DISCLAIMER

This report, produced in April 2006, was commissioned by the Department of Trade & Industry as part of the Government’s preparations for the 2006 Energy Review Report. It summarises historic policy and practice for the siting of nuclear power stations and makes some suggestions as to which issues may be relevant in considering the siting of any new nuclear build. The report was produced as a discussion paper only, to provide input to the policy discussion process. The views and any conclusions reached in the report are those of the authors, Jackson Consulting, at the time, and do not represent Government policy or the policies of the devolved administrations, nor the views of any other organisation.

The Government has set out, as part of its May 2007 consultation on nuclear energy, a proposed process for a Strategic Siting Assessment (SSA) of potential locations for new nuclear power stations. This would be carried out only if the Government concludes following this consultation that nuclear should continue to be part of our energy mix. The SSA would be based on robust objective criteria on which we would consult in advance. The Government has no views on the relative suitability of potential locations for new nuclear power stations pending the carrying out of an SSA and subject to the outcome of this consultation.

23 MAY 2007
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Commercial in Confidence

Siting New Nuclear Power Stations: Availability and Options for Government

Discussion Paper for DTI Expert Group

Ian Jackson and Shehnaz Jackson
Jackson Consulting (UK) Limited
26th April 2006

Final Paper
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- Health & Safety Executive (HSE)
- National Grid plc
- National Grid plc
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- Office of Gas and Electricity Markets (Ofgem)
- Scottish Executive
- Wales Office
- Welsh Assembly Government

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The paper was written by Ian Jackson with research assistance from Shehnaz Jackson of Jackson Consulting (UK) Limited. Shehnaz Jackson also prepared the computer graphics and designed the layout of this paper. The information presented and opinions expressed in this discussion paper are not intended to be a comprehensive study of nuclear siting issues, nor to provide legal advice and should not be relied on or treated as a substitute for specific advice concerning individual situations. We accept no responsibility to third parties to whom this paper is made known. Any such party relies on the paper at their own risk.
Executive Summary

In November 2005 Prime Minister Tony Blair announced a review of UK energy policy (the Energy Review) to be undertaken by DTI in consultation with a wide range of stakeholders. In February 2006 DTI established a nuclear siting expert group to consider the potential availability of UK sites for new nuclear power stations, should they be required, and for developing options for government action against possible nuclear energy policy scenarios.

The scale of a future nuclear build programme would depend partly on the availability of suitable sites in the UK. Pragmatically there would be little point in the Energy Review recommending policy options to Ministers in support of new nuclear build if no suitable candidate sites were likely to become available economically or within a realistic timeframe. The availability of potential sites will therefore directly affect the government’s view of the overall feasibility of a new nuclear build programme and the development of its energy policy.

Members of DTI’s nuclear siting expert group contributed toward the development of this discussion paper. The paper summarises the major business, economic, safety, environmental and technical factors that could influence the selection of a site for construction of one or more new nuclear power stations in the UK. Several existing nuclear sites in the South of England appear to be strong candidates as potential locations for new nuclear build funded by the private sector. The expert group suggested a preferred hierarchy for action on site selection, should new nuclear build be required by government.

Suggested Hierarchy for Site Selection
A preliminary assessment by the DTI expert group of the development potential of existing nuclear power station sites for new nuclear build identified 12 sites potentially suitable for a new single reactor (1,100MW to 1,600MW) and 10 sites potentially suitable for a new twin reactor (2,200MW to 3,200MW). The assessment findings are summarised below and were based on discussion and expert judgement informed by the conclusions of some previous studies and existing knowledge of the sites by their owners BE and the NDA.

Preliminary Assessment of Development Potential of Existing Nuclear Power Station Sites

