy of nuclear waste from a variety of different nuclear programmes. Many of the UK's existing nuclear facilities were built with a focus on construction and operation and not with waste management and decommissioning in mind. This has created a complex and expensive legacy that needs to be managed. By the time our existing facilities have been decommissioned we will have accumulated 2,300,000 tonnes of radioactive waste. Over 90% of this waste is of the low level waste category[229] and much of this low level waste will be at the lower end of the activity spectrum.

### BOX 8.1: UK CLASSIFICATIONS OF NUCLEAR WASTE

**Low Level Waste**

This is the lowest activity category of radioactive waste. Low Level Waste (LLW) was defined in the recent updated Government LLW policy statement as:

*"radioactive waste having a radioactive content not exceeding 4 gigabecquerels per tonne (GBq/te) of alpha or 12GBq/te of beta/gamma activity"*

Operational LLW from the nuclear generation sector is principally lightly contaminated miscellaneous waste that arises from maintenance and monitoring, such as plastic, paper and metal. Decommissioning LLW, such as building materials will form a large part of the total when existing nuclear facilities are demolished. Although LLW makes up more than 90% of the UK's waste legacy by volume, it will contain less than 0.0003 per cent of the total radioactivity[230].

There are lower activity limits, below which a further sub-category of "Very Low Level Waste" (VLLW) applies. Below certain activity levels and types of radioactivity, no specific regulatory control is required, as the levels become so small as to be insignificant in amongst everyday, natural background radiation.

**Intermediate Level Waste**

Waste with radioactivity levels exceeding the upper boundaries for LLW, but which does not generate heat that would influence the design of storage or disposal facilities is classified as Intermediate Level Waste (ILW).

Historically, ILW in the UK has arisen mainly from the reprocessing of spent fuel and from general operations and maintenance of radioactive plant. The major components of ILW are metals and organic materials, with smaller quantities of cement, graphite, glass and ceramics.

229 Nirex Report N/089, *Radioactive Wastes in the UK: A Summary of the 2004 Inventory,* DEFRA/RAS/05.001, October 2005

230 Nirex Report N/089, *Radioactive Wastes in the UK: A Summary of the 2004 Inventory,* DEFRA/RAS/05.001, October 2005

**BOX 8.1: continued**

**High Level Waste**
High Level Waste (HLW) is radioactive waste that generates heat. The UK has accumulated this, primarily at Sellafield, since the early 1950s, from the reprocessing of spent nuclear fuel. The heat-generating characteristic of HLW has to be considered in designing facilities to store or dispose of the material, to ensure the temperature of the waste does not rise significantly. Much of this waste is in liquid form. The current practice is to convert HLW into passively safe glass blocks, using a process known as vitrification.

**Spent Fuel**
Fuel removed from a reactor after use is known as spent fuel (SF). Typically, spent fuel, excluding the fuel cladding, consists of approximately 96% uranium, 1% plutonium, and 3% waste products. Spent fuel can be reprocessed, to separate out the useful uranium, plutonium and the waste, or packaged and directly disposed of in a repository. As such it is not currently classified as a waste in the UK. Spent fuel is also heat-generating and as for HLW, this characteristic has to be taken into account in designing storage or disposal facilities.

**Nuclear Materials**
In addition to spent fuel, there are a number of other radioactive materials that are not currently classified as wastes, but that may have to be managed in the same way as radioactive wastes. These arise as products and by-products from the manufacture of nuclear fuels and the reprocessing of spent fuels, and include plutonium and uranium stocks.

## The Government strategy for managing waste

8.5 With early nuclear power plants, the emphasis was on successful operation, rather than on managing the waste that was produced. Early disposal of the waste included practices that would now be unacceptable and are prohibited, such as sea dumping. Since then, work has been undertaken to develop strategies for waste management, and work by the nuclear industry, Nirex and later by the Committee on Radioactive Waste Management (CoRWM) considered how best to manage the waste.

### Government policy on LLW management

8.6 Currently, most LLW is permanently disposed of at the dedicated LLW repository located in West Cumbria. However, this site does not have enough capacity to meet the anticipated future production of LLW, particularly the large volumes envisaged from decommissioning the existing nuclear sites.

8.7 On 26 March 2007, the Government announced an update of its policy for LLW management[231]. Under the new policy, the NDA is now responsible for developing and maintaining a national strategy for handling LLW from nuclear

231 http://www.defra.gov.uk/environment/radioactivity/waste

sites and for ensuring continued provision of the waste management and disposal facilities required. There are a number of options that the NDA will need to consider, including:

- near-surface disposal facilities of the kind currently available at the LLW repository located in West Cumbria;
- near-surface disposal facilities on or near the site that creates the waste; and
- controlled burial of appropriate wastes to conventional landfill.

8.8 The waste hierarchy of avoiding waste creation, minimising arisings, re-using and recycling materials, and disposing of waste only when necessary, will continue to be an important element of the overall strategy. The LLW strategy that the NDA develops will be set out in its annual plans and strategy document in due course, and will be subject to public consultation.

8.9 The NDA competition for a new contractor to provide LLW management services for the UK is underway and is expected to conclude later this year. The contract will include ensuring that waste arising from the decommissioning of the current legacy sites is effectively managed and waste infrastructure is in place that could manage any waste created by new nuclear power stations.

## Government policy on managing higher activity wastes: the Managing Radioactive Waste Safely (MRWS) programme

8.10 In September 2001 the Government launched the Managing Radioactive Waste Safely (MRWS) programme to consider the issues of managing and disposing of the UK's higher level radioactive wastes and to reach a safe, environmentally sound and publicly-acceptable solution. This is a long-term programme comprising four main stages (see Table 8.1).

**TABLE 8.1 MRWS WORK PROGRAMME**

| Stage | Work | Timing |
|---|---|---|
| Stage 1 | The MRWS consultation on process, consideration of responses, planning for stage 2 | 2001-02 |
| Stage 2 | Establishment of CoRWM. | 2002-06 |
| | Research and public debate, led by CoRWM, involving option evaluation, using public and stakeholder engagement and the best available scientific knowledge. Government decision on the option(s) to implement | |
| Stage 3 | Consultation on the Government's framework for implementing its preferred option(s) | 2007 |
| Stage 4 | Implementation of preferred option(s) | 2008 onwards |

*Source: Defra*

Table 8.1 The Government's Managing Radioactive Waste Safely (MRWS) programme is undertaking a four stage process to consider the management and disposal of the UK's higher level radioactive wastes.

8.11 In November 2003, in line with the timetable above, the Government appointed the independent committee – CoRWM – to look at the issues. Its terms of reference set out that it was to assess and recommend the best option or combination of options for the long-term management of the UK's higher activity solid radioactive wastes, that can provide a long-term solution, providing protection for people and the environment[232]. The committee considered an inventory that included existing and committed nuclear legacy wastes, nuclear materials, such as plutonium and uranium stocks that may be classified as wastes in future and LLW that cannot currently be disposed of to the existing facility in West Cumbria[233]. CoRWM's terms of reference focussed principally on legacy waste. However, as part of its Inventory publication, the Committee made reference to the potential implications of a new build scenario involving the construction of 10 new AP1000 reactors[234]. CoRWM's public and stakeholder engagement work remained focussed on the ethical, social and political issues surrounding legacy waste.

8.12 In July 2006, CoRWM published a report of its findings. The committee recommended that geological disposal coupled with safe and secure interim storage was the right way forward for the long-term management of the UK's existing higher activity radioactive wastes[235]. Separate vaults would be needed for ILW and HLW/SF although it would be possible to co-locate the vaults into one location, with shared surface facilities and access shafts. CoRWM recognised that other management solutions may be appropriate for reactor decommissioning wastes because of the nature of the waste form. This could include interim decay storage or similar solutions to those arising from the new LLW Policy to allow the principal radiation emitters to decay. Box 8.3 and Figures 8.1 and 8.2 give an overview of the key points related to geological disposal. It is intended that more detail on geological disposal and its implementation will be published in a separate consultation on the next stages of the MRWS process.

8.13 In October 2006, the Government accepted the recommendations for geological disposal and confirmed its support to explore how an approach based on voluntarism (that is willingness of communities to participate) and partnership, as recommended by CoRWM, could be made to work in practice[236] with local communities in a UK context. The Government also accepted CoRWM's recommendation that a robust programme of safe and secure interim storage must play an integral part in the long-term management strategy, during the time it takes to plan and construct the geological disposal facility. CoRWM's recommendation focused on legacy waste. However, ensuring interim storage facilities capable of storing waste for a lengthy period of time will be important for any new build waste, to ensure that waste is safely stored until geological disposal facilities are available. Interim storage also allows waste to cool down and radioactivity to begin to decay, which could make the job of emplacing it in a repository later on simpler. The key points of the Government's response to CoRWM's recommendations are set out in Box 8.2.

232 http://www.corwm.org.uk/content-261
233 CoRWM Document 1279, *CoRWM's Radioactive Waste and Materials Inventory*, July 2005
234 CoRWM Document 1279, *CoRWM's Radioactive Waste and Materials Inventory*, July 2005
235 CoRWM Document 700, The full list of CoRWM's recommendations can be found in *CoRWM's Managing our Radioactive Waste Safely, CoRWM's Recommendations to Government,* July 2006, http://www.corwm.org.uk/content-1092
236 *Response to the report and recommendations from CoRWM by the UK Government and the Devolved Administrations,* October 2006. http://www.defra.gov.uk/environment/radioactivity/waste/pdf/corwm-govresponse.pdf

**BOX 8.2: GOVERNMENT RESPONSE TO CORWM RECOMMENDATIONS**

Key points of the Government response to CoRWM:
- the UK's higher activity radioactive waste should be managed in the long-term through geological disposal;
- a robust programme of interim storage must play an integral part in the long-term management strategy;
- the Government is supportive of exploring how an approach to siting based on voluntarism (that is willingness to participate) and partnership could be made to work in practice;
- NDA (incorporating Nirex) to be a strong and effective implementing organisation, with clear responsibilities and accountabilities;
- strong independent regulation by the statutory regulators;
- continued independent scrutiny and advice on the implementation programme by reconstituted CoRWM; and
- commitment to an open and transparent process throughout
- implementation undertaken on a staged basis, with clear decision points allowing progress to be reviewed and costs, value for money and environmental impact to be assessed before decisions are taken to move to the next stage.

8.14 The Government considers that geological disposal and robust interim storage would also be the best solution for dealing with waste from any new nuclear power stations. The technical and ethical issues surrounding this proposal are considered in this chapter.

## Overview of geological disposal

8.15 Geological disposal means the disposal of radioactive waste within geological formations. A facility for geological disposal is known as a repository. The basic idea is to use a combination of engineering and the natural geology to isolate the waste from the surface environment in a multi-barrier system. The packaged waste is secured in an engineered containment and supported by a geological barrier, which limits the scope for any radioactivity released from the engineered containment returning to the environment. A repository can be built at some depth below ground level, although the geological formation is a more important consideration than depth of a repository. The diagrams in Figures 8.1 and 8.2 show generic designs for ILW and HLW/SF repository concepts (as mentioned above, the ILW vaults and the HLW/SF tunnels could be co-located in the same repository).

## FIGURE 8.1. GENERIC DESIGN FOR ILW DISPOSAL CONCEPT

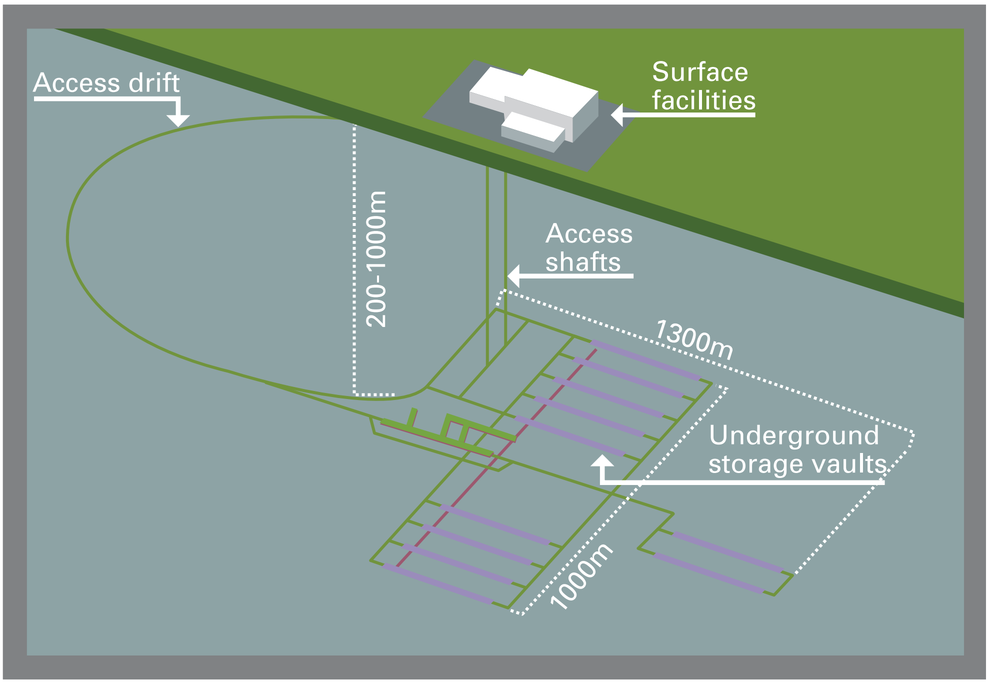



Figure 8.1: A generic design for ILW disposal concept: the waste would be immobilised in concrete and placed underground

## FIGURE 8.2. GENERIC DESIGN FOR CASINGS FOR HIGH LEVEL WASTE AND SPENT FUEL

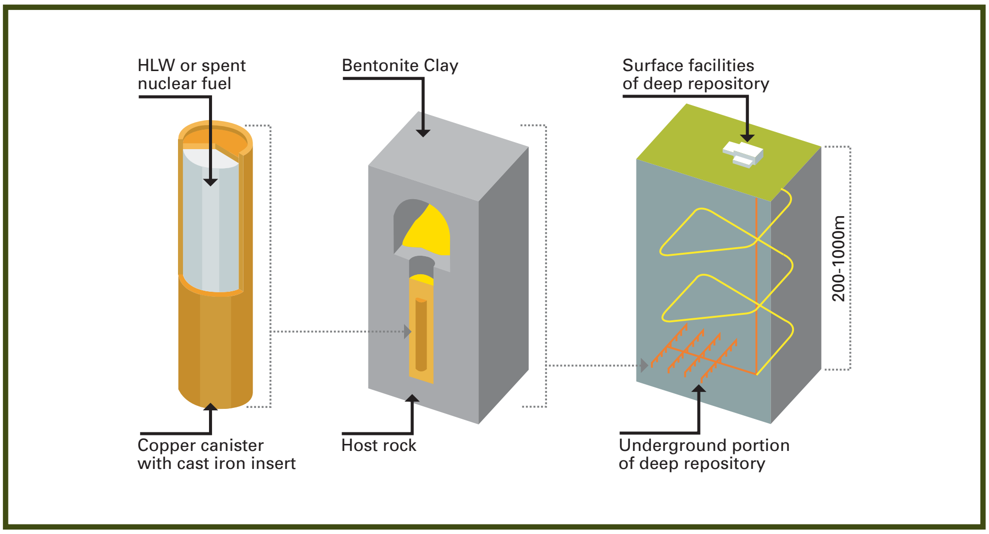



Figure 8.2 A generic design for high level waste and spent fuel disposal: the material would be encapsulated in copper canisters and then placed in deposition tunnels underground

**BOX 8.3: INTERNATIONAL EXPERIENCES OF GEOLOGICAL DISPOSAL**

Geological disposal is the solution adopted by a number of countries. The CoRWM report set out that "all countries with a nuclear power programme that have made decisions about long-term management of radioactive waste have adopted a strategy of interim storage followed by geological disposal, although the Netherlands has decided to postpone disposal for at least 100 years. Recently, both Canada and France have adopted a policy of interim storage followed by geological disposal[237]."

Varying degrees of progress have been made towards delivering this objective in practice.

Sweden has been disposing of LLW and ILW in its SFR Final Repository for Radioactive Operational Waste since 1998. SFR, which is situated at a depth of 50 metres below the floor of the Baltic, is made up of four rock caverns which house different classes of waste and a rock silo for the most active forms of ILW. Sweden does not currently reprocess spent fuel (and does not plan to) and has been conducting investigations at two potential sites for a repository for spent fuel. The design of the spent fuel repository would consist of a number of parallel tunnels, connected by a central tunnel, at a depth of approximately 500 metres. Each tunnel would house one canister of spent fuel, within a hole drilled into the floor and surrounded by bentonite clay.

In Finland, shallow repositories for LLW/ILW currently exist at its two nuclear sites and ILW is bituminised and LLW compacted at the power plants. The Government plans to dispose of spent fuel by deep geological storage, using a similar design concept to that proposed for Sweden, to be constructed 470 metres below ground. Investigation work at the chosen site at Olkiluoto is underway, and consists of constructing an underground rock characterisation facility.

In the USA, a license application is being prepared to construct a repository at Yucca Mountain, Nevada, to dispose of SF and HLW. The waste will be placed in steel, multilayered storage containers before being stored in a system of tunnels underground.

More information on international experience of geological disposal can be found in the CoRWM final Report[238].

237 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092

238 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092

8.16 The Government has given the NDA responsibility for planning and implementing geological disposal of higher activity radioactive wastes. It has also given the NDA the remit to develop a framework for repository development. As part of this arrangement, Nirex, the UK's former expert body on the science and technology of geological waste disposal, has now been incorporated into the NDA, and will strengthen the NDA's skills and experience. The aim is to create a single point of responsibility and accountability while providing the UK with a coherent, strategic view of radioactive waste management, from beginning to end. The NDA is developing its thinking on the best organisational structure for carrying this out.

8.17 Placing waste in a geological repository is a long-term solution. The NDA is also responsible for delivering interim facilities to store waste which are capable of storing waste in a passively safe form for over 100 years to allow time for the creation of geological disposal facilities. The current approach for ILW is to build storage facilities at the sites that create the waste and for example, this is the case at British Energy's Sizewell B station, where waste is encapsulated and stored pending availability of a repository. Spent fuel is also currently stored on site at Sizewell B. The NDA is considering a number of options for improving the current approach, through a review of its interim waste storage strategy. The NDA plans to include further detail on the updated interim storage strategy when they publish the next version of their strategy due in 2008/09.

8.18 CoRWM has continued to provide independent advice to the Government on specific implementation issues surrounding the concepts of a community, voluntarism and partnership approach to siting the disposal facility, following on from its main report. During 2007, CoRWM will be reconstituted to provide ongoing independent scrutiny and advice to the Government on the long-term management of radioactive waste. The Government and the NDA, with the new CoRWM providing independent scrutiny and advice, will ensure that the MRWS programme continues to be taken forward in an open, transparent and consultative manner.

8.19 Following CoRWM's report and recommendations, we are now entering Stage 3 of the MRWS process and the Government will consult on the framework for the implementation and siting process. This MRWS consultation, due to be launched in summer 2007, will cover:

- an outline delivery programme for geological disposal, including more information on repository concepts; and
- the process and criteria to be used to decide the siting of that facility, including amongst other things:
  - proposals for a voluntarist/partnership approach to the identification of potential sites; and
  - details of how the initial consideration of the geological suitability of sites would be carried out

8.20 The MRWS consultation will contain information that respondents may find useful in considering the proposals set out in this document on the role of nuclear power in the future UK energy mix. To ensure that respondents have access to this relevant information, this consultation will allow time for respondents to consider the issues raised in the MRWS consultation document. Further details on the MRWS consultation will be available on the Defra website[239] in due course: the Nuclear Consultations page of the DTI website[240] will also provide links.

## Impact of waste from new nuclear power stations on existing waste management strategy

8.21 There are a number of issues relating to the impact of allowing new nuclear waste to be produced, which need to be considered. These relate to both long-term geological disposal and interim storage for the period prior to a geological repository becoming available. The issues that arise include:

- the potential impact on the inventory of UK radioactive wastes that must be managed;
- technical considerations relating to the nature of the waste; and
- the MRWS programme and new nuclear power.

### The potential impact on the inventory of UK wastes that must be managed

8.22 It is the Government's position that, if we conclude that nuclear power could have a role to play in electricity generation in the UK, it would be for private sector energy companies to bring forward plans to build any new nuclear power stations. A consequence of this is that we cannot be sure of the timing and number of nuclear power stations that might be proposed. However, a scenario considered during the CoRWM process gives an example of the potential impact of replacing the existing nuclear capacity. The CoRWM Inventory report contains reference to a scenario of the construction of 10 new AP1000 power stations with an operating lifetime of 60 years each that would together generate 25% of the UK's electricity[241]. This well-documented scenario is used here purely for illustrative purposes and not as an indication of the number or design of new nuclear power stations that might be proposed by the private sector. This new build scenario would rather more than replace existing nuclear capacity which stands at approximately 18% of the generation mix. Such a replacement programme would, over its lifetime, generate around 160% of the electricity generated by the legacy nuclear reactors over their lifetimes[242].

8.23 In considering the impact on the UK waste inventory, there are two key factors that need to be considered:

239 http://www.defra.gov.uk
240 http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007
241 CoRWM's *Radioactive Waste and Materials Inventory,* CoRWM Document 1279, July 2005
242 NDA: *Potential Waste Volumes Arising from New Build Statement prepared by Dr Paul Gilchrist,* 17 October 2006

- **Volume**

Assuming this estimated scenario, the CoRWM inventory summary information document shows that this would, over the lifetime of the new stations, add 8% to the UK's existing volume of radioactive waste[243]. This figure is small because the majority of existing waste by volume is made up of ILW and LLW and as new nuclear power stations are smaller, better-designed and more efficient, they will generate smaller volumes of these types of waste than existing reactors. There would be a significant increase (in relative terms) to the spent fuel component of the inventory: most legacy spent fuel has been or will be reprocessed, but the Government does not envisage that spent fuel from new nuclear power stations would be reprocessed. However, spent fuel represents a small part of the overall amount of waste by volume, and new reactors produce less spent fuel for each unit of electricity produced (see chapter one). Also, without reprocessing, there would be no HLW, plutonium or uranium to dispose of from new nuclear power stations.

CoRWM stated that "the projected volume of higher activity wastes that will arise up to approximately 2120, following decommissioning of existing nuclear facilities, is 478,000 cubic metres (a volume five times that of London's Royal Albert Hall[244])". Based on the scenario set out above of the construction of 10 new AP1000 power stations with an operating lifetime of 60 years, we can estimate that the volume of higher activity wastes (ILW and SF) that would be produced would be approximately 40,900 cubic metres[245] – roughly half the volume of London's Royal Albert Hall. However, to understand the impact that waste from new nuclear power stations would have on the size of a repository, it is important to consider the level of radioactivity of the new waste, as this is a factor in determining how far apart the waste must be placed. Further information on the impact of new nuclear waste on the size of a repository can be found in Box 8.4.

- **Radioactivity**

Estimating the increase in radioactivity of the UK's waste iventory from new nuclear power stations is complex and depends on a number of factors, including the amount of time that the waste is left to cool before a measurement is taken. The radioactivity in spent fuel (and other radioactive materials) declines over time. The decay for spent fuel is particularly rapid initially, as the shorter-lived components decay. As a result of this change over time, the total radioactive content of the waste from new build for disposal (and hence the addition it would make to the total radioactivity) will depend on what assumptions are made about how long the spent fuel is kept in interim storage pending geological disposal. If an extended period of time were allowed for cooling of spent fuel (allowing the rapid initial decay in activity that occurs during this time[246]), the additional inventory of radioactivity, at the point of disposal, would be smaller. Spent fuel is usually stored for a period of time

243 CoRWM's Inventory Summary Information Document, http://www.corwm.org.uk/pdf/inventory%20summary%20information.pdf

244 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092

245 NDA: *Potential Waste Volumes Arising from New Build Statement prepared by Dr Paul Gilchrist*, 17 October 2006

246 NDA: *Potential Waste Volumes Arising from New Build, Statement prepared by Dr Paul Gilchrist*, 17 October 2006

to allow the initial rapid decay of the radioactivity and hence reduction of its heat output, to take place, before disposing of it. In its final report, CORWM estimated that the new build scenario of 10 AP1000 power stations could increase the total radioactivity content of the UK's waste iventory by a factor of nearly three[247].

## Technical considerations of waste from new nuclear power stations

8.24 The designs of new nuclear power stations that are currently available have simpler structures than most existing facilities, use fewer materials and would produce less ILW and LLW when decommissioned. For example, the AP1000 has 50 per cent fewer valves, 83 per cent less piping, 87 per cent less control cable, 35 per cent fewer pumps and 50 per cent less seismic building volume than a similarly sized conventional plant[248].

8.25 The designs do not give rise to some of the bulky, problematic waste forms, such as the very large volumes of graphite used as a moderator in AGR and Magnox stations from the legacy programme. Lessons learned from dealing with legacy waste point to the fact that where practicable, waste from new nuclear power stations should be dealt with and packaged in a passively safe form for eventual disposal as it arises. This would avoid the problems that the UK has experienced with legacy waste, where different waste forms have been left untreated for periods of time, mixed with other waste and allowed to degrade. Waste from new nuclear power stations would be less varied, easier to handle and dispose of and therefore less problematic or costly to deal with.

8.26 Virtually all new designs of nuclear reactors will use "oxide" fuels, which consist of ceramic pellets encased in zirconium alloy tubes rather than the uranium metal, magnesium alloy clad, fuels used within the earlier Magnox reactors. This fuel is chemically very stable and hence fuel degradation and significant contamination of irradiated fuel handling facilities should be avoidable. This is borne out by operational experience in the UK and elsewhere in the world. This will simplify the future decommissioning of the waste handling facilities and further reduce the volumes of waste arising from decommissioning. The spent fuel itself, which will have generated more electricity than spent fuel from legacy reactors, will be of higher activity than irradiated fuel from the UK's earlier reactors and a repository would have to be designed to cope with this. This could have an impact on the design and the size of repository required, however, its chemical stability will also make the spent fuel easier to isolate for the long-term in a repository than some of our existing, more chemically reactive waste forms.

8.27 The Government considers that it would be technically possible to dispose of waste from new build through geological disposal. Scientific consensus and international experience suggests that despite some differences in characteristics, waste and spent fuel from new nuclear power stations would not raise such different technical issues compared with

247 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
248 http://www.ap1000.westinghousenuclear.com

nuclear waste from legacy programmes as to require a different technical solution. It would therefore be technically possible to dispose of this waste in the same repository concepts as the legacy waste. The fact that we have not begun construction of a repository facility at this time allows us to build in any necessary engineering features to accommodate particular types of waste if that proves necessary and publicly acceptable. The size of any programme of new nuclear power stations will have an impact on whether all of the new waste could be stored in the same repository as the legacy waste.

8.28 If new build waste were to be accommodated in the same repositories as legacy waste, this would affect the overall cost of the geological disposal solution as additional space would have to be provided and the design would need to be modified. The extra costs arising would mainly be the costs of constructing additional vaults in a facility as the general infrastructure would be common to both legacy waste and new build waste. Due to the fact that it is heat-generating, spent fuel would not be as densely packed in a repository. The amount of time between taking the spent fuel out of the reactor and putting it in the repository will affect the requirement for spacing and the cost of disposal. While there are many technical issues such as these to be assessed, there are no reasons in principle why spent fuel or other waste from new nuclear power stations cannot be disposed of in this way, and indeed (as set out in Box 8.3) Sweden, Finland and the USA are planning to dispose of their spent fuel in a geological repository. It would be important to evaluate the final design of the repositories to accommodate this material, for operational and long-term safety. The Government proposes to do this through the MRWS programme including open and transparent discussions with any volunteer host communities over the final inventory of wastes and materials that may ultimately be proposed for inclusion.

8.29 As we have said, we cannot be sure of the size and timing of any new nuclear programme that might be proposed by private sector energy companies. However, as an illustrative example, we can make a high-level assessment of the impact on the potential size and cost of a repository (see Box 8.4). This assessment should be seen as a rough estimate and further work would be needed to establish a more accurate and up-to-date picture. It is important to note that in line with the principles we set out below, developers of any new nuclear power stations would have to meet their full share of waste management costs. Chapter thirteen sets out the work that will be carried out to estimate the costs of waste management for any waste from new nuclear power stations.

## BOX 8.4: IMPACT OF NEW NUCLEAR BUILD ON EXISTING WASTE INVENTORY

### New Nuclear Waste and Legacy Waste

Any decision on whether to allow nuclear power to play a role in the future UK energy mix will need to consider the likely impact on the strategy for disposing of waste from legacy programmes. If we take the example scenario from the CoRWM inventory report of a new build programme of 10 AP1000 reactors, with an operating lifetime of 60 years each and together generating 25% of the UK's electricity, we can estimate the impact of building these new reactors on the size and cost of geological disposal. As it would be for investors to make proposals to build new nuclear power stations, we cannot be sure of the size of any new nuclear programme, so the figures set out below are purely for illustrative purposes. There is also uncertainty in both the amount and nature of waste that would be produced from different designs and operational regimes of new build reactors, and in the possible range of costs.

**Impact on size of repository in this scenario**
According to analysis undertaken by Nirex:

- A stand-alone ILW repository for legacy waste would need to be around 3% bigger to accommodate waste from new power stations.
- A stand-alone HLW/SF repository would need to be approximately 89% bigger to accommodate waste from new power stations.
- The additional quantities of ILW and HLW/SF would increase the overall footprint of a co-located repository by approximately 50%[249].

**Impact on cost of repository in this scenario**
It is difficult to accurately state the additional costs of new build waste on the costs of geological disposal at this stage. As discussed (in chapter thirteen) further work will be undertaken to establish the costs, and the range of likely uncertainty, as clearly as possible. This will take place alongside work to settle the financing arrangements to cover the cost of waste management, and before new build is allowed to take place. At this stage we simply note that the 2003 cost estimates prepared by Nirex indicated that a new build programme of this size would add a little over £2bn (undiscounted)[250] to an overall geological disposal project costing approximately £10bn (undiscounted)[251].

251 Nirex (now NDA): *The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors* , Technical Note. February 2007.

252 Cost profiles for CoRWM Option 7 (Deep Geological Storage) and Option 9 (Phased Deep Geological Storage) - June 2006. Paper provided by Nirex (now NDA) to CoRWM in 2005/6

251 Nirex (now NDA): *The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors* , Technical Note. February 2007.

## The Managing Radioactive Waste Safely programme and new nuclear power

8.30 The focus of CoRWM's public and stakeholder engagement was always on the existing wastes and materials and there were no new build proposals for them to consider in detail. CoRWM set down that its *"recommendations are directed to existing and committed waste arisings"*[252]. CoRWM stated that it had *"no position on the desirability or otherwise of nuclear new build"*[253] and CoRWM believed that *"its recommendations should not be seen as either a red or green light for nuclear new build"*[254]. CoRWM stated that *"solutions for existing and unavoidable future wastes would also be robust in the light of all reasonably foreseeable developments in nuclear energy and waste management practices"*[255], although it felt there were issues associated with this. CoRWM felt that *"significant practical issues would arise, including the size, number and location of waste management facilities"*[256]. CoRWM also noted that *"the prospect of a new nuclear programme might undermine support for CoRWM from some stakeholders and citizens and make it more difficult to achieve public confidence"*[257]. CoRWM considered that *"should a new build programme be introduced…it would require a quite separate process to test and validate proposals for the management of wastes arising"*[258].

8.31 These are important issues. It is important that confidence is not lost for the programme to deal with legacy waste through the possibility of additional waste from new power stations and the Government recognises that it must face these issues as the MRWS programme progresses. The inventory of waste for disposal in a repository is likely to vary over time regardless of whether we have new nuclear power stations and the MRWS Stage 4 Implementation process will have to be capable of dealing with these. For example, there are stocks of nuclear materials (Uranium and Plutonium) which may have to be managed as wastes, and the CoRWM Inventory report considered these. Equally there may be a reduction in waste volumes through better practices in future decommissioning. The Government will deal openly with any volunteer communities about the amounts and impacts of any changes in the current waste inventory, including from any waste from new nuclear power stations, and the uncertainty surrounding this, and progressively resolving the practical issues outstanding. Through this consultation document, the Government proposes to ensure that the technical and ethical issues surrounding the creation and disposal of waste from new nuclear power stations can be properly considered.

8.32 Placing waste in a geological repository is a long-term solution. CoRWM envisaged a facility being opened by around 2045 and receiving waste for many decades, although their indicative timeline was based on the assumption that no new build waste would be consigned to the repository[259].

252 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
253 CoRWM statement on Nuclear New Build 16 December 2005
254 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
255 CoRWM statement on Nuclear New Build 16 December 2005
256 CoRWM statement on Nuclear New Build 16 December 2005, Addendum (March 2006)
257 CoRWM statement on Nuclear New Build 16 December 2005
258 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
259 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092

If waste from new nuclear power stations were to be placed in the same repository as legacy waste, the repository would need to be kept open for a longer period of time. This would need to be addressed with volunteer communities through the MRWS process. In the meantime, developers of any new nuclear power stations would be expected to manage their waste in accordance with the national interim storage strategy, being developed by the NDA, pending eventual disposal in a repository. This is likely to require on-site storage in facilities capable of holding the waste in a safe and secure condition for long periods until a waste repository is ready to receive it. If the Government concludes that nuclear should be allowed to play a role, operators of new nuclear power stations would be obliged to plan and construct appropriate interim storage arrangements, subject to the necessary regulatory approvals and in line with the NDA's declared strategy. These would need to be capable of being maintained safely, or replaced, until the waste is ultimately removed for disposal, which may be a significant period of time – perhaps 100 years or more. While it is expected that waste is likely to be transferred to geological disposal earlier, it is important to provide adequate contingency to ensure sufficient time to resolve known and emerging practical issues.

## The existing UK decommissioning strategy

8.33 When they reach the end of their working lives, buildings and facilities at nuclear sites need to be decontaminated and dismantled and any radioactive materials need to be appropriately contained and managed. This process is known as "decommissioning". The process of decommissioning can be complex, depending on the function and design of a facility, and may also require the construction of new buildings and facilities to treat resulting wastes. Waste generated by decommissioning is not limited to radioactive material: it also includes conventional industrial wastes as for some other forms of electricity generation.

### Establishing a UK-wide strategy on decommissioning

8.34 In 2002, the Government published the White Paper "Managing the Nuclear Legacy". This set out a greater focus on decommissioning and consulted on the need for a new authority to be given responsibility for the clean-up of existing nuclear sites.

8.35 The NDA came into being on 1 April 2005, following the 2004 Energy Act. The NDA is responsible for securing the decommissioning and clean-up of the 19 civil public sector nuclear sites previously owned by BNFL and the UKAEA. It also has an advisory role in relation to British Energy sites. The NDA's 19 core sites are managed and operated through contracts with British Nuclear Group (BNG), the clean-up subsidiary of BNFL and UKAEA. These contracts are progressively being let to the market, with that for the LLW Repository in West Cumbria to be awarded later this year, and Sellafield in 2008, followed by the Southern Magnox reactor sites. The objective is to stimulate and promote cost effective nuclear decommissioning and clean up through the introduction of innovation and competitive practices. This will also allow the NDA to take a co-ordinated view at a national level, allowing potential synergies to be exploited for the benefit of UK decommissioning. Further information on the NDA can be found in Box 8.5.

## BOX 8.5 KEY FACTS ABOUT THE NDA

### The Nuclear Decommissioning Authority (NDA)

- the NDA is a Non-Departmental Public Body (NDPB), set up in April 2005 under the Energy Act.
- the NDA was set up to provide the first ever UK-wide strategic focus on decommissioning and cleaning up nuclear sites.
- the NDA's mission is to deliver a world-class programme of safe, cost-effective, accelerated and environmentally responsible decommissioning of the UK's civil nuclear legacy in an open and transparent manner and with due regard to the socio-economic impacts on communities.
- the NDA has a responsibility to secure best value for the taxpayer by creating competitive decommissioning and clean-up markets.

## The NDA Strategy

8.36 The NDA's Strategy, approved by Government in March 2006, is the first ever UK-wide plan for dealing with the civil legacy of nuclear waste. Over the first year and a half of its life the NDA has sought to establish a clear focus on decommissioning and a clear programme for carrying it out. It has a commitment to openness and transparency which has been welcomed as a change from the historical approach in the nuclear industry.

8.37 The total estimated cost of cleaning up the UK's civil nuclear legacy set out in the NDA's Strategy in March 2006 is £35.4bn (discounted)[260]. These figures include the fuel business, research and development work and materials created by the Ministry of Defence that are managed by the NDA. Liabilities relating to waste from power stations account for only part of this amount. This is the long-term cost of the entire NDA mission, which will take more than a century to complete. In this the NDA has to consider the affordability of clean up programmes when agreeing its work plan with contractors.

8.38 The NDA has begun tackling difficult issues created by the legacy programme, including quantifying legacy decommissioning liabilities. We are confident that the NDA is already getting to grips with that legacy, but it will still be over 100 years before clean up activities at sites such as Sellafield are completed.

8.39 The high cost of decommissioning the civil nuclear legacy reflects the early emphasis on operations and the lack of awareness of the importance of decommissioning. This, coupled with the political imperative on quick production at the time, and the lack of appropriate waste management infrastructures meant that the decommissioning challenges were ignored or overlooked. We expect that it would cost significantly less to decommission any new nuclear power stations, with waste and decommissioning issues being considered from the design phase onwards.

260 NDA Strategy Document, March 2006
http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=4957

### Decommissioning issues for new nuclear power stations

8.40 All modern reactors are constructed to allow routine removal and replacement of virtually all components. They are also designed with eventual waste management and decommissioning in mind. The decontamination and dismantling of these reactors is therefore expected to be considerably easier than the work that the NDA is currently undertaking. Regulators require new plants to be designed with decommissioning in mind[261], to ensure that sites can be adequately cleaned-up, and to minimise the resulting waste and worker radiation doses.

8.41 Early consideration of decommissioning will ensure that the costs of decommissioning for new nuclear power stations are kept to a minimum. For example minimisation of materials used and measures that ensure that an accurate inventory of the materials used over the lifetime of the station is available, will help give greater certainty as to how materials should be dealt with. The waste hierarchy (avoid, re-use, recycle, dispose) would be important for any new build process to minimise the waste that is produced.

8.42 Uniformity of design across a number of nuclear reactors would also help to reduce the costs of decommissioning through economies of scale. The Government and the Regulators are keen to ensure that lessons are learned from the experience of other companies operating stations of the same design.

## The proposed protection that would be in place for the taxpayer against waste management liabilities

8.43 In the past, the Government has found itself called upon to cover the costs of decommissioning and waste management where owner/operators have been unable to do so. The Government proposes putting in place safeguards to mitigate, in so far as possible, against this risk for any new power stations that are built. The Government's proposals on how these safeguards would operate are set out below.

### Principles for waste and decommissioning funding for new nuclear power stations

8.44 It is the Government's proposal that if we conclude that nuclear has a role to play, there must be a robust structure to ensure that private sector owners and operators of any new nuclear power stations are obliged to accumulate funds to cover the full decommissioning costs and full share of long-term waste management costs. These arrangements would be based on the principles set out in Box 8.6.

261 NII Safety Assessment Principles (Sections 684 to 700), http://www.hse.gov.uk/nuclear/saps/saps2006.pdf. Also Construction and Design management regulations

**BOX 8.6: PRINCIPLES FOR WASTE AND DECOMMISSIONING FOR NEW NUCLEAR POWER STATIONS**

### Principles: The Risk Management Framework – Decommissioning

- there should be an upfront assessment of decommissioning costs.
- full responsibility for decommissioning costs to be retained by the private sector operator(s).
- protection will be given to the public sector regarding credit risk and reduced reactor life.
- the framework should be robust and transparent through time.
- these principles will form the basis of arrangements which will apply consistently to all new build operators and reactor types.

### Principles: The Risk Management Framework – Waste

- delivering and paying for a long-term waste management solution for legacy waste is a responsibility that falls to the public sector. Any long-term waste management solution developed by Government will factor in waste from new build.
- there will be an assessment of how new build affects the cost of delivering the national waste management solution.
- the private sector will pay a charge covering the full and equitable costs of managing the waste generated over the expected life of each new power station.
- the level of this charge will be informed by work on the Government's long-term waste management solution.
- the commercial nature of the arrangements in relation to waste disposal will incentivise participants to operate power stations in a way that seeks the optimal balance between performance and waste generation.
- protection will be given to the public sector regarding changes in reactor life and other factors.
- provision of interim storage over the life of the plant will be the responsibility of the operator.
- the framework should be robust and transparent through time.
- these principles will form the basis of arrangements which will apply consistently to all new nuclear build operators and reactor types.

## Financing arrangements in statute

8.45 To be satisfied that the arrangements are sufficiently robust, the Government proposes to establish the framework for financing arrangements in legislation. This would be presented to Parliament at an early opportunity and would be subject to Parliamentary scrutiny in the usual way. Such legislation would set the framework, allowing the Government to place certain new requirements and duties on potential private sector developers. For example, such legislation could set out:

- a requirement on prospective owner/operators of a new nuclear power station to provide a funding arrangement plan and a plan to show the finance provisions being made for decommissioning and waste management, to the Government for approval;

- the power for the Government to set out what an approvable funding arrangement plan must include;
- a duty on the owner/operators of a new plant to comply with this approved plan;
- sanctions should an owner/operator not comply with the terms of an approved plan.
- arrangements for regulations or guidance setting out the detail of how the arrangements would work.

8.46 Such regulations or guidance, would be the subject of public consultation and could cover:

- the governance arrangements for the fund or funds
- how the payments to the fund or funds would be scheduled
- how the performance of the fund or funds would be monitored and audited; and
- any additional safeguards which might be required to secure the fund or funds.

## Nature of the fund

8.47 There are a number of ways in which a fund could be structured to ensure that adequate funds would be accumulated over the operating life of a new nuclear power station to meet decommissioning and waste management and disposal costs. One or a combination of these approaches could be adopted. These approaches include:

- the owner/operator of a power station is required to accumulate funds in a ring fenced, separable, designated form albeit that the assets are still held within the company itself;
- the owner/operator is required to make specified payments to a designated Government controlled entity or direct to an Exchequer fund or account; and
- the owner/operator is required to make payments to separate, independent fund or funds held by a body or bodies, such as a trust.

8.48 Of these broad options, the Government prefers the third option. This would require owner/operators of new nuclear power stations to make regular payments to one or more separate, independent bodies or funds throughout the operational life of the station to meet the costs of an approved decommissioning and waste management plant. This approach would be transparent and would result in a fund which is insulated against the commercial fortunes of the operator. For example, if the operator were to become insolvent, an independent fund would be less accessible to creditors than a fund controlled by the operator itself. Furthermore, under this approach, provisions would be held as "real money" investments which could be liquidated reasonably readily to provide funding as required to discharge the liability.

8.49 At this stage, the Government is not seeking comments on proposals for ensuring that the full costs of decommissioning and full share of waste management costs are covered by the private sector owner/operators of any new nuclear plant. However, you are welcome to comment on the proposals above if you wish to do so.