<table>
<thead>
<tr>
<th>Existing Nuclear Power Station</th>
<th>Land Owner</th>
<th>New Single Reactor</th>
<th>New Twin Reactor</th>
<th>Earliest Date Available</th>
<th>Comment on Main Development Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinkley Point</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>3200 MW twin reactor may need planning consent for additional transmission line and investigation of grid rating. Possible conflict with potential windfarm development west of site.</td>
</tr>
<tr>
<td>Sizewell</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>3200 MW twin reactor may need planning consent for additional transmission line and investigation of grid rating.</td>
</tr>
<tr>
<td>Bradwell</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Limited cooling water availability in Blackwater Estuary for twin reactor because of environmental sensitivity and limits on abstraction capacity. Planning consent may be required for transmission line upgrade.</td>
</tr>
<tr>
<td>Dungeness</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Twin reactor would need planning consent for additional transmission line towards London. Environmentally sensitive location.</td>
</tr>
<tr>
<td>Hartlepool</td>
<td>BE</td>
<td>Amber</td>
<td>Amber</td>
<td>2014 +</td>
<td>Limited grid connection opportunity in Scotland means new reactor connection only realistic after closure of existing AGR plant in 2019 or later.</td>
</tr>
<tr>
<td>Sizewell</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>2020 +</td>
<td>Limited grid connection opportunity in Ireland means new reactor connection only realistic after closure of existing AGR plant in 2019 or later.</td>
</tr>
<tr>
<td>Torness</td>
<td>BE</td>
<td>Amber</td>
<td>Amber</td>
<td>2025 +</td>
<td>Limited grid connection opportunity in Scotland means new reactor connection only realistic after closure of existing AGR plant in 2019 or later.</td>
</tr>
<tr>
<td>Wylfa</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>2019 +</td>
<td>Limited grid connection opportunity in Wales means new reactor connection only realistic after closure of Wylfa in 2018 or later.</td>
</tr>
<tr>
<td>Calder Hall</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Requires planning consent for lengthy new transmission line avoiding Lake District National Park and limited grid connection opportunity.</td>
</tr>
<tr>
<td>Oldbury</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Limited cooling water availability in Severn Estuary because of environmental sensitivity and limits on abstraction capacity. Serves grid reinforcement needs.</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>2019 +</td>
<td>Limited grid connection opportunity in Scotland until 2019 because of many applications for connection of wind generators to the national grid.</td>
</tr>
<tr>
<td>Barton</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Requires planning consent for new transmission line. Existing grid connection dismantled. Very limited cooling water availability in upper Severn Estuary because of environmental sensitivity and limits on abstraction capacity.</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Cooling towers and freshwater reservoir necessary because no seawater cooling. Requires planning consent for cooling towers in Trawsfynydd National Park.</td>
</tr>
</tbody>
</table>

Source: Adapted from Preliminary Assessment of Development Potential For Single and Twin Reactors by DTI Expert Group (April 2008)
For sites regarded as potentially suitable for new nuclear build, some factors have a major impact on the likelihood of achieving project go-ahead, while others have a direct impact on the economic return that a project could achieve. Factors such as grid connectivity and operation, cooling water supply and land quality can significantly affect overall project economics (greater than 10% of estimated capital costs for new nuclear build). If existing grid connectivity and proximity to areas of electricity demand were the major siting factors, then the key opportunities for nuclear development in the UK are shown below.

Key Opportunities for Nuclear Development
1 Introduction

1.1 Background

In November 2005 Prime Minister Tony Blair announced a review of UK energy policy to be undertaken by DTI in consultation with a wide range of interdepartmental and external stakeholders (Energy Review - A Secure and Clean Energy Future, DTI, 29th November 2005). The review would be taken forward by Energy Minister Mr Malcolm Wicks reporting to the Secretary of State Alan Johnson and would draw on a range of external support and analysis both within and outside government. The review would consider all options including the role of current generating technologies including nuclear power. The 3 month public consultation phase of the Energy Review began in January 2006 (Our Energy Challenge - Securing Clean, Affordable Energy for the Long Term, DTI, 23rd January 2006).

The government's energy policy set out in its earlier 2003 Energy White Paper, Our Energy Future - Creating a Low Carbon Economy (Cm 5761, DTI, February 2003), did not propose to build any new nuclear power stations but promised to keep the nuclear option open. Because the 2006 Energy Review is likely to highlight a number of difficult policy questions especially on the future role of nuclear power, it is very important that the policy basis and conclusions of the Energy Review are credible, impartial and robust. The aim is to develop a UK energy policy statement by early summer 2006 underpinned by good strategic analysis.

Box 1
DTI Energy Review Public Consultation Document
Key Questions for the Review

Q.3 The [2003] Energy White Paper left open the option of new nuclear build. Are there particular considerations that should apply to nuclear as the government re-examines the issues bearing on new build, including long-term liabilities and waste management? If so, what are these, and how should the government address them?

Source: Our Energy Challenge - Securing Clean, Affordable Energy for the Long Term. DTI. Jan 2006

1.2 Expert group on nuclear sites issues

In February 2006 DTI established a nuclear siting expert group to consider the potential availability of UK sites for new nuclear power stations, should they be required, and to help DTI develop options for government action against possible nuclear energy policy scenarios. Membership of the group was drawn from central government (DTI), regulators (EA, SEPA and HSE), devolved administrations (Scottish Executive, Welsh Assembly Government), British nuclear power station operating companies (BNFL, BE) and the national electricity grid operator (National Grid). The key objective of the group was to provide advice on the likely availability of sites for new build, the timing of the sites becoming available, and any important barriers to development including a broad indication of their economic costs.
Members of the expert group met at DTI London on three occasions on 24th February, 23rd March and 11th April 2006 and provided additional inputs and comments by correspondence.

**Box 2**

**Issues for Nuclear Sites Expert Group**

A) Examine the availability of UK sites for new nuclear power stations, to inform the Energy Review and development of future energy policy.

B) Inform the development of options for possible government action against three possible policy scenarios:

1. Nuclear electricity generation remains included as a future energy option for the UK.
2. The UK energy mix should include some contribution from nuclear power.
3. The UK energy mix should include 10 new nuclear reactors* at sites identified and made available by government.

* 10 new nuclear reactors was used for illustration purposes as a bounding case scenario to help frame DTI expert group discussions. CoRWM has also considered 10 reactor scenarios in its policy planning.

1.3 Purpose of this discussion paper

Jackson Consulting was commissioned by DTI to help the siting expert group consider what strategic issues might affect the availability of sites in the UK for new nuclear power stations. This discussion paper summarises the major factors that the expert group considered when developing its preliminary site assessment, setting out the known facts on siting, range of opinion amongst experts, areas of agreement, disputed issues, and the factors that might influence combinations or choices of different energy policy options. The scale of a future nuclear build programme would depend partly on the availability of suitable sites in the UK. Pragmatically there would be little point in the Energy Review recommending policy options to Ministers in support of new nuclear build if no suitable candidate sites were likely to become available economically or within a realistic timeframe. The availability of potential sites will therefore directly affect the government's view of the overall feasibility of a new nuclear build programme and the development of its energy policy. The locations of the existing civil nuclear power stations in the UK (including power station decommissioning sites and some experimental reactor sites) are illustrated in Figure 1 and the timeline for their expected closure over the next 30 years is illustrated in Figure 2. Section 2 of this discussion paper examines the development of siting policy for nuclear reactors from the 1940s to the present day. Section 3 identifies the basic scenarios for siting new nuclear power stations in the UK and offers a suggested hierarchy for site selection. Section 4 examines the major factors that could affect site evaluation and discusses the potential importance of the electricity transmission and distribution grid when deciding on the optimum locations for siting new nuclear power stations. Section 5 gives a preliminary 'traffic light' assessment of the development potential of existing nuclear power station sites for new nuclear build.
1.4 Questions to help frame expert group discussions

To help generate discussion the expert group considered a number of questions focussing on the key issues that might affect decisions on the suitability of a site for new nuclear build.

**Nuclear siting policy**

- If required, should the government's siting policy for new nuclear power stations be different to siting policy for CoRWM nuclear waste management facilities?

- If CoRWM recommends voluntary site selection and community powers of veto, should this policy be extended to new nuclear power station sites?

- Are open siting processes viable for new nuclear reactor build or is a focussed siting process targeted at existing nuclear communities needed instead?

- Should the government invite the Health & Safety Commission (HSC) to advise on the adequacy of the current demographic siting policy for 'plants new to the UK' (which presently restricts new nuclear reactor technology to remote locations)?

**Land use planning**

- Should existing nuclear sites be developed first before reactors are situated in new locations?

- How far should the government protect the availability of existing sites using planning controls?

- Should planning restrictions be relaxed to allow the construction of grid transmission lines across sensitive areas such as National Parks?

- Would designated habitats prevent the development of new nuclear power stations at environmentally sensitive locations?

- Could the need for nuclear power station sites be reduced if reactors were built in twin rather than single configurations?

**Site ownership**

- Could NDA sites be made available for new nuclear build and what guidance from government would be required to prevent foreclosure of siting on NDA land?

- What other sites might be available for new nuclear build?
Electricity transmission and distribution

- Does local electricity demand drive site selection or can nuclear power stations be sited anywhere in the UK irrespective of grid transmission distances?

- Is existing connectivity to the national grid essential for site viability or can the transmission infrastructure be installed or reinforced cost effectively?

- What would be the best locations if existing grid connectivity and proximity to areas of electricity demand were the major siting factors?

- Do grid constraints and reinforcement needs drive site selection or can nuclear power stations be sited anywhere in the UK irrespective of grid transmission distances to centres of demand?

- Is an existing connection to the national grid essential for site viability or can connection and transmission infrastructure be installed or reinforced in a cost effective and timely way?

- What would be the best locations if existing grid connections and ability to accommodate power infeed were the major siting factors?

Climate change mitigation and adaptation

- Are modern nuclear power station designs resilient to the impacts of climate change expected over their 100 year lifecycle?

- What engineering solutions are available that can protect existing low-lying coastal nuclear power station sites from sea level rise and serious flooding?

- Is engineering protection cost effective or would high costs drive site selection toward less vulnerable coastal sites or inland sites?

- Is coastal siting essential for locating nuclear power stations or could sufficient cooling be achieved cost effectively by utilising cooling towers at inland sites?

- If inland siting was needed, what UK rivers would have sufficient fresh water abstraction capacity for feeding cooling towers?

Options for government action

- What are the options for government action on site selection, should new nuclear build be required?