## The ethical considerations of allowing new nuclear waste to be produced

8.50 CoRWM also set out views on the ethical considerations of building new nuclear power stations. On this issue they stated: *"future Government decisions on new build should be subject to their own public assessment process, including consideration of waste, because such decisions raise different political and ethical issues when compared with the consideration of wastes which already exist"*[262]. CoRWM also set out that "*an ethically sound solution for wastes arising from new build might be different from the option that might be ethically acceptable for the unavoidable wastes that were within CoRWM's remit"*[263]. The ethical issues around radioactive waste are discussed further in the CoRWM report on "Ethics and Decision Making for Radioactive Waste"[264] (although the discussions reported here focus primarily on legacy waste).

8.51 The Government agrees that the creation of new waste raises ethical issues and that these should be the subject of consideration with the public through this consultation.

8.52 We consider that the key ethical question that needs to be considered as part of the discussion on the future role of nuclear power is ***whether*** to create new waste; once new waste is created it would need to be managed and disposed of, in the same way as existing waste.

8.53 Nuclear power may provide significant benefits to future generations, particularly in terms of reducing $CO_2$ emissions and in generating wealth. However, the creation of nuclear waste is also a potential burden while it requires active management or care and maintenance. Radioactive waste remains potentially hazardous for many years to come and if not properly managed, could be a burden on future generations. Some radioactive isotopes remain hazardous for tens to hundreds of thousands of years, although their radioactivity will naturally decay exponentially to background levels over time. Such long-lived hazard is not unique to nuclear power – other spheres of human activity involve the use of hazardous materials, such as heavy metals like lead and cadmium, which unlike radioactive materials do not become less hazardous with time. The Government has developed sustainable development principles[265] within which the issues related to nuclear power can be considered. These principles are:

- living within environmental limits.
- achieving a sustainable economy.
- using sound science responsibly.
- ensuring a strong, healthy and just society.
- promoting good governance.

262 CoRWM statement on Nuclear New Build 16 December 2005
263 CoRWM's *Managing our Radioactive Waste Safely* (CoRWM Document 700), CoRWM's Recommendations to Government, July 2006. http://www.corwm.org.uk/content-1092
264 "Ethics and Decision Making for Radioactive Waste" – CoRWM Document Number 1692
265 Securing the future, delivering UK sustainable development strategy. The UK Government Sustainable Development Strategy, Cm 6467. Presented to Parliament by the Secretary of State for Environment, Food and Rural Affairs by Command of Her Majesty March 2005

Specifically, the principles of sustainable development require that the benefits to current generations should not compromise the quality of life of future generations. So, in considering the ethics of new nuclear build, we particularly need to assess how the creation of waste now, which delivers benefits to current generations in terms of carbon-free electricity, balances against the potential burden placed on future generations.

8.54 If no new nuclear power stations are built there would be no additional radioactive waste. On the other hand, there could be negative consequences for the environment due to increased carbon dioxide emissions if some fossil fuel power stations, without carbon capture and storage (CCS) technology, are built to meet energy demand instead of nuclear. The economic modelling set out in chapter five suggests that if energy companies are not allowed to construct new nuclear power stations, the private sector would construct in the medium-term (up to 2030) more gas and coal fired power stations because these technologies remain more economic compared to renewables. Some of this fossil fuel plant might be fitted with CCS technology, reducing the carbon impact. However, chapter five also explains that because of its novelty, there are inevitably a number of uncertainties related to the ability of CCS to contribute to meeting our carbon emissions reduction goal. There are currently no commercial scale power stations equipped with CCS technology in existence, but even if it can be made to work safely and reliably, it results in large amounts of carbon dioxide which would need to be stored underground for the long-term avoiding release into the atmosphere.

8.55 Renewables are another option and the Government is committed to ensuring that renewables will make an increasing contribution to energy supply in the UK. However, if all the existing nuclear capacity were replaced by wind power alone, it would take 25GW[266] of wind capacity, when currently around 2GW is available. Assuming a turbine size of 2MW, this would mean more than 12,000 turbines. Each GW of wind power would cover around 10,000 hectares of land[267]. In addition, as wind is an intermittent type of generation, and is not available at all times, it would not provide a reliable baseload supply of energy. Besides nuclear, the only other proven low-carbon form of generation of baseload electricity is large-scale hydro, which as a technology has limited potential for further capacity increases as many suitable sites have already been exploited. Without new nuclear, and considering the uncertainty surrounding the development of CCS, it seems likely that a significant proportion of the new capacity built to meet baseload demand for energy will come from additional fossil fuel power stations. Increasing the amount of fossil fuel power stations would increase the emissions of carbon dioxide into the atmosphere adding to the growing problem of man-made climate change.

8.56 We should also consider the extent to which the burdens to future generations, as outlined above, can be mitigated. We already have a significant inventory of waste that we need to deal with from legacy nuclear programmes. A technical solution for disposing of radioactive waste has been agreed and the Government proposes that this solution should also apply to

266 This is because of the intermittency of wind power. The turbines only produce electricity when local weather conditions are favourable.
267 British Wind Energy Association, http://www.bwea.com/ref/faq.html

waste from new nuclear power stations. The Government is taking forward work on the implementation of geological disposal, although we are at the beginning of this process. The NDA has been given the role of delivering a geological repository for radioactive waste. Disposing of legacy radioactive waste will be costly and this would also be the case for waste from new nuclear power stations. Lessons learned from dealing with legacy waste and improved station designs would ensure minimisation of additional waste levels and cost, and the financing arrangements described above should ensure that potential private sector station operators put aside sufficient funds to meet the costs. This is in line with the "polluter pays" principle.

8.57 The long-term consequences of man-made climate change are relatively unknown and as yet, there is no solution for dealing with or reversing the problems created. Climate change will be a costly burden for us and future generations to deal with and the costs will impact on everyone: not just those who are having the greatest impact on the environment. The Stern Review of the economic impacts of climate change estimated that the costs could be as much as 20% of global GDP[268], although this Review did not give a view on the merits of nuclear energy. The fourth report of the Intergovernmental Panel on Climate Change (IPCC) Working Group III also highlights the growing problem of climate change and global warming. The report sets out that nuclear power could have a role to play alongside other low carbon energy sources in reducing carbon dioxide emissions, although it does also state that safety, weapons proliferation and waste remain as constraints[269].

8.58 Radioactive waste and carbon dioxide emissions are both potentially hazardous and will impact on both current and future generations. Our understanding of radioactive waste and how to deal with it is arguably more advanced than our knowledge of the impact of man-made climate change and as yet we have no solution for mitigating the risks posed by increased carbon dioxide emissions. We have no solution for reversing the adverse global environmental effects of these emissions, whereas we do have an established technical solution for handling radioactive waste safely that is already being taken forward in several other countries.

8.59 Finally, a decision not to allow new nuclear power to play a role would mean that one less source of power would be available to future generations. This could have implications for future diversity and security of supply and thus must be considered with the other ethical issues raised.

8.60 The time to consider these ethical issues is now, and we believe that the intergenerational issues of radioactive waste should not be considered in isolation, but alongside the long-term impact of climate change. We consider that we need to balance the creation of additional radioactive waste with the increase in carbon dioxide emissions that would be produced if energy demand is met by fossil fuel rather than new nuclear power stations. We are inviting views on the ethical issues of creating new nuclear waste through this consultation.

268 Sir Nicholas Stern, The Stern Review: *The Economics of Climate Change*, October 2006

269 Intergovernmental Panel on Climate Change (IPCC), Working Group III Report *Mitigation of Climate Change*, Summary for Policy Makers, May 2007. http://www.ipcc.ch/SPM040507.pdf

## Is now an appropriate time to take a decision on new nuclear power stations?

8.61 Progress has been made in developing a solution for waste management. However, a site has not been selected, nor have all practical details been finalised as these will depend on the precise site and final inventory of waste. It is therefore reasonable to ask whether it is appropriate to take a decision in principle on new nuclear power generation at this stage, as opposed to postponing a decision.

8.62 There are two broad reasons which suggest that it may be reasonable or even necessary to take a decision now. First, there is now a window for making investment decisions in energy generating capacity. Energy companies will need to invest in around 30 – 35GW of new electricity generating capacity over the next two decades; around two-thirds of this investment will be needed by 2020. Due to the long lead times for new nuclear power stations, new nuclear generation could make only a limited contribution to new electricity generation capacity in the period up to 2020. If nuclear is to play a role beyond 2020 it is important that the market receives a clear signal about whether or not nuclear is an investment option as early as possible. It would be during the period up to 2020 that companies wishing to build new nuclear power stations would need to obtain the necessary consents and begin construction so that new nuclear could become available at the earliest possible opportunity. Continuing uncertainty about the Government's approach to nuclear may result in companies deciding to wait for further policy development before making any investment decision. This in turn would have implications for carbon emissions.

8.63 The second reason is that the final resolution of all the issues relating to geological disposal will take many decades. We could wait until all these issues have been resolved. However, given that addressing climate change is an urgent issue, a more appropriate test may be whether there is confidence that the practical issues will be resolved in due course. While there is clearly work to be done, a number of positive steps have been taken which have given the Government that confidence:

- we now have technical solutions for waste disposal that experience from abroad suggests could accommodate all types of wastes from any new nuclear power stations;
- we have an implementing body, with expertise in this area;
- we are reconstituting CoRWM to provide independent scrutiny and advice;
- we have a framework for implementation of geological disposal, which will be consulted on this Summer;
- we are developing specific proposals to protect the taxpayer against risk resulting from waste from and decommissioning of new nuclear power stations; and
- this consultation document also highlights for public consideration the ethical and intergenerational issues and considerations in any decision to allow the creation of new nuclear waste.

**The Government believes that new waste could technically be disposed of in a geological repository and that this would be the best solution for managing waste from any new nuclear power stations. The Government considers that waste should be stored in safe and secure interim storage facilities prior to a geological repository becoming available.**

**We consider that it would be desirable to dispose of both new and legacy waste in the same repository facilities and that this should be explored through the MRWS process.**

**There are also important ethical issues to consider around whether to create new nuclear waste, including the ethical implications of not allowing nuclear power to play a role, and the risks of failing to meet long-term carbon emissions targets. The Government has taken a preliminary view that the balance of ethical considerations does not require ruling out the option of new nuclear power. However, we intend that these ethical issues should be considered through this consultation document and respondents are invited to give their views.**

Question 8
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?

Question 9
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?

Question 10
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?

CHAPTER 9

# Nuclear power and the environment

## Introduction

**This chapter looks at the impacts of nuclear power stations on the environment and landscape. It considers positive and negative impacts, and similarities and differences with other forms of electricity generation. It also describes the regulatory framework for environmental protection that applies to the nuclear industry in the UK.**

9.1 The biggest environmental benefit from nuclear power is its contribution to reducing the UK's carbon emissions and in ameliorating the effects of climate change. Carbon emissions from nuclear power are very much lower than the emissions produced by fossil-fuel power stations and are comparable with those from wind power (we discuss this is in more detail in chapter two).

9.2 The most significant environmental challenge of nuclear energy lies in managing the radioactive waste produced by nuclear power stations. We discuss waste management elsewhere in this consultation document (see chapter eight).

9.3 In this chapter we describe other environmental impacts that arise at different stages in the nuclear life cycle. In particular, we consider:
- landscape and construction issues;
- water use and thermal discharge;
- mining and milling of uranium ore; and
- preparation of fuel for nuclear power.

9.4 In doing so we compare the environmental effects of nuclear power with those that arise from other forms of electricity generation. In many cases, the effects on the environment do not depend on the fuel used in a power station. As such, the same regulatory framework will apply to any centralised power generation facility.

## The UK regulatory framework for environmental protection

9.5 In the UK, the opportunity to assess the environmental impact of applications to construct new nuclear power stations arises under the energy planning process. Under section 36 of the Electricity Act 1989, developers of all onshore power stations with a capacity of greater than 50 MW need consent from the Secretary of State in England and Wales or Scottish Ministers in Scotland. The Secretary of State is required to call a public inquiry if a "relevant planning authority" objects to the proposal which can consider relevant issues, including environmental ones. The public inquiry would consider such applications, with a public discussion of issues, including environmental ones. The process for granting consent to the construction of new power stations in Northern Ireland is covered by separate legislation for Northern Ireland.

9.6 The Government's recent White Paper, *Planning for a Sustainable Future*[270] proposes reforms to the planning system for nationally significant infrastructure projects, including large energy infrastructure projects. The planning White Paper, and the consultation document on its proposals can be found at http://www.communities.gov.uk. The implications of its proposals for the energy sector are also discussed in more detail in the Energy White Paper[271]. A key component of the reforms proposed in the planning White Paper is the creation of an independent planning commission to manage inquiries and take decisions on applications for nationally significant infrastructure projects. The commission would deal with major infrastructure projects above statutory thresholds, as well as projects designated to it by national policy statements or ministers.

9.7 In addition to the planning consent process, there are environmental assessment measures provided under European legislation to which any proposals to develop new nuclear power stations would be subject. These comprise in particular the Directives on Strategic Environmental Assessment (SEA)[272] and the Environmental Impact Assessment (EIA)[273].

9.8 The SEA Directive requires a high-level assessment of plans or programmes that are likely to have significant environmental impact. We recognise the need for a strategic assessment of the environmental issues relating to new nuclear power stations. If the Government confirms its preliminary view that it is in the public interest to allow energy companies to invest in new nuclear power stations, we propose to undertake an SEA as part of a Strategic Siting Assessment, the detail of and proposed timetable for which is set out in a detailed consultation alongside this consultation on the issue in principle.

9.9 Under the EIA Directive, all developers of nuclear power stations must prepare an Environmental Statement and submit this with their application for development consent[274]. As well as covering the direct environmental impacts of the proposal, the Environmental Statement must provide details of, amongst other things, the description of the physical characteristics of the proposed development and land use requirements[275]. The Environmental Statement must also describe how the applicant plans to mitigate any adverse impacts.

270 http://www.communities.gov.uk/planningwhitepaper
271 http://www.dti.gov.uk/energy/whitepaper
272 Directive 2001/42/EC of the European Parliament and of the council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (O.J. L197, 21.7.2001, p.30).
273 Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (O.J. L175, 05/07/1985 p. 40).
274 The directive is transposed in England and Wales through the Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2000 (S.I.2000/1927).
275 More information about Environmental Statements is available at http://www.dti.gov.uk/energy/markets/consents/page22743.html

9.10 It is also necessary to consider whether any proposed new nuclear power station would affect protected environmental sites. Protected sites include Special Areas of Conservation & Special Protection Areas protected under the European Birds and Habitats Directives[276], Sites of Special Scientific Interest (SSSIs) that are protected under UK domestic legislation[277], and non-statutory Local Nature Reserves and Local Sites. Designated areas under UK legislation comprise the National Parks, the Broads and Areas of Outstanding Natural Beauty. Many protected sites are designated as of national or international importance, or both. Any plan or proposal that could have a significant effect on these sites must be assessed against the site's conservation objectives and have regard to the statutory purposes of the designations. The process must also take full account of the potential impact of any proposal on the Government's national biodiversity strategies and how the proposal relates to national, regional and local planning policies[278].

## The siting of any new nuclear power stations

9.11 If we confirm our preliminary view that it is in the public interest to allow energy companies to invest in new nuclear power stations, it would be for them to propose, construct and operate such power stations. This would include selecting a proposed location. Industry has indicated that the most viable sites for new nuclear power stations are likely to be adjacent to existing nuclear power stations. Energy companies would be guided by the Strategic Siting Assessment (as discussed earlier in this chapter). This would be a Government process that would develop criteria for determining the suitability of sites for new nuclear power stations. Alongside this consultation, the Government is also seeking views through a detailed consultation on the proposed process for this assessment[279].

## Landscape and construction

9.12 The impacts of nuclear power on the environment and landscape are broadly similar to those of other centralised forms of electricity generation. The most significant impacts are during construction, and the visual impact of the power station on the local area when construction is complete. Most power stations require similar structures, including separate buildings for the reactor, turbine, generator, cooling water pump house or cooling towers, the main control buildings and other service and maintenance facilities. The planning process considers these impacts and any mitigating action that might be needed.

9.13 The environmental impacts of construction arise from the mining and transport of aggregates and other components, and from on-site activity. One way to mitigate some of these effects on coastal sites is to bring in

276 Council Directive 79/409/EEC of 2nd April 1979 on the conservation of wild birds (O.J.L103, 25.4.1979, p.1) and Council Directive 92/43/EEC of 21st May 1992 on the conservation of natural habitats and of wild fauna and flora (O.J. L206, 22.7.1992, p.7).
277 The key provisions are set out in Section 28 of the Wildlife and Countryside Act 1981 as amended by the Countryside and Rights of Way Act 2000 and the Natural Environment and Rural Communities Act 2006.
278 Planning Policy Statement (PPS) 7 on Sustainable Development in Rural Areas, and PPS 9 on Biodiversity and Geological Conservation.
279 http://www.dti.gov.uk/energy/whitepaper/consultations/nuclearpower2007

construction materials by sea (as happened at the UK's newest nuclear power station, Sizewell B), rather than by road.

9.14 The visual impact of any power station on the locality, whatever its fuel, is due to the size of the buildings and, if there are any, the station's cooling towers. At up to 100 metres high, cooling towers can have significant consequences for the visual character of the landscape. In the UK, there are no operational nuclear power stations with cooling towers, unlike most coal-fired power stations. The "containment building" that houses the reactor is one of the larger buildings in a nuclear power station and is one difference between nuclear power stations and other ways of generating electricity. The reactor building of the designs that might be built in the UK can be around 70 metres high[280].

9.15 A nuclear power station needs about the same land area as a coal- or gas-fired power station or an on-shore "windfarm". For example, it is estimated that a 1GW PWR nuclear power station in the UK would need between 25 and 75 hectares[281] of land, while 1GW of onshore wind power capacity needs an estimated 180 hectares of land[282]. This is based on the land occupied by the wind turbine, access roads and substations, and the assumption that surrounding land remains accessible for other activities. If surrounding land is included, then the land-take from windfarm is much higher. According to the British Wind Energy Association, 12,000 MW of wind energy capacity would extend over 80,000 to 120,000 hectares of land, depending on the size of the wind turbines[283]. This implies land take of approximately 10,000 hectares for a 1GW windfarm.

9.16 Nuclear power stations can bring environmental benefits that can compensate for other adverse local impacts. The International Atomic Energy Agency (IAEA) has pointed out that limiting development around these sites can yield environmental benefits, supporting vulnerable eco-systems[284]; such as the use of land for pastoral farming or wildlife refuges.

9.17 One of the more visible environmental "presences" of any centralised electricity generation, whatever the fuel, is the transmission system. The main impact of transmission lines is visual – pylons can be prominent features on the landscape. The land corridor needed for transmission can stretch to over 60 km, depending on how close the power station is to the load centre[285]. In remote locations, the land on either side of the pylons can be used, for example, for low intensity farming or wildlife corridors. It is possible to build near to transmission lines, although this has to comply with statutory safety clearances. National Grid provides detailed guidance on building near to transmission corridors. The purpose of the guidelines is to minimise the visual impact of the transmission corridor[286].

280 Westinghouse AP1000 Advanced Passive Plant, Westinghouse Electric Company, http://nuclearinfo.net/twiki/pub/Nuclearpower/WebHomeCostOfNuclearPower/AP1000Reactor.pdf
281 http://www.publications.parliament.uk/pa/cm198889/cmhansrd/1989-02-03/Writtens-2.html
282 SDC, *The role of nuclear power in a low carbon economy, Paper 3: Landscape, environment and community impacts of nuclear power*, March 2006.
283 http://www.bwea.com/ref/faq.html#space
284 IAEA, *Non-technical factors impacting on the decision making processes in environmental remediation,* 2002.
285 SDC, *The role of nuclear power in a low carbon economy, Paper 3: Landscape, environment and community impacts of nuclear power*, March 2006.
286 http://www.nationalgrid.com/uk/Senseofplace/FAQs/

## Water and cooling

9.18 All thermal power stations, whether coal, gas or nuclear, use substantial volumes of water for cooling. However, because of their lower thermal efficiency most currently operating nuclear power stations need more cooling water[287]. Some new designs of nuclear power station have a higher thermal efficiency which may lead to lower cooling water needs.

9.19 Without careful management, water intake can have a negative impact on the local aquatic environment, potentially because of the number of organisms killed when the water is screened to remove debris and through the use of biocides to keep the condenser clean. This issue is common to all energy generation that uses once-through cooling. Measures to deter fish from the inlet and to return fish to the sea that have entrained in the cooling water can help to reduce this impact.

9.20 Cooling water can also have an impact on the marine environment when it is returned from the power station. Large temperature and salinity differences between the discharged water and ambient water temperatures could lead locally to the loss of some species and habitats[288].

9.21 A regulatory framework enforced by the environment agencies aims to prevent these negative impacts of water abstraction and discharge on the environment. Under the Water Resources Act 1991, before any power station is allowed to abstract water from rivers or ground water for cooling (or for other purposes, e.g. construction of the power station), the operators must first obtain licences from the relevant environment agency. Operators must also obtain a consent to discharge water into the sea, rivers or an estuary. These permits would specify where the water can be taken from, the quantities that holders are allowed to take and what it can be used for. The permits would also have conditions to protect the marine environment, such as an upper limit on the temperature of the water returned to rivers or the sea.

## Uranium mining and milling

9.22 Uranium used by the UK nuclear power industry is sourced internationally; the majority is currently from Australia. The mining of uranium is therefore not subject to the UK environmental protection framework. However, its impact on those countries where uranium is mined needs to be understood in order to gauge the impact of the nuclear fuel cycle across the global environment.

9.23 In most respects, conventional mining of uranium is the same as mining of any other metalliferous ore or coal for power stations. There are two main types of mining:

- Open pit mining is used where deposits are close to the surface. In 2005, 30% of uranium production came from open-pit mines[289];

287 Barszak and Kilpatrick, *Energy Impacts on Georgia's Water Resources*, University of Georgia 2003.
288 SDC, *The role of nuclear power in a low carbon economy, Paper 3: Landscape, environment and community impacts of nuclear power*, March 2006.
289 Uranium Information Centre Limited: *World Uranium Mining: Briefing Paper 41*, July 2006, http://www.uic.com.au

- Underground mining is used to recover deeper deposits, typically more than 120 metres deep. In 2005, underground mines accounted for 38% of uranium production[290].

9.24 The remainder of uranium is produced through in-situ leaching (21% – see below) and from by-products (11%).

9.25 Uranium mining can have a significant effect on the environment. On average, every tonne of uranium mined creates 3.5 tonnes of waste[291]. Open-pit mines require large holes to get at the ore. Underground mines usually have relatively small surface disturbance and have to remove much less material than an open pit to get at the ore. However, underground mines need ventilation systems to protect workers from the natural radon gas which is emitted from uranium ore which can have an effect on health.

9.26 An increasing proportion of the world's uranium now comes from in-situ leaching (ISL), 21% in 2005[292], a process that does not require the ore to be physically mined. ISL involves circulating oxygenated groundwater down into the ground through pipes on one side of a uranium deposit and up through pipes on the other side, recovering the ore by dissolving it. In-situ leaching is also used to "mine" other metals, such as copper. ISL has the benefit of removing much less rock and other material than extraction, but it can have a significant negative impact on the watertable and is not suitable for all types of uranium deposits.

9.27 There are established environmental constraints to minimise the environmental impacts of mining operations[293]. For example, the International Organisation for Standards Environmental Management System Framework (ISO14001) certifies that operators are demonstrating sound environmental management. In Australia, from where the majority of uranium used in the UK is sourced, all major companies either have, or are close to having, ISO14001 certification.

9.28 After mining, the next stage in nuclear-fuel preparation is to "mill" the uranium, and to turn it into a product known as "yellow cake". A uranium mill extracts uranium from mined ore chemically, usually with sulphuric acid as the leaching agent. Typically, mills crush and leach the ore to separate the uranium from the ore in a process that not only extracts uranium but also several other constituents, such as vanadium, selenium, iron, lead and arsenic. Conventional mills extract 90 to 95 per cent of the ore's uranium[294]. The "spoils" and "tailings" are the sands left after leaching.

290 Uranium Information Centre Limited: *World Uranium Mining: Briefing Paper 41*, July 2006, http://www.uic.com.au

291 SDC: *The role of nuclear power in a low carbon economy, Paper 3: Landscape, environment and community impacts of nuclear power*, March 2006.

292 Uranium Information Centre Limited: *World Uranium Mining: Briefing Paper 41*, July 2006, http://www.uic.com.au

293 Uranium Information Centre Ltd: *Environmental Aspects of Uranium Mining*, July 2006, Briefing Paper 10, February 2006; http://www.uic.com.au

294 http://www.nrc.gov/materials/fuel-cycle-fac/ur-milling.html

9.29 As with many mines, it is possible to reclaim land used for uranium mining and milling. Waste rock discarded during mining can be used in rehabilitation or shaped and replanted. Some mines have already been reclaimed. For example Australia's first major rehabilitation project of a uranium mine was the Mary Kathleen mine in Queensland. The reclamation involved the plant site, a 28-hectare tailings dam and 60-hectare area for evaporation ponds. Following the reclamation, the whole area was returned to a cattle station, with unrestricted access[295].

## Fuel preparation

9.30 Yellow cake is not itself usable as a fuel for a nuclear reactor. Most reactors require fuel that has been through additional processing to convert uranium into uranium hexafluoride, sometimes known as "hex". The hex then travels in secure containers to the uranium enrichment plant where the "fissile" component of the fuel is increased from its natural level of just 0.7% to the 3 to 5% needed for most modern reactors[296]. All fuel enrichment in the UK is carried out in the facility operated by Urenco at Capenhurst in Cheshire.

9.31 The next stage in fuel production is to transport enriched uranium hexafluoride in metal containers to a fuel fabrication plant where it is converted to uranium dioxide powder and pressed into small pellets. These pellets, inserted into thin tubes usually made of zirconium alloy or stainless steel, form fuel rods. Sealed and assembled in clusters, the rods form fuel assemblies that are put into the core of the nuclear reactor. Most fuel fabrication in the UK is carried out in the Springfields facility operated by Westinghouse in Lancashire.

9.32 The environmental impact of uranium enrichment depends on the process used. Some gaseous diffusion plants, for example, require cooling towers with associated visual impacts. There are no cooling towers at Capenhurst, which uses the gas centrifuge enrichment method. Gas centrifuges consume much less electricity, with a much lower impact on the environment, and have lower maintenance costs, making them much more economical than gaseous diffusion.

9.33 Like any nuclear facility, facilities for fuel processing require decommissioning and clean-up. When it is eventually decommissioned, the Springfields fabrication facility is unlikely to have any lasting impacts on the landscape and the environment. The Nuclear Decommissioning Authority's programme for decommissioning and clean-up assumes an end state to be a licensed site with the potential for restricted re-use[297].

295 Uranium Information Centre Ltd, *Environmental Aspects of Uranium Mining*, Briefing Paper 10, February 2006, http://www.uic.com.au
296 http://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html
297 Nuclear Decommissioning Authority, *Strategy*, April 2006.

**The Government believes that the environmental impacts of new nuclear power stations would not be significantly different to other forms of electricity generation and given the UK and European requirements in place to assess and mitigate the impacts, that they are manageable. Therefore, the Government believes that they do not provide a reason to not allow energy companies the option of investing in new nuclear power stations.**

**We recognise the need for a strategic assessment of the environmental issues relating to new nuclear power stations. If the Government confirms its preliminary view that it is in the public interest to allow energy companies the option of investing in new nuclear power stations, we propose to undertake an SEA as part of a Strategic Siting Assessment, the detail of and proposed timetable for which is set out in a detailed consultation alongside this consultation on the issue in principle.**

Question 11
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?

CHAPTER 10

# The supply of nuclear fuel

## Introduction

**This chapter discusses the availability and access to fuel for nuclear power stations. It would be for private sector energy companies to obtain fuel for their nuclear power stations, subject to regulatory requirements and safeguards. However, it is important to consider the implications of several issues associated with fuel supply. These include the distribution of global uranium reserves, the rising costs of uranium and the implications of moving to lower-grade ores.**

10.1 If it is to contribute to the world's energy needs, nuclear power needs a reliable, affordable and sustained supply of fuel, especially uranium. After some time at historically low levels compared to the 1970s, uranium prices have started to rise in response to increased worldwide demand, with a sharp increase since 2000. With further increases likely, in line with market pressures, there has been increasing scrutiny of available resources.

10.2 At present, there are more than 430 reactors operating worldwide[298]. The UK has 19 operable reactors at 10 power station sites, with a total installed capacity of approximately 11GW although actual operational capacity is lower. As of January 2007, there were 30 new reactors under construction and 64 more planned around the world[299]. If nuclear power is to help us to meet the challenge of climate change, then there could be moves to build many more nuclear power stations globally which would have implications for the global supply of fuel.

10.3 This chapter sets out information on:
- uranium resources;
- fuel fabrication facilities;
- potential impact on costs, diversity of supplies and carbon emissions; and
- potential alternatives to uranium as a source of fuel.

298 IAEA Power Reactor Information System (PRIS) http://www.iaea.org/programmes/a2/index.html
299 World Nuclear Association, http://www.world-nuclear.org/

## Uranium resources

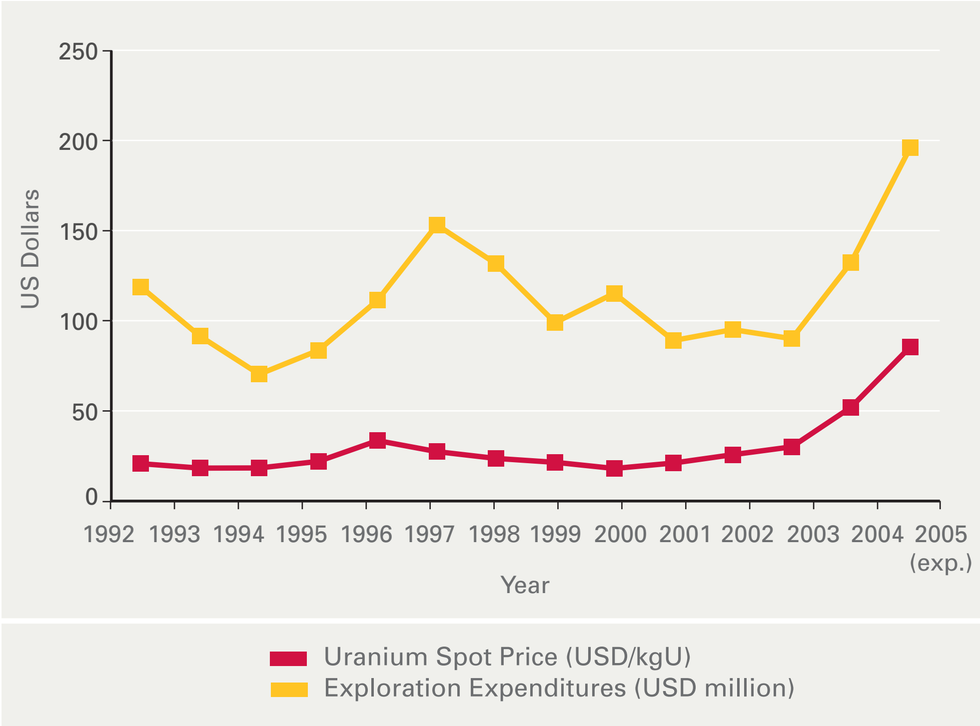
10.4 As with oil and gas reserves, it is difficult to identify economically recoverable ore and to produce accurate estimates of uranium resources. The IAEA and OECD estimate[300] that about 4.7 million tonnes of known conventional uranium resources can be mined for less than $130/kg, although there are significant further reserves that would be more expensive to recover. Based on the level of nuclear electricity generation in 2004, these reserves would last for approximately 85 years. The Sustainable Development Commission (SDC)[301] and the IEA[302] have concluded that world uranium resources are more than adequate to supply the expected global expansion of nuclear power.

10.5 The market price for uranium is likely to increase as demand for uranium continues to rise, driven by the expected increase in global nuclear capacity. According to the IAEA's and OECD's joint report, improved market conditions and higher prices are the primary driver of new investment to find new reserves or to expand existing production. Their most recent analysis[303] shows that since 2001, investment in uranium exploration has tracked the rising price of uranium[304]. The Euratom Supply Agency, which *"is responsible for the regular and equitable supply of nuclear fuels for Community users,"* has also acknowledged that exploration for uranium continues to increase significantly[305].

10.6 In recent years, data collected by the IAEA and OECD show that mining companies have increased their spending on uranium exploration, in part due to increased prices for uranium. In 2005 that spending could be more than twice the amount committed in 2001 (see Figure 10.1). They conclude that *"a continued strong market and sustained high prices will be necessary for resources to be developed within the timeframe required to meet uranium demand"*.

300 NEA and IAEA, *Uranium 2005: Resources, Production and Demand,* 2006 (The "Red Book")
301 Sustainable Development Commission – *Paper 8 Uranium Resource Availability.*, http://www.sd-commission.org.uk/pages/060306.html
302 IEA, *World Energy Outlook* 2006
303 NEA and IAEA, *Uranium 2005: Resources, Production and Demand,* 2006 (The "Red Book")
304 In the past, the uranium market has been affected by the re-cycling of weapons material into civil reactor fuel, which halved demand for mine output through the 1990s. This dividend has now been exhausted and, from January 2001 to November 2005, the price of uranium increased from USD16.64/kgU to USD87.10/kgU.
305 http://ec.europa.eu/euratom/mission_en.html

**FIGURE 10.1. TREND IN URANIUM EXPLORATION EXPENDITURES FOR SELECTED COUNTRIES**




*Source: IAEA/OECD (NEA) Red Book 2005*

Figure 10.1 Spending on uranium exploration has fluctuated over the years. It has risen recently in line with uranium prices.

## Fuel fabrication

10.7 Uranium mining is just the beginning of the nuclear fuel cycle. Before it can fuel a nuclear reactor, natural uranium needs to be first refined, then enriched and then fabricated into fuel assemblies. There are several sources of refinement, enrichment and fabrication services throughout the world, with Europe being particularly strong. The IAEA believes it will be relatively easy to expand these services to meet demand[306]. Fuel fabrication facilities in the EU continue to provide adequate coverage of the needs of member states[307].

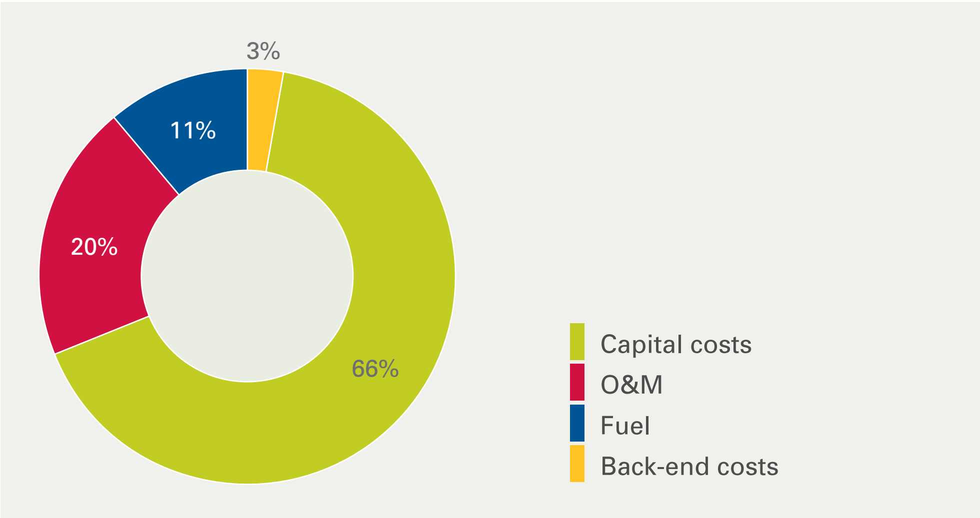
10.8 Older gas diffusion enrichment technology has mostly given way to newer more efficient centrifuge technology[308]. As a result, $CO_2$ emissions from uranium enrichment have fallen significantly.

306 IAEA Report, *Multilateral Approaches to the Nuclear Fuel Cycle* INFCIRC/640, February 2005, http://www.iaea.org/Publications/Documents/Infcircs/2005/infcirc640.pdf
307 Euratom Supply Agency: Annual Report 2005, http://ec.europa.eu/euratom/ar/last.pdf
308 Sustainable Development Commission, *Paper 2: Reducing $CO_2$ emissions – nuclear and the alternatives,* http://www.sd-commission.org.uk/pages/060306.html

## Impact of uranium price on overall generating costs

10.9 While rising uranium prices will certainly influence the cost of nuclear power, the overall generating costs are relatively insensitive to increases in the price of fuel. As discussed in chapter 4, fuel costs represent about 11% of the levelised cost of electricity generation from nuclear power stations (see Figure 10.2). Enrichment and manufacture of fuel rods account for about half of the fuel cost[309]. By contrast, the cost of gas-fired generation is much more vulnerable to changes in the price of fuel, which makes up 71% of its levelised cost of electricity generation[310].

**FIGURE 10.2. NUCLEAR COSTS BY STAGE**




***Source: DTI, 2006***

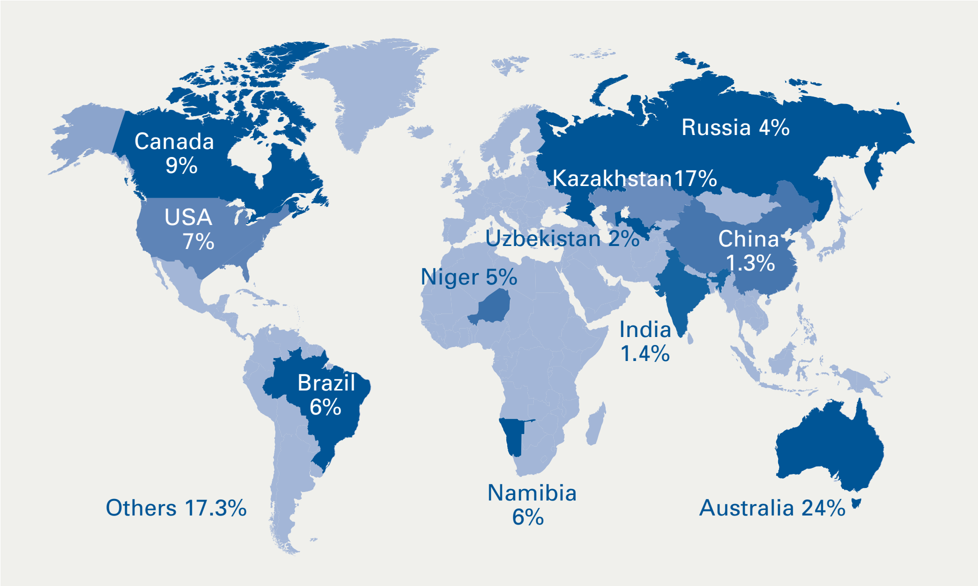
Figure 10.2 Capital expenditure accounts for most of the cost of electricity generation from nuclear power.

## Impact on diversity

10.10 Another important factor in considering the desirability of nuclear power is the vulnerability of fuel supplies to factors beyond those of resources and costs, and benefits of having a diverse supply of fuel in insuring against potential interruptions. From this aspect, uranium is less vulnerable than other fuels. Deposits of uranium are widely dispersed across a number of countries. The potential sources include countries that we do not currently rely on for fossil-fuels. There are also considerable reserves available in OECD countries (see Figure 10.3). In this respect, increasing the UK's use of nuclear power for electricity generation would increase the diversity of our energy supplies, at a time when we are becoming increasingly dependent on imports of fossil-fuel to meet our energy demands.

309 World Nuclear Association: *The Economics of Nuclear Power* http://www.world-nuclear.org/info/inf02.htm November 2006
310 DTI analysis 2006 – this assumes gas costs of 36.6p/therm

**FIGURE 10.3. URANIUM SOURCES**




*Source: IAEA/OECD (NEA) Red Book 2005*

Figure 10.3 Identified uranium resources are spread across the world. The known uranium reserves are spread amongst different geographical areas to the world's fossil-fuel resources.

10.11 Most of the UK's uranium supplies come from Australia[311]. The Euratom Supply Agency[312] monitors the market, in particular the supply of natural and enriched uranium to the EU, ensuring that utilities in the EU have diversified sources of supply and do not become over-dependent on any single source. In reality, European utilities obtain uranium from a diverse spread of suppliers[313] (see Table 10.1).

**TABLE 10.1: ORIGINS OF NATURAL URANIUM DELIVERED TO EU-15 UTILITIES IN 2005**

| Country | Percentage of natural uranium supplied |
|---|---|
| Canada | 28.38 |
| Australia | 17.40 |
| Niger | 13.57 |
| Russia | 10.15 |
| South Africa and Namibia | 5.40 |
| United States | 4.30 |
| Uzbekistan | 3.88 |
| Kazakhstan | 3.20 |

*Source: Euratom Supply Agency*

311 Information provided by Uranium Asset Management Ltd. (UAM Ltd), a 100% owned subsidiary of Westinghouse UK. UAM procure uranium to support fuel supply to the UK AGR reactors and PWR reactor.
312 Euratom Supply Agency: Annual Report 2005, http://ec.europa.eu/euratom/ar/last.pdf
313 Euratom Supply Agency: Annual Report 2005, http://ec.europa.eu/euratom/ar/last.pdf

## Impact on carbon emissions

10.12 As discussed in chapter two, although nuclear power stations are carbon free at the point of generation, there are carbon emissions that arise from the fabrication of fuel. Any move to ores containing less uranium would require more energy to extract and process, with a possible increase in carbon emissions. However, there is no evidence to suggest that there will be a need to mine significantly lower-grade ores than we currently use[314]. This suggests that the emissions of $CO_2$ from nuclear power will not differ greatly from those created by wind power.

10.13 The true impact of producing nuclear fuel on carbon emissions is, however, disputed. For example, in 2000 the Green parties of the European Parliament requested a study which concluded that the recovery and processing of lower-grade uranium ores is inefficient and would increase $CO_2$ emissions[315]. The study also concluded that mining and milling "lean" uranium deposits (i.e. where the concentration of uranium ore is low), may have a negative energy balance and that it would take more energy to extract the uranium than could be recovered using the uranium as fuel. However, as discussed at paragraph 10.2, we have no evidence that there will be a need to mine significantly lower-grade ores.

## Alternative sources of fuel

10.14 Nuclear power differs from other forms of energy in that the fuel is not completely consumed in the reactor. Over time, the reactivity of the fuel declines reducing the efficiency of the nuclear reaction and therefore of the power station. To maintain the power station's output, fresh fuel is introduced. This entails removing "spent fuel" that still contains much of the original uranium (about 96%) as well as plutonium that is produced by nuclear reactions.

10.15 It is possible to extract some of the useful energy from this spent fuel through a process called reprocessing (see chapter twelve) to separate out the useable uranium and plutonium from the radioactive waste bi-products of the nuclear reaction. Fuel fabrication facilities can then process the recovered fuel to make a mixture of the uranium oxide and plutonium oxide, creating what is known as mixed oxide, or MOX, fuel.