- How might the issues identified feed into options for future government action on siting?
Figure 1
Civil Nuclear Power Stations in the UK

Figure 2
Decline of Nuclear Generating Capacity

Nuclear generation is projected to decline rapidly between 2006 and 2023, losing around 80% of peak 1990's nuclear capacity

Source: EA (2001); NAO (2004); NDA (2005); DTI (2006)
### Table 1

**Station Closure Programme and Loss of Nuclear Capacity**

<table>
<thead>
<tr>
<th>Nuclear Power Station</th>
<th>Year Closed</th>
<th>Output Lost (MWe)</th>
<th>Remaining Nuclear Capacity (MWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berkeley</td>
<td>1989</td>
<td>200</td>
<td>12,370</td>
</tr>
<tr>
<td>Hunterston A</td>
<td>1989</td>
<td>200</td>
<td>12,170</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>1991</td>
<td>390</td>
<td>11,780</td>
</tr>
<tr>
<td>(Sizewell B)*</td>
<td>(1995)*</td>
<td>(1,188)*</td>
<td>12,968</td>
</tr>
<tr>
<td>Hinkley Point A</td>
<td>2000</td>
<td>470</td>
<td>12,498</td>
</tr>
<tr>
<td>Bradwell</td>
<td>2002</td>
<td>246</td>
<td>12,252</td>
</tr>
<tr>
<td>Calder Hall</td>
<td>2003</td>
<td>200</td>
<td>12,052</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>2004</td>
<td>200</td>
<td>11,852</td>
</tr>
<tr>
<td>Sizewell A</td>
<td>2006</td>
<td>420</td>
<td>11,432</td>
</tr>
<tr>
<td>Dungeness A</td>
<td>2006</td>
<td>450</td>
<td>10,982</td>
</tr>
<tr>
<td>Oldbury</td>
<td>2008</td>
<td>434</td>
<td>10,548</td>
</tr>
<tr>
<td>Wylfa</td>
<td>2010</td>
<td>980</td>
<td>9,568</td>
</tr>
<tr>
<td>Hinkley Point B</td>
<td>2011</td>
<td>1,220</td>
<td>8,348</td>
</tr>
<tr>
<td>Hunterston B</td>
<td>2011</td>
<td>1,190</td>
<td>7,158</td>
</tr>
<tr>
<td>Hartlepool</td>
<td>2014</td>
<td>1,210</td>
<td>5,948</td>
</tr>
<tr>
<td>Heysham 1</td>
<td>2014</td>
<td>1,150</td>
<td>4,798</td>
</tr>
<tr>
<td>Dungeness B</td>
<td>2018</td>
<td>1,110</td>
<td>3,688</td>
</tr>
<tr>
<td>Torness</td>
<td>2023</td>
<td>1,250</td>
<td>2,438</td>
</tr>
<tr>
<td>Heysham 2</td>
<td>2023</td>
<td>1,250</td>
<td>1,188</td>
</tr>
<tr>
<td>Sizewell B</td>
<td>2035</td>
<td>1,188</td>
<td>0</td>
</tr>
</tbody>
</table>

* Sizewell B opened in 1995 adding 1,188 MWe of new nuclear capacity.

Source: EA (2001); NAO (2004); NDA (2005); DTI (2006)
2 Siting policy for nuclear power stations

2.1 Early nuclear siting policy during the 1940s-1950s

The first nuclear reactors to be constructed in the UK, GLEEP and BEPO, were built at the Atomic Energy Research Establishment (AERE) Harwell in Oxfordshire in the late 1940s. GLEEP was constructed in 1946 and operated for 43 years through to 1990. BEPO was constructed in 1948 and operated for 20 years until 1968. Sir John Cockcroft selected the former RAF Harwell airbase as the site for AERE - and by implication the site of the first British nuclear reactors - in February 1946 using a simple practical siting criteria\(^1\).

**Box 3**

**Siting Criteria for the First British Nuclear Reactors at AERE Harwell, 1946**

We considered the desirable conditions for the future Establishment. It should not be too far from London; there should be easy access to a University; there should be some degree of isolation and lastly the countryside should be pleasant to live in. It was also thought necessary to start with a prepared site with roads, services, and some permanent buildings, and Lord Cherwell suggested that we should look for a suitable RAF Airfield. So, in a hurried visit to England in the Autumn of 1945, Professor Oliphant and I looked at airfields. Most of those suggested had very few temporary buildings and offered little advantages over open sites; we were left with a short list of Duxford (near Cambridge), South Cerney (near Cirencester), Benson and Harwell [in Oxfordshire]. Duxford, in spite of the great advantages of proximity to Cambridge, was voted to be too inaccessible to most universities and there was not enough water available. South Cerney was an attractive airfield but somewhat too isolated; so in the end we were given Harwell, and on a windy day of February 1946... I was able to look closely at our heritage.


Although Harwell was selected mainly for its existing infrastructure and relative ease of access to London a more remote site at Sellafield in Cumbria was chosen in 1947 for construction of Britain's military reactors Windscale Pile No. 1 and Windscale Pile No. 2. Pile No. 1 became operational in October 1950 and Pile No. 2 in June 1951. Windscale was chosen based partly on American siting criteria developed for reactor piles constructed at Hanford in the United States; 5 miles from any town with a population of 1,000 people, 25 miles from any town with 10,000 people and 50 miles from any town with 50,000 people.\(^2\)

---


2.2 Magnox and AGR siting policy during the 1960s-1970s

The government's 1955 White Paper *A Programme of Nuclear Power* (Ministry of Power, 1955) set out a 10 year programme for construction of a fleet of Magnox civil nuclear power stations intended to supply between 1500-2000MW of electricity to the national grid. The Magnox programme was intended to provide 25% of UK electricity needs at a total cost of £300 million (£4,593 million in 2002 prices). The first three orders were placed in 1956 for Berkeley, Bradwell and Hunterston based on the design of the Calder Hall reactor. Some 22 Magnox reactors were eventually built on 10 nuclear sites across the UK. Most sites contained twin Magnox stations except Chapelcross and Calder Hall which had 4.