10.16 Reprocessing could enable operators of nuclear power stations to avoid any tightening in the supply of fresh uranium or future price increases. However, this would depend on the economics of the process. If newly mined uranium is much cheaper than reprocessed material, then there is little incentive to use MOX technology. As we have already explained, fuel costs makes up only 11% of the total costs of electricity generation, with uranium ore accounting for approximately 1.5% of total generation costs. This percentage is of course dependent on uranium ore prices.

314 Sustainable Development Commission – *Paper 8 Uranium Resource Availability*, http://www.sd-commission.org.uk/pages/060306.html
315 J.W.S. van Leeuwen and P. Smith, *Nuclear Power: The Energy Balance*. July 2005. www.stormsmith.nl/

10.17 MOX fuel is currently manufactured in the UK at the Sellafield MOX Plant (SMP). However, SMP is devoted to servicing overseas contracts. Based on current performance, it is far from certain that SMP could meet the needs of new operators. However, there are other sources of MOX fuel outside the UK.

10.18 In the UK there is also a stock of uranium and plutonium which has arisen from historic nuclear programmes, which could be used to produce MOX fuel. The NDA has undertaken a review of the nuclear materials for which it is responsible including stocks of uranium and plutonium. This review which is expected to be completed in the first half of 2007 will set out options to the Government on the future use (as fuel) or disposal of these materials.

10.19 There are other alternative nuclear fuel cycles that can make more efficient use of uranium and in so doing reduce dependency on global supplies. For example, a number of countries are exploring the use of Fast Breeder Reactors, such as the now closed research reactors at Dounreay in Scotland, which can be designed to breed more fissile material than they consume (see chapter one).

**Based on the significant evidence that there are sufficient high-grade uranium ores available to meet future global demands, and the relatively small impact that allowing energy companies to invest in new nuclear power stations in the UK would have on global demand for uranium, the Government believes that there should be sufficient reserves to fuel any new nuclear power stations constructed in the UK.**

### Question 12
### 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?

CHAPTER 11

# Supply chain and skills implications

## Introduction

**This chapter explores issues surrounding the supply chain and skills requirements of building new nuclear power stations in the UK. It pays particular attention to the ability of suppliers in the UK and other countries to deliver the UK's needs at a time when we expect a high worldwide demand for nuclear power.**

11.1 It takes a long time to plan and build new nuclear power stations. In some ways this makes it easier for the market to manage. The industry has time in which to develop or secure resources and even to train people. However, there is a wide range of opinion on the ability of operators in the UK to build new nuclear power stations. At one extreme is the view that, in the 13 years since Sizewell B was completed and the 20 years since the end of the Advanced Gas Cooled Reactor (AGR) programme, the UK has lost the skills base and the supply chain to the extent that new build is not possible. At the other is a view, strongly held by the companies that are still active in the nuclear sector, that the UK's engineering construction sector has plenty of capacity to build new nuclear power stations. It is important to remember that the supply chain is global and that the labour market is international. The Government's interest is around seeing projects delivered if the market decides to do so.

11.2 Any assessment of the UK's ability to carry out new nuclear construction has to consider the issues surrounding the supply chain and the availability of the skilled people industry will need if they are to build and operate new power stations. The chapter covers the following issues:

- the need for skills and supply chain capacity to support the UK's energy sector;
- the global demand for, and capacity to provide, key power station components;
- availability of general and the specialised skills and components needed for new nuclear power stations; and
- the UK's investment in specialised nuclear skills and R&D.

## The need for skills and supply chain capacity across the UK energy sector

11.3 There is a growing global need to replace power stations that are coming to the end of their operational lives. There is a parallel need to build new capacity to meet an increasing demand for energy. The nuclear industry is not alone in facing a challenge to ensure a workforce with the appropriate skills needed to satisfy that demand for new electricity generating capacity[317].

11.4 Limited recruitment and training over the last 15 years means that the workforce in the energy sector in UK is ageing. There is a lack of staff aged between 28 and 45, people who are essential for the long-term sustainability of the skills pool. Detailed research by the Sector Skills Councils[318] shows that, mostly, the situation is not extreme and that there is time to act before retirement takes its toll, but that any action must begin soon. The general view is that industry in the UK can manage any skills shortages by a combination of delayed retirement, increased recruitment, training and strategic immigration. However, there may be upward pressure on wages, further exacerbated by competition for skills and resources from overseas.

11.5 The demand for resources and skills for new electricity generating capacity could well run ahead of supply for a period. This could result in longer delivery times and upward pressure on prices. However, the Government expects the market to increase supply to meet demand. In the meantime, forward planning by industry and placing early contracts well in advance for resources will ease pressure. The Government is committed to working with industry to develop the skills that the energy sector will need irrespective of whether we build new nuclear power stations.

## Global perspectives

11.6 Around the world, power stations are ageing with much of the nuclear capacity in the second half of its working life. Most coal- and oil-fired power stations – which are, in capacity terms, four times larger than the nuclear fleet – are old and inefficient. Many of them will also have to close in line with European environmental legislation or because they are coming to the end of their working lives. Only gas-fired combined cycle gas turbine (CCGT) power stations are relatively young, with the first generation built in the 1990s.

11.7 The DTI analysis suggests that, worldwide, operators will need to treble their investment in generating capacity over the levels of recent years[319]. The Stern report on the economic implications of climate change[320] suggests that we will need to increase the deployment of low-carbon technologies by a factor of two to five to meet the global targets for carbon reduction. To meet

317 Department for Education and Skills – *STEM Programme Report* http://www.dfes.gov.uk/hegateway/hereform/stem/programmereport.cfm and DTI *Science and Innovation Investment Framework 2004-2014 Next Steps* http://www.dti.gov.uk/science/science-funding/framework/next_steps/page28988.html

318 Cogent Sector Skills Council Labour Market survey, 2005

319 DTI research based on data from sources such as the IEA, IAEA and US Department of Energy

320 HM Treasury, Stern Review on the Economics of Climate Change, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

this demand, the skills base and supply chain will have to grow significantly at every level and across the entire energy sector. The Government estimates that the UK will require 30-35GW of new electricity generating capacity over the next two decades, with two thirds of this by 2020. While this is relatively large, it represents only around 1% of global demand. Worldwide supply and demand will therefore heavily influence the ease or difficulty of building electricity generating capacity of any sort in the UK.

## Skills and supply chain

11.8 A nuclear power station project requires engineering skills and suppliers in six areas:
- engineering and services;
- the nuclear island;
- the conventional (or turbine) island;
- control and data acquisition;
- the spent fuel interim storage facility; and
- the balance of plant.

11.9 Most of the skills and resources necessary to build new nuclear power stations are generic to large engineering projects[321]. The specialist skills and resources required are those related to the nuclear island, and to operating the plant safely and securely once it has been built.

11.10 While global demand and competition from other major infrastructure projects might create shortages for non-nuclear skills and resources, the long lead times associated with nuclear build allow for forward planning by industry. For example, placing orders in advance to secure slots for the manufacture of certain components, or training and recruiting should mitigate such risks. However, there are pinch points in some areas of skills and resources that are specific to nuclear power: for reactor vessels and forgings, for example.

### Engineering and services

11.11 An important component of any major project comes through engineering and services. This covers everything from the technology package or design of the project, licensing, engineering design, project management, specialised consultancy, construction management and construction plant and services. Overall, there are potential risks at various links in the supply chain for engineering and services, but as discussed below, there are strategies that private sector developers would be able to deploy to manage them.

11.12 The technology package is the responsibility of the technology vendor of the nuclear reactor design. The vendor would normally also provide a dedicated team to supervise each project. The number of simultaneous projects that a vendor can undertake depends on its ability to provide these teams. Vendors are already increasing their staff levels to meet the growing demand for projects. Forward planning and contracting resources ahead of time can reduce the risk of delays due to demand exceeding supply.

321 The House of Commons Trade and Industry Committee report (New Nuclear? Examining the issues p 26) identifies that construction of a nuclear power plant comprises 55% plant and equipment, 30% civil engineering and 15% project management.

11.13 The UK has world-class strengths in engineering design, project management, procurement and construction management together with specialised consultancy in engineering, legal, financial, planning and environmental services. This resource is in worldwide demand. While this capacity could be overstretched, the developers of any new power station can mitigate this risk by forward planning.

11.14 A new nuclear power station would require around 2% of the UK's national construction capacity, this is well within the normal levels of variation of demands placed on this capacity[322]. Engineering construction to install the plant and equipment is an area of concern when it comes to resources. This is largely because this specialised workforce is shrinking as retirement takes its toll. At the same time project activity is increasing sharply. The Engineering Construction Industry Training Board is working with its client industries to increase recruitment and training. Bringing in labour from overseas is also an option available to the private sector.

11.15 Construction plant and services, such as heavy-lift cranes or off-site construction of modules, are in short supply and need to be booked well in advance. This sector may also require investment to increase capacity.

## Nuclear island

11.16 The nuclear island comprises the reactor vessel (sometimes called a pressure vessel), the primary coolant circuits that transfer heat from the reactor to raise steam for the turbines, steam generators, pumps and, for a Pressurised Water Reactor (PWR), a pressuriser vessel.

11.17 The reactor vessel and its head closure come from a small handful of manufacturers worldwide, who, in turn, rely on a small number of forgeworks to supply components. These factories also make replacement parts and must service life-extension programmes at the same time as they cater for new nuclear power stations. Even if industry in the UK built no new nuclear power stations, the global demand for new reactors will increase, requiring extra capacity.

11.18 Where demand exceeds supply, a lag in capacity could well persist for some years. This will result in longer delivery times and upward pressure on prices. However, the nuclear island accounts for only a small part of the overall cost of the station and thus price rises would not be expected to significantly affect the overall economics of a project. Forward planning and securing manufacturing slots ahead of need could help to manage these delays.

11.19 The primary circuit and its components for Sizewell B, including pipework, pressuriser, steam generators, pumps and valves, were manufactured in the UK. Most of these suppliers still have manufacturing in the UK although it would need investment by them to recover their capability[323]. Whether companies make this investment will depend on their perception of the market. However, there are alternative manufacturers elsewhere in the world, but a risk remains that demand could exceed supply.

322 Nuclear Industries Association *The Capability to Deliver a New Nuclear Build Programme.* http://www.niauk.org/position-papers.html and House of Commons Trade and Industry Committee report. New Nuclear? Examining the issues. pp 26
323 Information provided to the DTI by manufacturers.

11.20 The nuclear island sits within the containment building, the most visible aspect of a nuclear power station. It consists of a steel liner, usually just under 5-cm thick, covered by reinforced concrete. This is a specialised plate produced in mills that are busy with bulk orders for other, non-nuclear projects. They might be reluctant to stop production to make a relatively small amount of special material. As demand rises, the market can be expected to make it attractive for mills to produce the plate. The containment liner for Sizewell B was fabricated in the UK and the manufacturing capability still exists.

## Conventional island

11.21 The conventional island consists of the steam circuit, steam turbines, alternators, re-circulating pumps, condensers and cooling circuit, plus the heavy electrical switchgear and transformers that export the power. This equipment is very similar to that used in fossil fuel power stations, thus the market is driven by demand from the much larger fossil fuel sector. The market is polarised between the 50 Hz supply (Europe, China) and the 60 Hz supply (North America, Korea). This limits supply chain flexibility.

11.22 The UK no longer manufactures steam turbine/alternator equipment for new electricity generation plant, although it does manufacture replacement equipment. The new power stations that are expected to be built in the next decade in the USA are likely to take up all the North American capacity. It is therefore likely that equipment for any new projects would come from Europe or Japan. To meet forecasted demand, industry needs to increase its capacity, including in the sub-supply chain for these individual components, such as blade and rotor forgings.

11.23 The UK has lost 70% of its manufacturers of transformers and switchgear since 1990[324]. However, those that remain are high quality and internationally competitive. There is also limited capacity in cable manufacturing. There is scope for private sector developers to source these components internationally and to increase manufacturing capacity at home and abroad. The exception is for very large transformers – those that convert the output from the alternator to the voltage required for the transmission line – where a significant increase in demand could expose weaknesses in the small global manufacturing base. Diesel generators, to provide power for start-up and shut-down, might also be on long delivery. There could also be capacity problems in the sub-supply chain for these individual components, including steel for transformers and sulphur hexafluoride for switchgear, which could limit output.

11.24 As with the nuclear island, equipment supply may lag demand, but market forces should improve the output, while forward planning and securing manufacturing capacity ahead of time could also pre-empt pressures on extended delivery and pricing. It is important to note that other types of power station would also feel the pressure of delays in supplies for the supply chain for the conventional island.

324 Data from the British Electrotechnical & Allied Manufacturers Association

### Control and data acquisition

11.25 Control systems of the past were bespoke, hard-wired and manufactured for their particular application. Modern control technology relies more on software, embedded in standard hardware and connected by standard interfaces. Technology vendors often specify control systems and perhaps preferred suppliers. A range of suppliers can produce the underlying hardware and there is no indication of any major supply constraints in the market.

### Spent fuel interim storage facilities

11.26 The storage of spent fuel facilities is a civil engineering project. Comparable plant is under construction as part of the UK's nuclear decommissioning programme. The UK supply chain can design and construct such facilities. There is no indication of any major supply constraints in the market.

### Balance of plant

11.27 The remaining facilities – workshops, stores, canteen and offices – are routinely delivered in the UK across major projects ranging from power stations to petrochemical works. There might be problems in the supply chain if a lot of other projects were underway at the same time, but industry can manage this by forward planning.

## Nuclear R&D and specialist skills

11.28 Estimates suggest that around 56,000 people work in the nuclear industry in the UK, about 40,000 of them are in science, engineering and technology occupations. The current skills status of the nuclear industry is generally sound[325] although there are skills gaps[326]. The Sector Skills Council is working with the industry to address these. In 2002, Government identified that, while there was no immediate overall nuclear skills shortage, measures were needed for the UK to maintain its ability to deliver these skills[327]. Potential skills shortages are emerging in a few specialisations such as project management, and specialists in nuclear safety and instrumentation or system.

11.29 If private sector companies in the UK proposed to build new nuclear power stations, industry would have to strengthen its skills base in science, engineering, project management and on-site trade/technician skills base[328]. During the construction of any new nuclear power stations, industry must also train a new workforce that can operate the plants.

11.30 Alongside industry's own initiatives, the Government and universities are working through the Sector Skills Councils, National Skills Academies, academic partnerships, and Research Councils, with industry to address the potential skills shortages in research.

325 Cogent, *Sector Skills Council Labour Market survey, 2005*, http://www.cogent-ssc.com/industry/nuclear/LMI_reports/index.php
326 Cogent, *Skill Needs Assessment for the Nuclear Industry,* http://www.cogent-ssc.com/industry/nuclear/LMI_reports/index.php
327 DTI/MoD, *Nuclear and Radiological Skills Study: Report of the Nuclear Skills Group*, http://www.dti.gov.uk/files/file23309.pdf
328 Cogent, *Nuclear Employers Survey 2005*, http://www.cogent-ssc.com/research_and_policy/LMI_and_reports/Nuclear_Employers_Survey.pdf

## Cogent and the National Skills Academy for Nuclear

11.31 Government has invested in the network of Sector Skills Councils – bodies that are led by their industry sectors to champion their skill needs and to influence the delivery of relevant training. Cogent, one of these Sector Skills Councils was set up in 2004 to take a develop a strategy for skills development in the nuclear sector. It set out to ensure that the education and training base can meet the nuclear industry's current and future needs. Cogent is working with the Engineering Construction Industry Training Board and industry to tackle the need for suitably qualified and experienced people skilled in project management, project control, nuclear science and engineering and environmental science.

11.32 Cogent is developing, with the industry, a Sector Skills Agreement[329]. This is based on recent research and will set out the strategy to address existing and potential skills gaps and shortages. The objective is to secure the range and level of skills necessary for the nuclear industry to achieve productivity at international levels. The agreement will:

- lead to better planned and more integrated delivery of skills training;
- help to produce credible, cost effective, quality assured and better tailored training provision;
- help to target public funding more effectively; and
- encourage employers to invest more in developing their workforce.

11.33 Cogent successfully applied for funding to create a National Skills Academy for Nuclear (NSAN) in October 2006. The employer-led NSAN will seek to deliver a coherent skills strategy that will address the needs of the wider nuclear industry, including decommissioning and power generation. The success of the application for the skills academy demonstrates that industry has put forward a clear plan for tackling long-term skills needs, together with a strong proposal for joint investment with the Government. The industry has now entered the detailed planning stage to determine the precise types of training needed, in the volumes required by the industry, and delivered through a network of providers that can be hand-picked to partner the academy and operate the required standards of excellence. The NSAN is now in the business planning stage.

## The Engineering and Physical Sciences Research Council

11.34 The Engineering and Physical Sciences Research Council (EPSRC) is also investing in research and training in the nuclear sector. The EPSRC is the main UK government agency for funding research and training in engineering and the physical sciences, investing around £650 million a year in a broad range of subjects.

11.35 As part of its "Towards a Sustainable Energy Economy" programme, the EPSRC has awarded a research grant of £6.1 million over four years to a consortium of researchers. It has also provided funding of about £1 million to

329 Sector Skills Development Agency, *Sector Skills Agreement – Consultation draft.* www.ssda.org.uk/default.aspx?page=2528

a "Nuclear Technology Education Consortium" to provide masters-level and continuing professional development training for the nuclear industries. The consortium brings together Imperial College London, the University of Manchester, Cardiff University, University of Sheffield, University of Bristol, University of Leeds and the Open University. The universities are working with BNFL, which has contributed £0.5 million, and other interested parties that include British Energy, the Department for Environment, Food and Rural Affairs, the Environment Agency, the Health and Safety Executive, Mitsui Babcock, the Ministry of Defence, Nirex, AMEC NNC, Rolls-Royce PLC and the UK Atomic Energy Authority.

11.36 The EPSRC has also agreed a future collaboration on research and training activities in nuclear technology and engineering. The first action is a Centre in Nuclear Engineering under the Engineering Doctorate scheme[330], with funding of £5 million from EPSRC and contributions anticipated from private and public sector partners.

## Universities

11.37 In terms of university initiatives, an education, training and research initiative led by the University of the Highlands and Islands (UHI) has been launched in partnership with the University of Aberdeen and the North Highland College. The University of Manchester has established the Dalton Institute which aims to be at the forefront of nuclear education and research.

## The National Nuclear Laboratory

11.38 The Secretary of State announced in October 2006 that, subject to contractual terms being agreed, and the Government expects that there will be a UK National Nuclear Laboratory (NNL). It would be based around the British Technology Centre and Nexia Solutions in Sellafield, West Cumbria. The NNL will take its place in a nuclear research market where its future will be shaped by the demands of customers within industry, public sector and academia. We will conclude as soon as possible the detailed work we have been doing to develop an appropriate organisation structure for the laboratory that will allow it to play a key role in supporting the UK's R&D requirements and ensuring unique skills are safeguarded.

330 http://www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/Funding/TrainedPeople.htm

**The Government believes that the international supply chain and skills market should be able to respond if the Government were to allow energy companies to invest in new nuclear power stations. This view is based on:**

- **the long lead times associated with new nuclear power stations;**
- **the financial incentives for the private sector to meet the demands created by the building of new nuclear power stations; and**
- **the facilitative work that Government, the academic sector and industry are undertaking to support skills development in the relevant sectors.**

**Therefore, the Government believes that the supply of skills and supply chain capacity do not provide a reason to prevent energy companies from investing in new nuclear power stations.**

Question 13
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?

CHAPTER 12

# Reprocessing of spent fuel

## Introduction

**This chapter explores issues related to the reprocessing of spent nuclear fuel. It also sets out the Government's expectation that the UK will not reprocess spent fuel from new build reactors.**

12.1 Nuclear power stations generate energy through the fission of uranium (see chapter one). Depending on the reactor's fuel cycle, operators replace fuel about every 12-18 months. They do this to maintain the efficiency of the fission process. At that stage, the fuel still contains more than 90% of its original uranium (see chapter eight), along with plutonium and a variety of other radioactive materials created in the fission reactions that produce the heat that the power station then uses to generate electricity. There are then several options as to how to deal with the spent fuel, one of which is to reprocess it to recover the uranium and plutonium for reuse.

12.2 This chapter sets out information on:
- open and closed nuclear fuel cycles;
- advantages of reprocessing;
- disadvantages of reprocessing;
- the Nuclear Decomissioning Authority's (NDA) current review of spent fuel; and
- the Government's policy on reprocessing in relation to potential new nuclear power stations.

## Open and closed fuel cycles

12.3 There are two options for nuclear fuel cycles: open and closed. In an open fuel cycle, spent fuel is disposed of directly, or in some cases held in long-term storage so that it is available should there be a later decision to reprocess the material. In a closed nuclear fuel cycle, reprocessing separates out the useful uranium and plutonium from fission products. Fuel can be reprocessed in this way to provide the raw materials for the manufacture of fresh, typically MOX (Mixed Oxide) fuels. Alternatively, operators may reprocess spent fuel for safety and environmental reasons. For example, there is no proven alternative to reprocessing fuel from Magnox power stations, which cannot be stored in water for the long-term.

12.4 Reprocessing in the UK is viewed by many as controversial. This is principally because of concerns about a number of issues:
- the long-term storage of plutonium recovered in the process;
- the management of associated waste materials, and
- the transport to and from the UK of nuclear material connected with overseas spent fuel reprocessed at the THORP plant at Sellafield.

12.5 There have been questions raised about the long-term economic viability of investments in the THORP plant and supporting plant at Sellafield. People have also raised concerns about plant safety and about historical discharges of radioactive materials into the Irish Sea.

### International perspective

12.6 Several countries have reprocessing facilities. Within Europe, the UK and France operate a closed nuclear cycle: they also reprocess spent fuel for foreign customers. Russia also has reprocessing facilities. After a gap of several decades, the US is considering re-entering the reprocessing market. Japan has a reprocessing plant at Rokkasho to meet its own future needs.

12.7 There are proposals to develop reprocessing techniques that raise fewer concerns about nuclear proliferation. Recently, the US has announced the Global Nuclear Energy Partnership (GNEP) as part of the country's Advanced Energy Initiative[331]. The goal of GNEP is to allow the safe and secure development of nuclear energy worldwide, while reducing the risk of nuclear proliferation. GNEP aims to develop and demonstrate the reprocessing of nuclear fuel in a way that reduces waste without separating out plutonium.

## Advantages of reprocessing

12.8 Operators remove nuclear fuel from reactors because fission products build up, absorbing neutrons that would otherwise take part in nuclear reactions. These neutron losses eventually increase to the point where it becomes impractical to continue to use the fuel. By weight of metal, spent fuel is about 95% uranium-238,1% uranium-235, 1% plutonium and 3% fission products. Typically, a significant percentage of the energy content of fuel remains unused.

12.9 Reprocessing gives nuclear operators a choice as to whether to store spent fuel pending final disposal or to reprocess the fuel, and to recover uranium and plutonium for re-use. Reprocessing can therefore increase the security of supply by recovering more energy from each tonne of uranium.

12.10 Others advantages of reprocessing are that it can minimise the volume of high level waste (HLW). Subsequently, vitrification can then produce a physically stable glass-like waste (see chapter eight). Through its separation of uranium and plutonium from this waste, reprocessing also minimises the quantity of fissile material in the waste product. Income from reprocessing contracts can be substantial and the proceeds can support decommissioning of the facilities needed to carry out the process.

## Disadvantages of reprocessing

12.11 Reprocessing requires high capital investment in major plant and supporting infrastructure such as separation tanks and evaporators, some of which have to be replaced over time to meet regulatory obligations or because of the aggressive chemicals used to dissolve spent fuel. In the UK,

331 http://www.gnep.energy.gov

poor plant performance, relative to similar plant in France, has meant that consistency in the volume of vitrified waste produced from current reprocessing operations has been lower than expected. As a result, the UK has large volumes of waste liquors in storage. This in turn has led to the need for fresh investment to improve throughput. Delays due to plant unavailability have also delayed reprocessing of spent fuel from overseas. This in turn will put back the point at which we can return HLW to these customers.

12.12 Although reprocessing produces less HLW than a once-through cycle, it increases total waste volumes. For example, it creates more intermediate level waste (ILW) because the higher radioactive material comes into contact with a large amount of plant in the reprocessing facility which in turn will need to be managed as waste.

12.13 Reprocessing at Sellafield results in discharges to the Irish Sea. Compared to the 1970s, these are now at historically low levels. These releases have a very low environmental impact in line with discharge limits set by the Environment Agency. Reductions in discharges at Sellafield have only been possible by substantial investment in new plant. Despite stringent regulatory controls, such discharges remain controversial.

12.14 Reprocessing in the UK for overseas customers requires spent fuel to be transported through the Irish Sea to and from Sellafield. These continue to be of concern to other countries, particularly Ireland, although such transports have a very good safety and security record.

## NDA's current review of spent fuel

12.15 The UK's Nuclear Decommissioning Authority, which is responsible for the country's existing nuclear legacy, is due to complete a review of spent fuel management in the first half of 2007. Government policy decisions taken in light of this review will set out the requirements that developers of new nuclear power stations will have to meet. This will include clarity on the need to provide onsite storage of spent fuel for the lifetime of the power station or some alternative strategy.

12.16 The Government's current assumption is that spent fuel from any new nuclear power stations would be treated as waste. There should be on-site storage for an appropriate period, prior to placing the spent fuel in a geological repository.

## The Government's policy on reprocessing in relation to potential new nuclear power stations

12.17 As the Government has received no proposal for reprocessing it has concluded that any new nuclear power stations that might be built in the UK should proceed on the basis of a once-through cycle, with spent fuel disposed of as a waste. This is consistent with our assumptions on waste and decommissioning (see chapter eight).

**The Government has concluded that any nuclear power stations that might be built in the UK should proceed on the basis that spent fuel will not be reprocessed and that accordingly waste management plans and financing should proceed on this basis.**

### Question 14
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?

CHAPTER 13

# Proposals for Government facilitative action

## Introduction

**This chapter sets out the action that the Government would undertake should it conclude, after consultation, that energy companies should be allowed to invest in new nuclear power stations in the UK. These actions include improvements to the planning process to remove uncertainties and inefficiencies. Alongside this in-principle consultation, there is a linked technical consultation on the details of running a Justification process and a Strategic Siting Assessment.**

13.1 The Government is not proposing to build nuclear power stations. If we conclude that energy companies should be allowed to invest in new nuclear power stations, the Government would carry out a package of facilitative action as we have also carried out for other generation technologies[332] designed to reduce the regulatory and planning risks associated with investing in nuclear power stations. The package of measures is designed to reduce the uncertainties in the pre-construction period for new nuclear power stations through improvements to the regulatory and planning processes. The measures will also set out arrangements for the funding of decommissioning and waste management and disposal.

13.2 This chapter sets out information on:

- why facilitative action is necessary;
- what facilitative action the Government proposes to take;
- information on the specific proposals; and
- work that is happening alongside this consultation on a contingent basis.

## Why is facilitative action necessary?

13.3 Nuclear power stations have long lead times and require major capital investment (see chapter four). To proceed in a competitive market, investors have to be confident that the regulatory requirements are clear and that decision making is timely. If the Government were to conclude that energy companies should be allowed to invest in new nuclear power stations, it would be necessary to undertake facilitative action to reduce this investor uncertainty before it is likely that private sector energy companies would bring forward proposals. The nature and scope of the action that would be needed is a factor in assessing the case for nuclear power.

332 For more details of all our energy policies see the Energy White Paper http://www.dti.gov.uk/energy/whitepaper

13.4 The report of the 2006 Energy Review, "The Energy Challenge", set out the difficulties that developers would face in the UK before they can start to build new power stations. In the past, there has not been clarity on when the regulatory and planning processes would consider issues relating to the construction of a nuclear power station. A number of these issues are regulatory in nature, for example the safety of the design for a nuclear power plant.

13.5 Respondents to the Energy Review consultation, and the subsequent consultation on Nuclear Policy Framework in July 2006, commented that they would not invest in nuclear power stations unless there was action to reduce the regulatory risks[333].

## What facilitative action is Government proposing?

13.6 The objective of our facilitative action is to reduce the regulatory uncertainty and risk associated with investing in nuclear power stations. We propose to achieve this by:

- improving the energy planning system for nuclear power stations by ensuring it gives full weight to national, strategic and regulatory issues that have already been the subject of discussion and consultation, rather than reopening them. In developing these proposals we will obviously need to take account of any areas in which the Devolved Administrations have competence;
- running a process of Justification (in accordance with the Justification of Practices Involving Ionising Radiation Regulations 2004) to test whether the economic, social and other benefits of specific new nuclear power technologies proposed outweigh the health detriments;
- running a Strategic Siting Assessment process to develop criteria for determining the suitability of sites for new nuclear power stations. Subject to some European legislative requirements, this would limit the need to discuss in detail the suitability of alternative sites for nuclear proposals during the planning process;
- taking further our consideration of the high-level environmental impacts through a formal Strategic Environmental Assessment (SEA) in accordance with the SEA Directive[334]. This would limit the need to consider such high-level environmental impacts of nuclear power stations during the planning process;
- assisting the nuclear regulators, to pursue a process of Generic Design Assessment[335] of industry preferred designs of nuclear power stations, to complement the existing site-specific licensing processes. This would involve assessing the safety, security and environmental impact of power station designs, including waste arisings and radioactive discharges to the environment. This would limit the need to discuss these issues in depth during the site-specific planning process; and
- introducing arrangements to protect the taxpayer by ensuring that private sector operators of nuclear power stations securely accumulate the funds needed to meet the full costs of decommissioning and full share of waste management costs. These arrangements would need to be agreed before proposals for new nuclear power stations could proceed. This would avoid

333 http://www.dti.gov.uk/energy/review/consultation-submissions/page27883.html
334 Directive 2001/42/EC, of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (O.J. L197, 21.7.2001, p.30)
335 This is sometimes referred to generically as "pre-licensing".

the need to discuss in depth during the planning process whether the taxpayer will be exposed to the waste and decommissioning costs of any new nuclear power stations that might be constructed.

13.7 The Government has previously consulted on a similar package of proposals, through the July 2006 consultation on a Nuclear Policy Framework. Because the proposal has been refined, we are consulting again on this issue. If respondents would like us to reconsider their responses to the previous consultation, then they should indicate this in their response to this consultation.

## Improving the energy planning system for nuclear power stations

13.8 In the past, the energy planning process has been the main opportunity for interested parties to engage on all the issues relevant to the construction of nuclear power stations. This has led to inefficiencies, where issues that have already been addressed are considered at every public inquiry held to consider specific projects: for example, of the 340 days at the inquiry into the Sizewell B power station, 150 were devoted to the safety of the design, even though there was a separate regulatory process that addressed this issue[336]. Many of these issues were then covered again in a subsequent inquiry into a new nuclear power station at Hinkley Point that was of a very similar design.

13.9 The Government has recognised the impact that the energy planning system can have on achieving our energy goals. It recently published proposals for a fundamental reform of the planning system for major infrastructure projects of national importance[337]. The reforms recognise the need to set a clear national case for new infrastructure development, and to set a clear framework for making decisions on individual proposals.

13.10 A key component of the reforms proposed in *Planning for a Sustainable Future* is the creation, by 2009, of an independent Infrastructure Planning Commission (IPC). The IPC would manage inquiries and take decisions on applications for nationally significant infrastructure projects, including major energy projects, above statutory thresholds, as well as projects designated to it by National Policy Statements or Ministers. Under these proposals, there would be three main phases for the new planning system for nationally significant infrastructure projects:

- **The strategic phase.** The Government would produce National Policy Statements which would establish the national case for infrastructure development and set the policy framework for Infrastructure Planning Commission decisions. The statements would explain how they integrated strategic economic, social and environmental policy objectives to deliver sustainable development. There would be public consultation on National Policy Statements, and an opportunity for Parliament to consider and debate them before they were finally adopted. National Policy Statements

336 Timothy O'Riordan, Macmillan Press, page 228, *Sizewell B: An anatomy of the inquiry* 1988.
337 Planning for a Sustainable Future, http://www.communities.gov.uk/planningwhitepaper

would be the primary, but not the only consideration for the IPC in determining applications for development consent for nationally significant infrastructure projects;

- **The project development phase.** An active pre-application phase that would provide greater certainty for promoters of infrastructure projects and will help ensure all developers more thoroughly prepare applications by:
  - making better advice available to them;
  - requiring them to consult publicly on proposals for development; and
  - by encouraging early and effective engagement with key parties such as local authorities and statutory bodies.
- **The decision-making phase.** The IPC would then examine and take decisions on applications for development consent for nationally significant infrastructure projects, within the framework of the relevant national policy statement. The White Paper, *Planning for a Sustainable Future*, envisages that, other than in exceptional cases, the IPC would work to a statutory time limit of nine months for its examination and decision: six months for examination of the project and three months for determination.

13.11 If we conclude that energy companies should be allowed to invest in new nuclear power stations, then we propose developing a National Policy Statement that would cover the construction of nuclear power stations, which would be subject of public consultation. This would establish:

- the national case for new nuclear power stations, in the context of tackling climate change and contributing to secure supplies of energy, and how this could be achieved in a way which integrated economic, environmental and social objectives to deliver sustainable development;
- the Government policy on a number of generic issues (reflecting the topics addressed in this consultation document), and how the Government's objectives for the sector had been integrated with other specific government policies, including other National Policy Statements;
- criteria that determine the locations where the Government would support the construction of new nuclear power stations, and an indication of certain locations that met these criteria;
- an assessment of the strategic environmental impacts of the construction and operation of new nuclear power stations; and
- the Government's policy on whether the benefits of generating electricity from certain designs of new nuclear power stations outweigh the specific health detriments.

13.12 We would develop and consult as appropriate on this National Policy Statement once we have completed the Strategic Siting Assessment process in order to incorporate the outputs of this process. The power to consent to the construction of power stations has been executively devolved to Scottish Ministers and it is also devolved in Northern Ireland. In developing the National Policy Statement we will need to take account of any areas in which the Devolved Administrations have competence, for example Scottish Ministers will continue to take any planning permission decisions for new nuclear power station proposals.

13.13 In the event that there are delays to the implementation of the reforms to the planning system, we will consider other options to make clear the national case for new nuclear power stations.

## Justification

13.14 Nuclear power stations use radioactive materials and are therefore subject to stringent regulatory requirements regarding their design and operation. It is an internationally accepted principle of radiological protection that no practice involving exposure to ionising radiation should be adopted unless it produces sufficient benefits to the exposed individuals or to society in general to offset the health detriment it may cause[338].

13.15 This decision comes under a process known as Justification. It is one of a number of statutory regulatory or license clearance processes. It does not, by itself, authorise the construction or operation of any particular plant or activity, nor does it replace the detailed safety, security and environmental assessments carried out by the nuclear regulators.

13.16 It is a high-level assessment, which is not site-specific, to determine the benefits and detriments associated with a particular class or type of nuclear practice. Before a new class or type of practice can be introduced into any European Member States, including the UK, it must be justified, i.e. a decision must be taken by the relevant Authority that the benefits of its introduction would outweigh the health detriment[339]. It is not necessary to show that the class or type of practice is the best of all available options, but instead that there is a net benefit.

13.17 If the Government were to confirm its preliminary view on new nuclear, it will issue guidance on how the Justification process will be applied to new nuclear power stations. This guidance would include details of plans to publish applications and to consult interested parties, the nuclear regulators and other statutory consultees and the public on a draft decision document.

13.18 The Government's current preference is to invite applications on the Justification of new nuclear power stations in early 2008, although applications can be made at any time. The Justifying Authority for civil nuclear power is the Secretary of State (and in this case the Secretary of State for Trade and Industry will be responsible for reaching a Justification decision). Based on our current proposals, it is expected that the Justification process for new nuclear power stations would run from early 2008 to 2009.

338 Council Directive 96/29 Euratom of 13 May 1996 laying down basic safety standards for the protection of health of workers and the general public against the dangers arising from ionizing radiation (O.J.L 159 29/06/1996 p.1).
339 Pursuant to Council Directive 96/29 EURATOM of 13 May 1996.

13.19 There are some specific consultation questions on our proposed approach in the accompanying consultation document on the detail of Justification. These cover the proposed structure of the Justification process, the indicative content of an application, and the proposal to consider concurrent applications in a single assessment.

## Strategic Siting Assessment

### Develop criteria for suitable sites for new nuclear power stations

13.20 Some of the issues relating to the siting of nuclear power stations are national in nature, rather than site specific. Since the mid 1950s, successive Governments have made a number of policy statements relating to nuclear power plant siting. There are also regulatory issues in relating to siting that are reflected in the HSE/NII Safety Assessment Principles (SAPs)[340], which are set at a national level.

13.21 The purpose of the Strategic Siting Assessment (SSA) would be to identify siting criteria that would assist developers in identifying potential locations where the Government would support the development of new nuclear power stations. The siting criteria, to be developed as part of the SSA, would take account of the technical safety considerations set out in the SAPs to ensure consistency between the two where appropriate. However, the purpose of the SSA would be to look at a broad range of strategic factors that go beyond the technical safety considerations. These criteria would then be used to assess the suitability, at a strategic level, of any sites nominated for new nuclear power stations. Such criteria could include, for example, over-arching environmental and infrastructure issues.

13.22 It is intended that the SSA would also indicate areas of the UK within which there are sites which meet the criteria. The SSA would provide the opportunity to consider the broad suitability of sites before the planning inquiry. The SSA would provide guidance to the planning regime, making it clear that, in areas meeting the criteria, the strategic case had already been established for new nuclear power stations. This would then enable local planning inquiries to focus on local issues relating to any proposed site. Based on our current proposals, it is expected that the SSA process for new nuclear power stations would run from early 2008 to 2009.

13.23 There are some specific consultation questions on our proposed approach in the accompanying consultation document on the detail of the SSA. These cover the proposed structure of the Strategic Siting Assessment process, the relationship with Strategic Environmental Assessment Directive[341], and the relationship with the planning process.

340 HSE (2006) Safety Assessment Principles for Nuclear Facilities
341 Directive 2001/42/EC of 27 June 2001 on the assessment of the effects on the environment of certain plans and programmes, on the environment (O.J. L197, 21.7.2001, p.30)

### High-level Strategic Environmental Assessment

13.24 The Government recognises the need for a strategic assessment of the environmental issues relating to new nuclear power stations. Therefore, we propose to integrate a Strategic Environmental Assessment (SEA), under the European SEA Directive[342] into the SSA process.

## Generic Design Assessment

13.25 As part of the 2006 Energy Review, the Government asked the nuclear regulators – the Health and Safety Executive (HSE), the Environment Agencies and the Office for Civil Nuclear Security – to consider the potential contribution that generic assessments of candidate designs of nuclear power stations could make to reducing the risk and uncertainty associated with investing in nuclear power, while ensuring that industry continues to sensibly manage the associated risks.

13.26 Following the 2006 Energy Review, the Government requested the regulators to introduce a system of Generic Design Assessment. The HSE, along with the other nuclear regulators, published new guidance material on the process in January 2007[343]. Under the new system, the regulators will consider whether generic safety, security and environmental aspects of power station designs were acceptable in advance of making their site-specific assessments. As with existing site licensing and other authorisations, private sector applicants would meet the costs of Generic Design Assessment.

13.27 Generic Design Assessment will reduce the regulatory risk by providing the regulators with the opportunity to assess the generic elements of the design of a nuclear power station before developers have to commit significant investment in site-specific proposals. After a design has undergone a successful Generic Design Assessment, the regulators will take full account of their previous assessments. Subsequent site-specific assessments will therefore be significantly shorter and more predictable[344].

13.28 Developers should have confidence that if a power station design has gone through a successful Generic Design Assessment, the regulators are unlikely to require significant design modifications at the site-specific licensing stage. This will reduce the risks of delays at this stage, by which time the developer has to make significant investments in components and financing arrangements.

13.29 Generic Design Assessment will also provide benefits for the nuclear regulators, because it should allow for better resource management: they will not need to reconsider the generic aspects for every proposal that might come forward.

342 Directive 2001/42/EC on the assessment of the effects on the environment of certain plans and programmes.
343 http://www.hse.gov.uk/nuclear/reactors/guidance.htm
344 HSE report, *The health and safety risks and regulatory strategy related to energy developments. An expert report contributing to the Government's Energy Review 2006*. EA report, *Pre-licensing assessments of new nuclear power stations and streamlining the regulatory process.*

13.30 Given the limited availability of suitably skilled and experienced regulatory staff to undertake generic assessments and the need to make progress now in tackling climate change, the first stage in this new regulatory process is for industry to identify the priority designs on which it would like the regulators to focus their resources.

13.31 The regulators have identified that they should be able to manage assessment of three designs concurrently and that the process should take approximately three years. It is expected that the regulators will be able to begin their assessments on a contingent basis alongside this consultation.

## Framework for nominating reactor designs and identifying industry preferences for the first tranche of Generic Design Assessment (or "pre-licensing")

13.32 In line with the market approach to energy policy, it is the Government's objective that, if we decide to go ahead with new build, potential operators of new nuclear power stations in the UK should have a choice of viable designs available to them. Viable designs will be considered to be those which have been subject to Generic Design Assessment (or pre-licensing) by the UK regulators. If nuclear power is to play a role in addressing the "energy gap" which will open in the time-period 2016-2022, viable designs for the UK would need to be identified by 2010-2011 (in order to allow sufficient time for subsequent site-specific permission and construction). However, due to resource constraints, the regulators can assess only a limited number of designs in the 3-3½ year period leading to 2010-2011.

13.33 The objective of this operator preference-based framework is therefore to allow the regulators to focus their resources on those designs which would be most likely to be licensed and operational in the UK within the 2016-2022 timeframe.

13.34 Any work relating to pre-licensing carried out during the nuclear consultation period will be done on a contingent basis and is subject to the outcome of that consultation; any money spent on this process by the industry will therefore be at its own risk.

### Identifying possible reactor designs for new nuclear build in the UK

13.35 The Government is now inviting applications from vendors of nuclear reactor designs who are interested in having their design assessed through the Generic Design Assessment process.

### Stage 1: Entering phase 1 of Generic Design Assessment – Fundamental Review

13.36 Vendors have one month, until 22 June 2007, to send letters to the regulators' Joint Programme Office (4N2 Redgrave Court, Merton Road, Bootle, Merseyside, L20 7HS), nominating the designs for which they intend to seek Generic Design Assessment in the UK. Vendor nominations submitted after this one month period will not be considered in the initial tranche of designs to be assessed in this 3–3½ year period, though they could be considered in any subsequent tranches of Generic Design Assessment.

In their applications, vendors must:
a) State that their proposed design will be deployable in the UK such that it could start generating electricity on a commercial scale (with a capacity in excess of 50MW) by 2016-2022; and
b) Provide a letter of endorsement from a credible nuclear power operator which states that the operator considers that the design is a serious contender for deployment by that operator in the UK by 2016-2022.

A credible nuclear power operator is one which:
1. Currently operates a nuclear power station anywhere in the world; and
2. Has made a commitment to become or continue to be an operator of an electricity generating station (with a capacity in excess of 50MW) by 2016-2022 in a market subject to UK health and safety and environmental regulation.