The government's follow-up 1964 White Paper *The Second Nuclear Power Programme* (Department of State and Official Bodies and Ministry of Power, 1964) set out a programme for construction of a second generation of British nuclear power stations based on the Advanced Gas-cooled Reactor (AGR) design. The AGR fleet was intended to provide a further 5,000-8,000MW and the first AGR Dungeness-B was ordered in August 1965.

The government took a deliberately cautious approach to the siting of the first steel pressure vessel Magnox nuclear power stations, locating them in comparatively remote or rural areas to minimise the numbers of people at risk in the event of an escape of radioactivity. This safety and siting policy was later reviewed in 1968 under the Nuclear Safety Advisory Committee as a result of which AGRs with pre-stressed concrete pressure vessels were allowed to be built closer to population centres in near-urban environments such as Heysham and Hartlepool (which is only 5 miles from Middlesbrough).

The Royal Commission on Environmental Pollution (RCEP) examined siting policy for reactors in its Sixth Report (Cm 6618, *Nuclear Power and the Environment*, RCEP 1976). RCEP supported the government's policy of near-urban siting for commercial nuclear power stations for a variety of reasons; safety of the public was considered to derive more from high standards in the design, construction and operation of nuclear power stations than from remote siting (siting within 30km of an urban load centre was thought to be ideal); the need for electricity transmission cables would be reduced improving the aesthetic amenity of the nuclear power station; and it might be possible to recover or recycle some waste heat from station cooling water as an energy efficiency measure for use in local district heating.

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The nuclear siting criteria initially adopted by the government in the 1960s and later reaffirmed in the 1970s was originally based upon siting risk analysis techniques developed by Mr F.R. Farmer, the former Director of the UKAEA Safety and Reliability Directorate (SRD), in 1967\(^7\),\(^8\). Farmer developed a series of probability curves (F-N curves or Farmer curves) quantifying the risk to members of the public from accidental releases of the fission product iodine-131 during a severe reactor accident. Releases of iodine-131 are particularly hazardous because they may cause thyroid cancer in children. Farmer developed three risk curves for reactor accidents scenarios taking place in urban city environments, semi-urban environments and remote rural environments. In densely populated countries such as the UK the difference between the three curves represents the maximum safety advantage that can be obtained from remote site selection. As an approximation, choosing a semi-urban site for locating a nuclear power station increases the radiological accident risk to members of the public by about a factor of 10, with a further factor of 10 increase if the reactor is sited in an urban city centre. This is not surprising since the difference in population density between rural and urban environments is about 1:100. Farmer concluded that site selection can reduce risk to members of the public from accidental releases of radioactivity by only about a factor of 100. In other words there is only a relatively small safety advantage in siting nuclear reactors in remote locations and, as RCEP pointed out, these advantages might be outweighed by other more practical factors in favour of siting reactors closer to industrial and population centres that actually consume the majority of electricity.

2.3 Regulatory nuclear siting policy during the 1980s-1990s

The nuclear safety regulator HSE published its first set of Safety Assessment Principles for Nuclear Power Reactors in 1979. The principles were amended in 1988 following a recommendation from the Sizewell-B PWR public inquiry and revised again in 1992 so that they could be applied more generally to all nuclear installations (not just nuclear power reactors). The current set of principles are codified in the HSE Safety Assessment Principles for Nuclear Plants (HSE-NII SAPs, 1992). These principles are currently under review again in 2006 to better reflect the increasing role of decommissioning of civil nuclear liabilities in the UK following the creation of the Nuclear Decommissioning Authority (NDA) under the Energy Act 2004. This has broadly consolidated the former decommissioning activities previously managed separately by UKAEA, BNFL and Magnox Electric under the umbrella of the NDA.

HSE also published its thinking on risk management at nuclear installations in The Tolerability of Risk from Nuclear Power Stations (HSE-NII TOR, 1988, revised 1992). This thinking was later expanded in 2001 to apply more generally to all risk management activities regulated by HSE in its policy document Reducing Risks, Protecting People - HSE's Decision-making Process (HSE R2P2, 2001). Although TOR and R2P2 are significant policy documents, the SAPs are of central importance to the siting of new nuclear power stations because they specify a number of key siting principles (P56 - P60) explained in Box 4 below.