13.37 The purpose of the requirement for any proposed reactor design to be supported by a credible nuclear power operator is to ensure that limited regulatory resources will not be diverted onto designs which have no reasonable prospect of being deployed by an operator in the 2016-2022 timeframe.

13.38 The regulators will pass the application letters to the DTI, who will verify that the applications meet the specified criteria and are therefore eligible for phase 1 of Generic Design Assessment. This first phase, which is expected to last until around the start of 2008, includes a fundamental safety and environmental overview of the reactor design and an initial, broad assessment of whether a design is potentially licensable in the UK. The presumption would be that all those applications which meet the criteria would commence assessment through phase 1 of Generic Design Assessment. The regulators will also be able to seek independent advice, or take into account any other relevant factors, in deciding how to allocate their resources.

13.39 The applications and letters of endorsement will be made public.

## Stage 2: Entering phase 2 of Generic Design Assessment – Detailed Review

13.40 Phase 2 of Generic Design Assessment encompasses the majority of the detailed assessment work on the designs and would be expected to run from early 2008 until 2010-2011. As this phase is more demanding on regulators' limited resources, it is unlikely that more than three designs could be assessed concurrently within the specified timeframe. Consequently, if more than three designs remain viable following the first phase of assessment, then a second prioritisation process will need to be run to select no more than three designs to proceed to phase 2. This process will not happen until after the Government has reached a conclusion, following this consultation, on whether energy companies should be allowed to invest in new nuclear power stations.

13.41 This second prioritisation will take account of the designs' likelihood of being deployed in the UK by 2016-2022. We will announce the detail of how this prioritisation process would operate in due course.

## Waste and decommissioning regulation

13.42 If energy companies are allowed the option of investing in new nuclear power stations, it is the Government's policy that there must be a robust framework to ensure that owners and operators of such stations accumulate funds to cover the full costs of decommissioning and their full share of long-term waste management and disposal costs.

13.43 To enable the estimation of the potential costs of waste management, and ensure adequate provision for their financing, we will set out a route for waste storage and disposal. This route – or base case – will build on existing policy but will need to include assumptions where uncertainties exist. Operators of any new nuclear power stations will need to have regard to the provisions in the base case when developing their waste and decommissioning plans, although there will be flexibility to allow companies to propose more effective/efficient ways of dealing with waste if they choose to do so. After meeting the requirements of the safety, environment and security regulators, each operator's waste and decommissioning plan will need to be subject to additional Government approval to ensure that it includes all the elements for which the Government considers that financial provision should be made. Once approved by the Government, the operator is obliged to follow the plan, although amendments can be made subject to Government approval, in addition to that of the regulators as appropriate. The Government's proposals around the base case are explored further below.

13.44 As prefaced in the Energy Review Report, in January 2007 the Government appointed an individual with senior financial experience of major capital investment projects to lead the development of arrangements for the costs, financing arrangements and other commercial matters associated with new build decommissioning and waste management.

13.45 Dr Tim Stone has since been appointed. He reports to the Secretary of State for Trade and Industry and the Chief Secretary to the Treasury. He is supported by officials from the DTI and HM Treasury and is leading discussions with industry on these topics and will make proposals based on the principles set out in the Energy Review report.

13.46 The arrangements that the government will put in place will provide important clarity to potential developers of nuclear power stations both on the costs of waste and decommissioning in a UK context, but also how they should finance them. This will be important for developers in making financial assessments of potential new nuclear power station proposals, making it possible to take a more accurate view on the profitability of such investments.

## Financing arrangements to protect taxpayer against liabilities from new nuclear power stations

13.47 To be satisfied that the arrangements are sufficiently robust, even in the event of insolvency or early decommissioning of the power station before the fund is mature, the Government proposes to establish the financing structure in legislation. This legislation would be presented to Parliament at an early opportunity and be subject to Parliamentary scrutiny in the usual way.

13.48 Such legislation would set the framework, allowing Government to place certain new requirements and duties on potential developers. For example, such legislation could set out:

- a requirement on prospective owners/operators of a new nuclear power station to provide a funding arrangement plan to Government for approval;
- the power for Government to set out what an approvable funding arrangement plan must include;
- a duty on the owners/operators of a new plant to comply with this approved plan;
- the creation of sanctions should owners/operators not comply with the terms of an approved plan; and
- a power to make regulations setting out the detail of how the arrangements would work.

13.49 If, after this consultation, Government decides that energy companies should be allowed to invest in new nuclear power stations, it would consult on detailed proposals for ensuring these costs are covered by owners/operators, in the form of draft regulations. Draft regulations, setting out the detail of how the arrangements would work, could cover:

- the governance arrangements for the fund or funds;
- how the payments to the fund or funds would be scheduled;
- how the performance of the fund or funds would be monitored and audited; and
- any additional safeguards required to guarantee that the fund or funds are sufficient to cover costs.

13.50 There are a number of ways in which a fund could be structured to ensure that adequate funds to meet the costs of decommissioning and waste management and disposal would accumulate over the operating life of a new nuclear power station. One or a combination of these approaches could be adopted. These approaches include:

- the owners/operators of a power station are required to accumulate funds in a ring-fenced, separable, designated form, though the assets are still held within the company itself;
- the owners/operators are required to make specified payments to a designated Government controlled entity or direct to an Exchequer fund or account; and,
- the owners/operators are required to make payments to a separate, independent fund or funds held by a body or bodies, such as a trust.

13.51 Of these broad options, the Government prefers the third approach. Under this option, owners/operators of new nuclear power stations would be required to make regular payments to one or more separate, independent bodies or funds throughout the operational life of the station. The funds would be there to meet the costs of an approved decommissioning and waste management plant. This approach would be transparent and would result in a fund which is insulated against the commercial fortunes of the operator. For example, if the operator were to become insolvent, an independent fund would be less accessible to creditors than a fund controlled by the operator itself. Furthermore, under this approach, financial provisions would be held as "real money" investments which could be liquidated reasonably readily to provide funding as required to discharge the liability.

## Cost estimates and a base case for decommissioning and waste management

13.52 To ensure that the Government can have confidence that owners/operators of new nuclear stations would meet the full costs of decommissioning and their full share of waste management costs, it will be important to have a better understanding of the likely costs of waste and decommissioning. It is the Government's intention that work to determine robust estimates of costs will support the development of a funding structure.

13.53 Cost estimates will be built up through an understanding of the drivers behind the costs. It will be important for these cost estimates to take into account the level of uncertainty attached to some of these drivers, in particular the uncertainties related to the costs of geological disposal.

13.54 In the case of decommissioning, when developing the costs of dismantling modern reactors and providing interim storage until the point that waste is ready for emplacement in a repository, the Government will draw on experience both in the UK and abroad and on information from companies that design, operate and dismantle nuclear stations.

13.55 To enable the estimation of the potential costs of waste management, and ensure adequate provision for their financing, we will set out a route for waste storage and disposal. This route – or base case – will build on existing policy but will need to include assumptions where uncertainties exist. The Government will work with the NDA in developing this base case.

13.56 Operators of any new nuclear power stations will need to have regard to the provisions in the base case when developing their waste and decommissioning plans, although there will be flexibility to allow companies to propose more effective/efficient ways of dealing with waste if they choose to do so. As well as meeting current regulatory requirements, each operator's waste and decommissioning plan will need to be subject to Government approval to ensure that it includes all the elements for which financial provision will need to be made. Once a plan is approved, the operator will be required to follow it, although operators can amend the plan, subject to Government approval.

13.57 We expect the base case to specify (among other things):

- the arrangements that would need to be in place for handling waste on site;
- the specification of the on-site storage facilities that will need to be constructed;
- how long these storage facilities would need to remain in place;
- the treatment and disposal of low level waste;
- how soon decommissioning would take place after closure; and
- when and on what terms we would assume that waste could be transferred to a geological repository.

13.58 We intend that for the purposes of the base case, we will assume that spent fuel will not be reprocessed, but packaged for geological disposal. We propose consulting on the detail of this base case and the assumptions that need to be made later in 2007 or early in 2008.

13.59 In the case of waste disposal costs, we recognise that there would need to be a mechanism that shares the burden between the existing legacy wastes – including those wastes that will arise in the future from existing nuclear plant and which we are already committed to producing – and the cost arising from any nuclear new build. This reflects the fact that it will be for the public sector to fund facilities for storage and geological disposal for waste that already exists or that existing facilities are already committed to producing. However, we would need to decide what contribution owners of new nuclear plant should make to the total costs of the geological disposal facility to cover the storage and final disposal of their waste. It is the Government's position that they should meet their full share of these costs.

## Proceeding with facilitative action on a contingent basis

13.60. There is a limited window for replacing a significant amount of our existing electricity generating capacity. Energy companies will need to invest in around 30-35GW of new electricity generating capacity – as coal and nuclear plants retire – over the next two decades, with around two-thirds needed by 2020. This is equivalent to about one third of our existing capacity. We know that there is an urgent need to tackle climate change.

13.61. New nuclear power stations have long lead times. This time is necessary to secure the relevant regulatory and development consents which must be obtained before construction can begin, but there is also a long construction period compared to other generating technologies[55].

13.62. New nuclear power stations are therefore unlikely to make a significant contribution to the need for new capacity before 2020. Even with our expectation that the share of renewables will grow, it is likely that fossil-fuel generation will meet some of this need.

13.63. However, beyond that date there are still significant amounts of new capacity needed; for example in 2023 one third or 3GW of our nuclear capacity will still be operational, based on published lifetimes. Given the likely increase in fossil-fuel generation before this date, it is important that as much of this capacity is replaced with low carbon technologies. Nuclear power stations could make an important contribution to this need and make a contribution to our energy security.

13.64. However, without early clarity on the Government's policy, we will foreclose the opportunity for nuclear power because of the long lead times. There will not be a time when climate change and energy policy will stop evolving and adapting. Meeting our energy challenges will require changes to the UK energy system, it is important that we make progress now.

13.65. We therefore believe it is prudent to start working on this facilitative action now, on a contingent basis, so that no time is wasted if we do conclude that nuclear power has a role to play. We will therefore be starting work on some of these activities, in particular on the Generic Design Assessment process and the arrangements for waste and decommissioning funding, on a contingent basis alongside this consultation. We will review whether to continue with this work in the light of the consultation responses.

**While it will be for the private sector to bring forward proposals to build new nuclear power stations, the Government believes that having nuclear power stations as an investment option for energy companies would reduce the risks and costs associated with meeting our energy goals to tackle climate change and ensure energy security. However, as part of its role in creating the right market and regulatory environment to encourage investments that help us achieve our energy goals, the Government is proposing a package of measures to reduce the uncertainties related to investing in nuclear power stations, so that it is a viable and competitive option compared to other forms of electricity generation.**

Question 18
Do you think these are the right facilitative actions to reduce the regulatory and planning risks associated with such investments? Are there any other measures that you think the Government should consider?

ANNEX A

# Partial Regulatory Impact Assessment

## 1. Purpose and intended effect of measure

This impact assessment provides a high level analysis of:

- the potential impact on the UK of giving the option for the private sector to construct new nuclear power stations; and
- the impact of our package of facilitative measures to reduce the regulatory risks that we have proposed to undertake if we conclude that new nuclear power stations do have a role to play in the future UK generating mix.

### 1.1 The Objective

There are two objectives of the proposal:

- to provide clarity to the market on whether nuclear power stations have a role to play in the future UK generating mix alongside other low carbon generating technologies; and
- to set out a programme of actions to create the regulatory conditions whereby nuclear would be a viable option alongside other forms of low carbon generation. This would be done by introducing a number of measures to simplify the regulatory and planning frameworks for building new nuclear power stations. The new measures will not reduce regulatory scrutiny nor reduce the opportunity for public participation in the process.

Securing planning permission and the other necessary consents is a particular regulatory barrier for nuclear power stations. There are a large number of complex and controversial issues that need to be considered. Many of these are of a strategic national perspective or are the subject of consideration and monitoring by a number of independent regulators. The proposed measures would allow for these issues to be addressed in a more efficient way than has been the case previously. This would mean that generic nuclear issues and some regulatory issues will be considered once before proposals go through the planning system, during which more specific and local issues will form the focus of the inquiry.

In the past, issues that had already been considered were reopened at each individual planning inquiry, for example at the Hinkley Point C inquiry into a power station of the same design as that constructed at Sizewell B, the inquiry covered almost the same grounds and evidence, including generic issues such as the safety of the design. The new regulatory framework would make the process for building new nuclear power stations more certain and efficient without reducing any of the regulatory scrutiny.

## 1.2 Background

Following the 2006 Energy Review, the Government has formed the preliminary view that nuclear generation has a role to play in the future UK generating mix alongside other low carbon generation options. We have formed this view following a comprehensive assessment of the issues relevant to the future of nuclear power, in particular waste and economics. In the light of the 2007 High Court ruling, the Government is now consulting on this preliminary view.

The 2006 Energy Review also looked at the impact of the planning and regulatory systems on the UK energy sector and the ability of the market to deliver our Energy White Paper goals to tackle climate change and ensure energy security. Experience has shown that important, large energy infrastructure projects and, in particular, nuclear power stations can suffer long delays in securing planning permission; for example the most recently constructed nuclear power station, Sizewell B, took approximately six years to secure planning permission. It also identified the long lead times and engineering challenge of constructing nuclear power stations.

As well as affecting the timely delivery of projects in the shorter-term, the uncertainty and delay created through the planning system could make the UK electricity sector less attractive for investors, which would mean that even if the Government confirmed that nuclear should be one of the options available to the private sector to invest in, that developers would choose alternative, lower-risk investments[345].

In the 2007 Planning White Paper, the Government has announced proposals for fundamental reform of the planning system for major infrastructure projects. The new system will be based on a suite of National Policy Statements that set out the strategic case for infrastructure development and provide a background against which decisions on whether to grant planning permission would be taken by an independent Infrastructure Planning Commission.

The proposed facilitative work on nuclear, is complementary to the proposed planning reform and it includes plans to develop a National Policy Statement on new nuclear power stations.

## 1.3 Risk Assessment/Scale of the problem

**The risks of meeting our energy policy goals if nuclear is excluded**

Nuclear power currently provides around 18% of our country's electricity supplies and a significant proportion of its baseload capacity. However, a significant amount of generation plant will close over the next two decades. By 2025 10GW of nuclear generation capacity is expected to close. Over the next two decades it is likely that the UK will need 30-35GW of new electricity generating capacity, of which of two-thirds is needed by 2020, equivalent to approximately one-third of current installed capacity.

345 Industry respondents to the Energy Review consultation stated that they would not bring forward nuclear proposals without reform of the planning and regulatory frameworks.

In the UK's electricity market, it is for companies to invest in new power stations within the market framework set down by the Government. Given the number of factors involved, it is impossible to predict the decisions that energy companies might make in their investments over the next 40-50 years. However, analytical modelling allows us to study possible scenarios of the future mix of electricity generation.

If the private sector is prevented from investing in nuclear power, we believe efforts to meet our long-term climate change and security of supply goals would carry a greater risk of failure and, if we were to be successful in meeting our goals, we would do so at a higher cost.

As part of the preparation for the Energy White Paper, the Government has undertaken such analysis. We have used different models, and a range of assumptions covering different time periods, to generate a series of projections. Our analysis has focused on the impact on our energy policy goals of not allowing the private sector to invest in new nuclear power stations in three periods:

- between now and 2020;
- between 2020 and 2030; and
- between 2030 and 2050.

New nuclear power stations have long lead times[346], so the modelling shows that new nuclear generation could make only a limited contribution to new electricity generation capacity in the period up until 2020. Therefore, not allowing the private sector to invest in new nuclear power stations would have a limited affect during the period.

In the period from 2020 to 2030, the results of our modelling suggest that in the medium term, preventing the private sector from investing in new nuclear power stations could increase the risks to our energy security because of its impact on the amount and type of new power stations of any type coming forward. It also shows that the carbon emissions from the electricity sector would be higher because it is likely that other new fossil fuel technologies would replace the existing nuclear power stations that are due to close during this period.

The dynamic investment modelling shows that excluding nuclear power results in less new capacity of any kind being constructed in this period. By 2030, the modelling suggests that we would have about 4GW less total new capacity compared to the equivalent scenario in which new nuclear is allowed as an investment option. The modelling indicates that the amount of spare electricity generation capacity – necessary to meet changes in electricity demand – that is available from 2022 onwards could be about 20% lower on average than under a scenario that includes nuclear technology as an investment option. The modelling therefore suggests that the risks of capacity related supply outages would be higher under the scenario that excludes new

346 Our conservative assumption is that for the first new nuclear power station the pre-construction period would last around eight years (to secure the necessary consents) and the construction period would last around five years. For subsequent power stations it is assumed that the pre-construction period will fall to five years.

nuclear from the generation mix. In addition, the modelling suggests that as a result of the tighter demand supply balance, wholesale electricity prices could be around 4% higher during this period than otherwise.

The generation mix in the scenario where new nuclear is excluded would also result in higher carbon emissions. The modelling suggests that during the period between 2020 and 2030, emissions would on average be 4.2 million tonnes of carbon higher each year when new nuclear power stations are excluded from the mix (in 2030 emissions are 5.6 MtC higher). This result reflects that, in the absence of nuclear, we would be more heavily reliant on carbon emitting fossil fuel based electricity generation. To put this into context, this is equivalent to about 16% of the total carbon savings we project to achieve under our central scenario from all the measures we are bringing forward in the Energy White Paper.

It is more difficult to predict the implications long into the future, in the period from 2030 to 2050. We have used the UK MARKAL-MACRO model to explore future scenarios of the UK's energy and generation mix that would allow us to meet our 2050 carbon emissions reduction goal[347]. There are, however, certain limitations to the MARKAL model: principally it does not take full account of some of the practical issues and costs associated with bringing forward the technologies suggested by the results of the model.

The analysis shows that where new nuclear power stations are not allowed, achieving our 2050 carbon emissions goal would require more effort through other, more expensive, means than the electricity sector to decarbonise the energy system. Emissions from the electricity sector would be higher where nuclear is excluded, by approximately 4MtC in 2050 (or double the amount of emissions expected from the sector by 2050, from 4.5MtC to around 9MtC). The overall costs to the economy of achieving our climate change goal are likely to be larger than when nuclear is unavailable.

Such options could include increased energy conservation measures, energy efficiency measures or greater deployment of alternative low-carbon generation technologies. The modelling shows that in the absence of a major low carbon technology such as nuclear, energy demand would be around 4% lower and electricity demand would be around 8% lower.

In the electricity sector, by excluding new nuclear power stations, we would also need to rely on more expensive technologies, such as wind, to generate electricity. The modelling shows significantly higher levels of renewables generation, around 41% of the 2050 mix, with wind providing around 30% of electricity supplies (about 100 Terawatt hours compared to approximately 14 TWh today). Carbon capture and storage (CCS), which is unproven on a commercial scale, would also have to play a larger role in reducing the UK's carbon emissions, providing up to 41% of the generating mix in 2050.

347 DTI: *The UK MARKAL model in the 2007 Energy White Paper* http://www.dti.gov.uk/energy/whitepaper
Strachan N., R. Kannan and S. Pye (2007), *Final Report on DTI-DEFRA Scenarios and Sensitivities using the UK MARKAL and MARKAL-Macro Energy System Models*, http://www.ukerc.ac.uk/content/view/142/112

Overall, the modelling shows the costs of meeting the 60% target to reduce carbon emissions would be around £1 billion higher in 2050 (a 13% increase compared to when nuclear is available), with additional costs also being incurred in earlier years. However, as discussed above, this figure is likely to be an underestimate of the cost because there are some additional costs to the economy and also the risks of excluding a major low carbon technology are not well captured by the model.

### The delay, uncertainty and costs created in the current planning and regulatory system

The current arrangements for securing the necessary consents for nuclear power station projects impose significant costs on developers, central and local governments and on other participants in the system such as voluntary groups and non-governmental organisations. In particular, the current approach of using public inquiries held as part of the planning process to consider all the issues relevant to new nuclear power stations adds significant cost and delay. However, it is the delay itself and the knock-on effects that create the greatest difficulties for potential investors in nuclear power stations.

The costs involved include the direct costs of delays and deferral of the benefits of proposed investment (including the benefits of additional low carbon generation and more diverse supplies of energy). The direct cost of delays to inquiries can be substantial:

- fees and possible provision of accommodation for the inquiry, Inspector and secretariat;
- participants travelling and overnight costs and loss of earnings;
- reproduction and circulation of documents;
- preparation of cases and other legal and professional costs, including expert witnesses; and
- legal representation at the inquiry itself.

Delays at the planning stage can have significant knock-on effects – it is at this stage that developers incur significant expenditure. Industry estimates that the cost of delays, through increased financing costs and potential design changes at a late stage, can be hundreds of millions; for example the direct inquiry costs for Sizewell B are estimated at £30 million[348]. In the most extreme cases, the cost and uncertainty could prevent the private sector from proposing projects that would reduce carbon emissions and improve the reliability of our supplies. These increased development costs ultimately feed into higher prices for electricity and gas for consumers, with an adverse effect on our fuel poverty targets and international competitiveness.

For other participants, such as local authorities and community groups, this cost can act as a disincentive to be involved in the process, which reduces the ability of the energy planning system to be fair, open and transparent.

348 Industry estimates

## 2. Options

The Energy Review considered a number of options to help the UK meet its medium and long-term energy policy goals. The Energy Review Report and Energy White Paper set out a comprehensive package of supply and demand side measures[349]. As a source of low-carbon generation, that helps to increase the diversity of energy supplies, the Government believes that nuclear power has a role to play in the future generating mix. The arguments are set out in more detail in the consultation document and a summary in the 2007 Energy White Paper.