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\(^7\) Farmer published his original work in Siting Criteria - A New Approach, FR Farmer. IAEA Conference on Containment and Siting. Vienna. April 1967. Farmer was later appointed as a technical consultant to the Royal Commission on Environmental Pollution's landmark review of nuclear power and the environment (RCEP 6th Report, 1976), chaired by Sir Brian Flowers.

93. If a company wishes to build a plant, it has to satisfy the NII first in relation to the site - that it conforms with the Government's siting policy and that the site characteristics are acceptable - and then in relation to the plant to be built on it. An important element of Government policy is that the first plant of a new type should be built on a remote site. This is deemed to be a prudent approach until sufficient experience is gained to allow more relaxed siting. With regard to site characteristics, to a large extent the site can be considered independently of the plant design. The objective as far as the design is concerned is that accidents should be prevented and their consequences contained. For the site, on the other hand, consideration has to be given to measures which would mitigate the effects of an accident in the unlikely event that a radioactive release occurred.

94. All nuclear plants are required, therefore, to have an emergency plan. For major plants such as power reactors, large reprocessing facilities and fuel stores, the plan should address the design basis accident which gives the most significant off-site release or, if the accident results in doses below the lower emergency reference level, should cover a minimum planning zone of 1 km. Off-site plans for minor plants should be made commensurate with the level of potential hazard they present. The principal aspects on which the NII requires to be satisfied are the demographic characteristics which have a bearing on accident mitigation, in particular the size, nature and distribution of the population around the site. The fewer people there are living, working or at leisure in the vicinity of the site, the smaller will be the number likely to be affected by an accidental release of radioactive material and for whom it may be necessary to initiate measures, such as evacuation from the area, if an accident occurs. Institutions with relatively large numbers of immobile people such as hospitals or old people's homes could present difficulties in the event of an emergency.

95. A second aspect for consideration comprises those features of the topography of the area around the site which can affect the dispersion of radioactive materials discharged from a plant in normal operation or released in the event of an accident. Other aspects of the topography which might affect the movement of people or of goods, the first being relevant to evacuation and the second to the normal movement of radioactive materials to and from the site, need also to be considered.

Box 4
HSE Regulatory Siting Criteria for Nuclear Plants

93. If a company wishes to build a plant, it has to satisfy the NII first in relation to the site - that it conforms with the Government's siting policy and that the site characteristics are acceptable - and then in relation to the plant to be built on it. An important element of Government policy is that the first plant of a new type should be built on a remote site. This is deemed to be a prudent approach until sufficient experience is gained to allow more relaxed siting. With regard to site characteristics, to a large extent the site can be considered independently of the plant design. The objective as far as the design is concerned is that accidents should be prevented and their consequences contained. For the site, on the other hand, consideration has to be given to measures which would mitigate the effects of an accident in the unlikely event that a radioactive release occurred.

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95. A second aspect for consideration comprises those features of the topography of the area around the site which can affect the dispersion of radioactive materials discharged from a plant in normal operation or released in the event of an accident. Other aspects of the topography which might affect the movement of people or of goods, the first being relevant to evacuation and the second to the normal movement of radioactive materials to and from the site, need also to be considered.
96. There is a third category of site related characteristics on which information will be required and these are the natural and man-made hazards in the area. Earthquakes, flooding, drought, high winds and extremes of ambient temperature are examples of natural hazards which need to be considered. Man-made hazards include the possibility of an aircraft crash on the site and the storage, processing or transport of hazardous materials in the vicinity. Interruption of essential services to the plant, such as power and water, could also jeopardise its safe working.

97. In general, these hazards will be dealt with as appropriate in the design of the plant. These aspects of the site-related risk are therefore covered in the hazards section of the engineering principles. The following principles [P56 - P60] are those specific to a site which need to be satisfied in order to obtain approval of the proposed site. Information required under the hazards principles must also be supplied, but generally that would lead to design provisions in the plant rather than being a determining factor in approval of the site.


2.4 New policy developments in voluntary nuclear siting and community veto

In July 2006 Defra's Committee on Radioactive Waste Management (CoRWM) is expected to make recommendations to Ministers on the best national option (or combination of options) for the management of Britain's higher activity radioactive wastes. The recommendations are likely to include a proposal that the selection of a national site (or a number of regional sites) for locating a waste management facility should be decided by a staged process that proceeds in a number of steps over several years. Crucially, CoRWM is likely to recommend that the site selection process should include a democratic mechanism that allows local communities to volunteer to host a site (community volunteerism) and that also offers participating local communities rights to withdraw from site selection at a number of agreed stages in the process (right of veto)⁹. For example site selection may involve both an open siting process potentially available for any local community to volunteer and a focussed siting process looking at sites where nuclear facilities already exist. CoRWM's volunteerism and veto proposals are likely to be supported by the Local Government Association (LGA) which recently completed a siting implementation study that reached similar conclusions¹⁰. Some of the apparent success factors are summarised in the Facility Siting Credo in Box 5 which reflect developing thinking on international best practice for hazardous facility siting¹¹, although it should be noted that these are not requirements of UK planning law.

⁹ Members of CoRWM held an internal workshop on implementation at the Open University, Milton Keynes on 15th-16th February 2006. A draft implementation discussion paper (V4.11, 2 February 2006) was prepared for CoRWM delegates. The discussion paper is currently being updated with workshop outputs and is expected to be published on CoRWM's website in April 2006.


While there are aspects of the siting credo that are embedded in the UK planning system there are also some clear departures that would be difficult to accommodate as these would require changes to the planning system. For example in the UK planning seeks consensus through a broad-based participatory process and aims to address all negative aspects of development. However at present the planning system does not *fully compensate* all negative aspects of development. At present it is difficult to envisage how a mechanism of full compensation for nuclear facilities could be implemented under current planning laws.

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**Box 5**

**The Facility Siting Credo**\(^\text{12}\)

1. Seek consensus through a broad based participatory process.
2. Work to develop trust.
3. Achieve agreement that the status quo is unacceptable.
4. Choose the facility design that best addresses a solution to the problem.
5. Fully address all negative aspects of the facility.
6. Seek acceptable sites through a volunteer process.
7. Consider a competitive siting process.
8. Work for geographic fairness.
9. Keep multiple options on the table at all times.
10. Guarantee that stringent safety standards will be met.
11. Fully compensate all negative aspects of a facility.
12. Make the host community better off.
13. Use contingent arrangements.
14. Set realistic timetables.

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If the government decides to implement a voluntary siting and veto approach for deciding the location of CoRWM radioactive waste management facilities then local communities may well expect government commitment to a similar voluntary process for siting new nuclear power stations. This could create difficulty principally because the timing of an unconstrained voluntary siting process for new nuclear power stations might essentially be open-ended, since voluntary processes inevitably involve substantial negotiation in which a fixed timescale cannot be guaranteed, potentially damaging business and investment confidence.

There are sound reasons why voluntary siting approaches that might be proposed for CoRWM facility siting should not automatically be applied to new nuclear power stations. A national radioactive waste management facility would probably be a new and unique national facility that is intended to be permanently located for at least 10,000 years whereas nuclear power stations would be relatively temporary structures with a lifecycle of around 100 years and a clear expectation of full decommissioning at the end of their working lives. Figure 3 illustrates some of the key differences that could justify separate siting mechanisms.

There are essentially three main differences between the siting of a nuclear power station and the siting of a radioactive waste facility; the differing lifecycles of the plants; the complexity of the licensing processes; and the differing degree of dependence on local geology. A new nuclear power station has only a limited lifecycle of around 100 years (10 years for reactor licensing and construction, 60 years for operation and 30 years for decommissioning) whereas a CoRWM repository facility is effectively permanent for all time since the repository would probably need to remain intact for somewhere between 10,000 to 1,000,000 years. Similarly there are also differences between the complexity and timing of the licensing process. Reactor licensing would benefit from a single stage combined planning permission and nuclear safety licence that can be delivered relatively quickly within around 2 to 5 years, whereas CoRWM facility licensing will probably need a series of licensing decision points linked to multi-staged planning consents perhaps over a 10 to 20 year timeframe. Finally from a technical perspective one of the main differences between the siting of a nuclear reactor and the siting of a CoRWM facility is the importance of local geology. Nuclear reactor siting is relatively independent of geology whereas the siting of a CoRWM storage repository would strongly depend on finding a site with suitable hydrogeology. The problem is somewhat different to the siting of standardised nuclear power station designs because the design of a storage repository is much more closely connected with the nature of the site. Many aspects of the design of the repository are likely to be site-specific and some iteration would probably be necessary between site characterisation, safety case assessment, repository design and facility construction. Moreover there is an established consenting process for the grant of planning permission for nuclear power stations, the most recent example being Hinkley Point C which was granted consent in 1990, although not constructed. This followed the grant of consent for Sizewell B in 1987 which is currently operational. The planning process includes full and detailed public consultation and is designed to enable stakeholders to voice their opinions and debate issues at Public Inquiry. It should be noted that in principle the planning process for nuclear power station siting is no different to that followed for conventional power stations.

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13 The main geological requirement for nuclear power station siting is to find a location that is not vulnerable to earthquakes or built upon geological faults, and where the ground is stable so that the weight of the power station can be properly supported over the 100 year lifecycle of the reactor.
There are sound reasons why voluntary community siting approaches that might be proposed for CoRWM facility siting should not automatically be applied to new nuclear power station siting, which is different in several key ways shown above.
3 Scenarios for siting new nuclear power stations

3.1 Market selection

In the Energy Review consultation document the government stated that it would expect any future nuclear power plant to be built and run by the private sector, within the regulatory framework set by government14. The Sustainable Development Commission's (SDC) recent analysis of nuclear economics suggests that the most likely scenario for financing new nuclear build would be via some form of project finance approach probably involving a consortium of investors, reactor vendors and utility companies joining together as the reactor builder/owner/operator15,16. From a business perspective decisions on where to site modern industrial facilities such as nuclear power stations are made in the same way as decisions on where to put any heavy industry; by private sector companies seeking the best combination of such key factors as proximity to markets and materials, availability of skilled and trained labour, well developed infrastructure, good transportation networks, electricity and water utilities, and low land and development costs17. A major practical consideration in the location of new nuclear generating plant is that potential sites should be strategically placed, both for connection to the transmission grid and to supply electricity to large areas of demand. Siting plant close to areas of demand reduces the need for long-distance power transfers that in turn reduce losses from the electricity grid, improving the efficiency of the network and reducing costs. Moreover an important factor is the ability of the grid system to accept power infeed at a particular site location without requiring costly and time-consuming reinforcement.