Having formed the preliminary view that nuclear should be allowed to play a role, the Government has considered whether it should undertake facilitative measures to enable new-build to go ahead should that view be confirmed following consultation. The Government has considered whether or not it would add any value to take a proactive role in setting a strategic policy context for all nuclear planning applications.

### 2.1 Conclude that nuclear should not play a role in the future UK generating mix

This option would be a simple statement that nuclear power does not play a role in the future UK generating mix, and that the Government would not approve any proposals to construct nuclear power stations. When the new planning reforms are implemented, we would not produce a National Policy Statement on nuclear power, so that the Independent Planning Commission would not be able to grant consent for any proposals. It might be possible, as a sub-option within this option to leave the door open for nuclear power playing a role in the future, as was the case in the Energy White Paper *"Our Energy Future – creating a low carbon economy"*[350].

### 2.2 Do nothing, i.e. conclude that nuclear should play a role in the future UK generating mix, but not take action to reduce the regulatory barriers

This option is to take no action other than to confirm that nuclear power should be allowed to play a role in the future UK generating mix alongside other low carbon technologies and should be one of the options for private sector investment. There would be no effort to tackle the potential delays and uncertainty for nuclear. It would mean allowing issues to be explored at every planning inquiry as has happened in the past, regardless of whether they had previously been addressed.

Industry has reported that without action to reduce the upfront risk in the planning sector, they would not bring forward any proposals for new nuclear power stations. Under this option, it is therefore unlikely that any new nuclear power stations would be proposed in the UK and the UK would not benefit from the reduced carbon emissions and increased diversity of supplies that they would bring.

349 A synthesis of the analysis supporting these measures is available at http://www.dti.gov.uk/files/file32177.pdf

350 HMG: Energy White Paper *Our Energy Future – creating a low carbon economy*, Cm 5761, 2003

## 2.3 Conclude that nuclear should play a role in the future UK generating mix and take action to reduce the regulatory barriers

The first step of this option would be, as above, to confirm that we believe nuclear power does have a role in the future generating mix and to set out a programme of facilitative action to reduce the regulatory and planning risks associated with investing in nuclear power stations. The Government would set a clear policy context within which the issues relating to new-build can be addressed, through the processes outlined in this consultation document.

The package of measures is designed to reduce the uncertainties in the pre-construction period for new nuclear power stations through improvements to the regulatory and planning processes. The measures will also set out arrangements for the funding of decommissioning and waste management and disposal. The package of measures covers:

- steps to improve the process for granting planning consent for electricity developments by ensuring it gives full weight to national, strategic and regulatory issues that have already been the subject of discussion and consultation. This would limit the need to discuss these issues in depth during the consenting process and could take the form of a National Policy Statement, consistent with the reforms proposed in the 2007 Planning White Paper. We would;
  – develop criteria for suitable sites for new nuclear power stations through a Strategic Siting Assessment. Subject to some European and domestic legislative requirements, this would limit the need to discuss in detail the suitability of alternative sites for nuclear proposals during the planning process; and
  – continue our consideration of the high-level environmental impacts through a formal Strategic Environmental Assessment in accordance with the SEA Directive[351]. This would limit the need to discuss high-level environmental impacts of nuclear power stations during the planning process.
- running a process of "Justification" (in accordance with the Justification of Practices Involving Ionising Radiation Regulations 2004) to test whether the economic, social and other benefits of specific new nuclear power technologies proposed outweigh the health detriments;
- assist the nuclear regulators, to pursue a process of Generic Design Assessment[352] of industry preferred designs of nuclear power stations to complement the existing licensing processes. This would involve an assessment of the safety, security and environmental impact of power station designs, including waste arisings and radioactive discharges to the environment. This would limit the need to discuss these issues in depth during the planning process.
- introduce arrangements to protect the taxpayer by ensuring that operators of nuclear power stations securely accumulate the funds needed to meet the full costs of decommissioning and full share of waste management costs. This would avoid the need to discuss in depth during the planning process whether the taxpayer will be exposed to the waste and decommissioning costs of any new nuclear power stations that might be constructed.

351 European Directive 2001/42/EC
352 This is sometimes referred to generically as "pre-licensing"

# 3. Benefits

Option 2 is the base case for this analysis. The consequences of option 1 are covered in section 1.3.

Although the specific benefits of any individual application would continue to be explored as part of the planning system, this proposal offers significant benefits:

- enabling the UK to meet its energy policy goals at lower cost and with lower risk by allowing the private sector to invest in nuclear power stations; and
- providing for a more efficient framework, thereby reducing the costs of participation in the relevant planning and regulatory processes.

## 3.1 Economic

**Realising the benefits of nuclear:**
As part of the Energy Review Report, the Government prepared a full cost benefit analysis, which has been updated as part of the Energy White Paper. This analysis has helped inform the Government's preliminary view on nuclear, by setting out the potential economic benefit that nuclear power could bring the UK under a number of scenarios of gas and carbon prices and nuclear costs. This Regulatory Impact Assessment should be considered alongside the full cost benefit analysis, available from the DTI website.

We believe that nuclear power can make an important contribution to reducing the UK's carbon emissions and the reliability of our energy supplies. The cost benefit analysis that we have prepared makes an assessment of these positive externalities:

- for carbon savings we have compared estimates of full lifecycle emissions from nuclear power with those from gas-fired generation.
  The value attributable to these carbon savings is dependent on the prevailing market price for carbon through the European Union Emissions Trading Scheme; and
- for security of supply we have estimated a potential value of this benefit by looking at the costs of gas supply interruptions and the costs of the most effective insurance against such interruptions. The most cost-effective insurance is oil distillate back-up at gas-fired power stations, which costs £100/GW. As a form of insurance against gas supply interruptions, this value can be attributed to nuclear generation.

The table below shows our estimates of whether nuclear generation would provide economic benefits to the UK, compared to gas-fired generation which we consider to be the most likely alternative. It takes into account:

- estimates of nuclear costs (in low, central and high cases);
- estimates of costs of gas-fired generation (in low, central and high cases);
- the difference in $CO_2$ emissions between nuclear and gas-fired generation, to calculate the value of carbon saved according to a number of different carbon prices; and
- the security of supply benefits of nuclear over gas-fired generation.

Where numbers in the table are positive (shaded white), they show that the carbon and security of supply benefits of nuclear outweigh the cost disadvantage versus gas-fired generation:

| TABLE 1: WELFARE BALANCE OF NUCLEAR GENERATION IN £MILLION/GW | | | | | |
|---|---|---|---|---|---|
| | Low Gas Price, Central Nuclear Cost | Central Gas Price, High Nuclear Cost | Central Gas Price, Central Nuclear Cost | Central Gas Price, Low Nuclear Cost | High Gas Price, Central Nuclear Cost |
| Carbon Price = €0/t$CO_2$ | -2000 | -1000 | 40 | 1100 | 1800 |
| Carbon Price = €10/t$CO_2$ | -1600 | -600 | 500 | 1600 | 2200 |
| Carbon Price = €15/t$CO_2$ | -1500 | -500 | 600 | 1800 | 2400 |
| Carbon Price = €25/t$CO_2$ | -1000 | -50 | 1000 | 2200 | 2800 |
| Carbon Price = €36/t$CO_2$ | -600 | 400 | 1500 | 2600 | 3300 |

*Source: DTI Cost Benefit Analysis*

Table 1 shows that:
- in the low gas case, nuclear would not provide economic benefit to the UK under any carbon price scenario;
- in the central gas case, whether nuclear provides economic benefit depends on the carbon price; and
- in the high gas case, nuclear provides economic benefits regardless of the carbon price.

Under central gas and nuclear cases, and with a carbon price of €36/t$CO_2$, the net present value over forty years of adding 6GW (used purely as an example of the scale of potential benefits) of nuclear capacity would be of the order of £6 billion.

**Providing more efficient processes:**
It is expected that in providing fora to discuss the national, strategic and regulatory issues before the planning process, it will be quicker and easier for the public to participate in the consideration of these important issues (by providing the most appropriate opportunities to do so) and for the Secretary of State to make informed decisions. This will reduce the costs of participating in the planning process for all parties through shorter, more focused inquiries. These sums can be significant; for example, industry estimates that the direct inquiry costs for the developer of Sizewell B were £30 million.

Without any changes, planning inquiries would remain the major opportunity to address national strategic and regulatory issues that are generic to nuclear power as well as all the local issues. This would mean that all inquiries would cover the same issues each time a proposal is considered. Based on the experience at Sizewell B, where only 30 of the 340 inquiry days were spent on local issues, the cost and time savings of considering national and regulatory issues first could be significant.

Potential developers of new nuclear power stations have stated, during the two consultations that Government ran in 2006 on this issue, that because of the large upfront investment required to bring forward nuclear power stations and the significant risks in the planning and licensing phases, **they would not bring forward any proposals under the current regime**. Therefore, it is unlikely that without the proposed facilitative action that the benefits of nuclear power discussed would actually be realised.

However, if the private sector does decide to put forward proposals for nuclear power stations without the facilitative action, it is possible to estimate the impact on the generating costs of nuclear power. Without this action the pre-construction costs would be higher because it would take longer to secure all the necessary consents. Pre-development costs are determined by the time taken to secure the necessary consents and the costs incurred in these processes, and can be seen to some extent as a high-level proxy for the fitness-for-purpose of the planning and regulatory framework.

The approach adopted follows that of the main nuclear cost benefit analysis, which is to compare the levelised costs of gas-fired and nuclear power stations[353]. Proceeding in this way incorporates commercial financing costs into the analysis, thus reflecting a commercial view of risks associated with power generation investments or *"the opportunity cost"* of capital. The assumptions underlying these costs are detailed in the updated nuclear cost benefit analysis that accompanies this consultation document and impact assessment.

Table 2 below shows the impact of variations in the pre-construction period and the overall costs of nuclear and gas-fired generation. The central case assumes a pre-development and planning period of eight years with an associated cost of £250 million. However, we believe that with the package of measures described above that a planning period of 5.5 years could be realistic under the new regulatory framework.

353 The cost penalty/advantage is regarded as a societal cost/benefit to be discounted at the Social Time Preference Rate (STPR). The analysis uses the UK Government discount rates of 3.5% for a period up to thirty years in the future, and 3% from thirty-one to seventy-five years. More information can be found in the "Treasury Green Book", which can be accessed via the Treasury website (http://www.hm-treasury.gov.uk), The 3.5% figure for the discount rate assumes a growth rate of 2%, and a pure time preference rate of 1.5%. Present values are estimated for base year – assumed to be 2021 – when nuclear generation could come on line. The methodology of levelising costs at a rate based on commercial financing costs and discounting back cost penalties/advantages at the STPR is consistent with the approach used in the UK Government's Climate Change Programme Review (CCPR), which compares costs of alternative options for carbon reduction ("Greenhouse gas policy evaluation in Government departments", DEFRA, April 2006).

**TABLE 2: NUCLEAR COST PENALTIES/ADVANTAGES IN GAS PRICE AND NUCLEAR COST SCENARIOS**

| | Levelised nuclear cost (£/MWh) | Levelised gas cost (£/MWh) | Annual cost penalty/ advantage per nuclear power station (£ million/GW)* | Net present value (NPV) over forty years (£ million/GW) |
|---|---|---|---|---|
| Central case (pre-development period 8 years, costs of £250 million) | 37.7 | 37.3 | -2.8 | -64.2 |
| Central case with lower planning period (5.5 years) and corresponding cost of planning (£200 million) | 37.3 | 37.3 | 0.3 | 8.4 |
| Central case with lower planning period (5.5 years) and corresponding cost of planning (£100 million) | 36.4 | 37.3 | 6.8 | 155.4 |

** A nuclear cost penalty is signified by a negative number, and a cost advantage by a positive number.*

*Source: DTI Analysis*

Table 2 summarises the cost penalties/advantages of nuclear generation in the various scenarios. In the central case, gas-fired generation has a cost advantage over nuclear generation. The annual cost advantage of gas-fired power stations is £2.8m/GW (equal to 7,450GWh annual output of a nuclear power station, multiplied by the levelised cost differential of just under £0.2/MWh). The NPV of this amount over a forty year period discounted at 3 or 3.5 % depending on the year is £64.2m/GW.

However, when lower pre-development costs cases are considered, nuclear has a cost advantage over gas-fired generation. If pre-development costs were reduced to £200 million, the cost advantage of nuclear power is £0.3m/GW (equal to 7,450GWh annual output of a nuclear plant, multiplied by the levelised cost differential of just over £0.1/MWh). The NPV of this amount over a forty year period discounted at 3 or 3.5 % depending on the year is £8.4m/GW. If more significant savings were realised, so that pre-development costs were £100 million, then this cost advantage would increase to £6.8m/GW (equal to 7,450GWh annual output of a nuclear power station, multiplied by the levelised cost differential of just over £1/MWh). The NPV of this amount over a forty year period discounted at 3 or 3.5 % depending on the year is £155.4m/GW.

It is important to note that the assessment above covers only estimates of nuclear costs, and does not take account of the positive externalities of reduced carbon emissions and security of supply benefit[354].

Another important consideration is the degree of uncertainty in estimating the exact impact of the proposed facilitative action on the pre-development costs of nuclear power. There are a number of other factors which affect these costs, and the extent to which the planning process does not reopen discussions already held is reliant on the extent to which the independent Infrastructure Planning Commission reflects the previous processes like Justification, Strategic Siting Assessment and Generic Design Assessment in managing the planning process.

### 3.2 Environmental

**Realising the benefits of nuclear power:**
Nuclear power is one way to tackle the problem of climate change – for every 1GW installed in place of a gas-fired generation; the UK's carbon emissions would be 0.7MtC lower. As highlighted above, by enabling nuclear power proposals to come forward, this allows the low carbon benefits of nuclear to be realised. In the context of carbon emissions and the environment, nuclear power can be deemed to be more beneficial than generation from fossil fuels. There is a full discussion of the environmental impacts (including nuclear waste) of nuclear power in the consultation document.

**Providing more efficient processes:**
The proposal should not have an adverse impact on environmental considerations. There will be no lesser scrutiny of environmental issues of proposals to build new nuclear power stations by having the appropriate regulators focus on the considerations outside of the public inquiry process.

The policy framework should enable the inquiry process to progress more smoothly and predictably with all parties having a clear understanding of their role, and that of others, in the inquiry process. We would expect all nuclear power proposals would continue to be accompanied by a full Environmental Impact Assessment to comply with the necessary European legislative requirements.

### 3.3 Social

We do not expect there to be any significant impact on the social benefits in relation to new nuclear power stations, as a result of the proposals.

## 4. Costs

This is a de-regulatory policy hence there are fewer additional costs than benefits.

### 4.1 To Government

There will be some administrative expenditure required by Government to undertake the necessary steps to set the strategic framework.

354 For the purposes of the Energy White Paper we have assumed the central case of eight years for pre-construction to reflect the conservative estimates used throughout our analysis.

It is expected that, in time, as applications are processed through the system that the burdens on the Government will be reduced through shorter planning inquiries. Shorter, more efficient inquiries, with more predictable timescales, will enable the Government to better manage its resources in the part of the DTI that is responsible for processing applications under the Electricity Act (once the Infrastructure Planning Commission has been established, these benefits will transfer to them). Inspectors should also be freed up more quickly to move on to other inquiries.

However, because the scale of the cost savings is dependent both on the number of proposals for nuclear power stations that are considered by the planning system and the extent to which inspectors do not explore strategic and regulatory issues already addressed, it is not possible to put an exact figure on the cost savings.

### 4.2 To regulators

It is expected that the regulators will incur fewer costs in exercising their duties. In the past, where regulatory issues such as the safety of a nuclear power power station, have been discussed in both the planning and licensing procedures concurrently, it has imposed a significant burden on the regulator. For example, at Sizewell B, the safety regulator had to make time for appearances at inquiries, and their protracted discussions as the design for the power station was modified. Addressing regulatory issues before planning inquiries will reduce the costs for the regulator during the planning and licensing phases.

### 4.3 To applicants

It is anticipated that costs to the applicant will be reduced, as discussed above. It will be for the private sector to make comprehensive assessments of the economics of any nuclear power station projects, in deciding whether to make a proposal for construction. Developers would only put forward proposals if they believed that there were economic under the market and regulatory framework set by Government.

### 4.4 To other participants in the planning system

By avoiding a long and drawn out planning inquiry, and improving the scope for appropriate public engagement throughout all stages of the planning process (i.e. on a strategic national framework, for example through justification and on local, project specific issues at the inquiry) it will reduce the cost of participating for objectors and local planning authorities. By focusing on the specific areas relevant to the planning inquiry there will be a better use of participants' time.

## 5. Equality and fairness

We do not expect there to be any significant race, health or rural impacts. The proposal does not reduce the level of regulatory scrutiny for health and safety issues, nor of discussions of potential siting for nuclear power stations, which have in the past been predominantly in rural locations.

The proposal makes it clear that such issues, which are of a national strategic or regulatory nature, should be discussed at an early stage, before any planning inquiries, which can be an expensive process for all participants. This proposal in itself will not identify suitable locations for new nuclear power stations, or make an assessment of the health and safety considerations of nuclear power stations, rather that such a full assessment should be carried out in the future, prior to individual planning applications.

Where it was considered that health and safety and rural considerations were relevant matters to any public inquiry, the inspector will still be able to explore these issues. Under the proposed system all planning inquiry would explore the impact of the development on the local communities, as they would under the current system.

## 6. Small business impact test

This proposal is designed to reduce uncertainty and risk for developers of nuclear power stations by setting the strategic context for any planning inquiries. It is our considered view, based on discussions with industry through the Energy Review consultation, that such proposals would not be made by small business, because of the scale and cost of nuclear developments. We have explored this with the Small Business Service to confirm that we have given this sufficient consideration and there is no impact on small business from the proposed regulatory framework.

## 7. Competition assessment

These changes will affect the electricity generation sector only, and most likely, only the larger players that would be more likely to bring forward a nuclear proposal, because of its scale, as outlined above (although it is feasible that a larger consortium of smaller players might come together with a proposal). It should affect all the players equally, in that the policy relates to setting a strategic context for new-build. It will also reduce the regulatory/planning barrier to developers engaging in new nuclear build, potentially opening the market to more players – there are currently only two nuclear operators in the UK. When implemented, the strategic policy framework will identify areas for future new-build, although we expect that this will assist developers with siting decisions rather than stymie them. We do not consider that there will be any major competition detriments.

## 8. Enforcement and sanctions

The policy framework will be implemented by the Government and by the independent regulators. There are no sanctions for non-compliance, although non-compliance would reduce the number of tools the Government had to achieve its Energy White Paper goals.

## 9. Monitoring and review

The Department of Trade and Industry will monitor the efficiency of the new policy framework over a five-year period. Given the infrequency with which nuclear power projects are expected to be proposed by industry, it is thought that to monitor over a shorter period would not be useful. As part of the monitoring, the impact on resources over time for the different parties will be assessed and, if necessary, changes will be considered.

# 10. Consultation

## 10.1 With Government

This policy proposal has been developed as part of the cross-Government Energy Review and Energy White Paper. The Review team has been made up of representative of the interested departments: Department of Trade and Industry, Department for Communities and Local Government, HM Treasury, Department for Environment, Food and Rural Affairs, Department for Transport and the Prime Minister's Strategy Unit. The comments of all departments have been taken into account in making this proposal.

## 10.2 Public Consultation

This policy proposal has been developed in the light of comments and evidence submitted as part of the Energy Review consultation. This consultation elicited over 5,000 responses, although only a proportion discussed planning issues. Of the responses from the key stakeholders in the energy market (including the UK Business Council on Sustainable Energy, non-governmental organisations, major utility companies and regulators) there was almost universal recognition of the need to reform planning processes such that they aligned with policy objectives of reducing uncertainty, cost and time involved in applications across the energy sector.

The DTI also ran a consultation specifically on the Nuclear Policy Framework from 12 July to 31 October 2006 to which we received a total of 893 responses, 753 of which were from two campaigns. The majority of responses were split between pro and anti-nuclear. Those responses which were pro-nuclear supported the introduction of a policy framework for nuclear new-build. Furthermore, there were those responses which were neutral about whether nuclear new-build should be an option but recognised that if it were to be introduced, a new policy framework was required.

There is now a further consultation on the proposals as set out in the accompanying consultation document.

# 11. Implementation and delivery plan

A contingent implementation and delivery plan is set out in the consultation document and this will be updated following the consultation, depending on the outcome. This will specify the measures to be put in place as part of the new regulatory framework and the draft timetable for each step assuming new nuclear build goes ahead.

A success measure for the new measures would be nuclear operators choosing to go through the process of building new nuclear power stations in the UK. In doing so, the planning process would work more quickly and efficiently while regulatory and public scrutiny would not be undermined.

ANNEX B

# Government Code of Practice on Consultation

1. Consult widely throughout the process, allowing a minimum of 12 weeks for written consultation at least once during the development of the policy.

2. Be clear about what your proposals are, who may be affected, what questions are being asked and the timescale for responses.

3. Ensure that your consultation is clear, concise and widely accessible.

4. Give feedback regarding the responses received and how the consultation process influenced the policy.

5. Monitor your department's effectiveness at consultation, including through the use of a designated consultation co-ordinator.

6. Ensure your consultation follows better regulation best practice, including carrying out a Regulatory Impact Assessment if appropriate.

The complete code is available on the Cabinet Office's website, address http://www.cabinetoffice.gov.uk/regulation/consultation/index.asp

## Comments or complaints

If you wish to comment on the conduct of this consultation or make a complaint about the way this consultation has been conducted, please write to: DTI Consultation Co-ordinator, 1 Victoria Street, London SW1H 0ET

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