3.2 Reactor types and build scenarios

The market would be free to choose the most economic type of nuclear power plant provided that this complied with UK regulatory requirements. In this paper the AP1000 and EPR nuclear power stations have been used as a bounding case scenario to help frame expert group discussions although this does not imply any preference by the expert group. The leading reactor designs such the 1,100MW AP1000 or 1,600MW EPR seem most likely to compete in any future UK market, but it might be possible to choose much smaller nuclear plants such as the 110MW-165MW PBMR18 for example as a direct replacement of shut-down 200MW Magnox stations. However as the Sustainable Development Commission points out PBMR technology remains under development and is unlikely to be available in the UK until close to 2020, whereas the AP1000 and the EPR are more realistic options for

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16 For example the International Project Finance Association (IPFA) held a briefing meeting for prospective nuclear investors on 29th March 2006 at Investec Bank, London on Nuclear Power - Can Nuclear Power Generation in the UK be Funded Using Project Finance Techniques? Speakers included Investec Bank, PricewaterhouseCoopers and Deloitte & Touche.
17 Business strategy and approach to facility siting is discussed in Chapter 4 How Siting Decisions Are Made published in Whose Backyard, Whose Risk - Fear and Fairness in Toxic and Nuclear Waste Siting. Michael Gerrard. MIT Press. 1995. Gerrard was writing about radioactive waste facilities but his business observations are more widely applicable for example to nuclear power station siting.
18 The electrical output of the Pebble Bed Modular Reactor (PBMR) appears to be quite flexible and can be configured to deliver baseload outputs ranging from 110 MW to 165 MW or higher if several modular units are constructed in pairs or quad configurations.
the UK because they have already achieved regulatory clearance in important international markets, the AP1000 in the USA and the EPR in Finland and France in Europe. Against this background there are probably two main reactor build scenarios and five main reactor siting scenarios suitable for the UK.

**Reactor build scenarios**

- Construction of a single nuclear station between 1,100 and 1,600MW.
- Construction of a twin nuclear station between 2,200 and 3,200MW.

**Reactor siting scenarios**

- Construction of a replacement nuclear power station at an existing Magnox site that is shut-down and planned to be decommissioned by the NDA.\(^{19}\)
- Construction of an additional nuclear power station co-located at an existing AGR or PWR nuclear generation site owned by British Energy (BE).\(^{20}\)
- Construction of a new nuclear power station at another existing civil nuclear licensed site in NDA ownership.\(^{21}\)
- Construction of a new nuclear power station on the site of an existing coal or gas fired conventional power station.\(^{22}\)
- Construction of a new nuclear power station at a completely new greenfield location that has not previously been developed.

**3.3 Suggested hierarchy for site selection**

Figure 4 shows a suggested hierarchy for site selection which comprises of existing nuclear power stations sites currently under NDA or BE ownership as the most preferred option, followed by other existing civil nuclear sites under NDA ownership as a second choice option, existing coal or gas fired conventional power station sites as a third choice option, and finally development at new greenfield sites as the least preferred option. The thinking underpinning the suggested hierarchy is explained in Section 3.4. Figure 5 illustrates the location of existing civil nuclear sites in the UK that might be potentially suitable as first and second choice siting options. Table 2 lists the site postcodes of nuclear sites that can be used to identify their approximately location on the Ordnance Survey's GIS web site.

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19 The Nuclear Decommissioning Authority (NDA) is a Non-Departmental Public Body (NDPB) operating independently of Ministers. The NDA is a public sector organisation funded by DTI.
20 British Energy Group plc is a public company whose shares are traded and listed on the London Stock Exchange (LSE). British Energy shares are currently listed in the FTSE100 index.
21 Not all nuclear sites in the UK would realistically be available for new nuclear build for example military nuclear sites and some commercial nuclear sites in the pharmaceutical bioscience sector.
22 The Association of Electricity Producers suggest that there are approximately 14 coal fired power stations and 46 gas fired power stations in the UK. Implementation of the EC Large Combustion Plant Directive may drive the early closure of some of the 14 coal fired power stations, potentially making some of them available for new nuclear build.
Figure 4
Suggested Hierarchy for Site Selection

Figure 5
Existing Nuclear Power Station Sites and Some Other Civil Nuclear Sites Potentially Suitable for Site Selection
**Table 2**  
Postcodes of Existing Civil Nuclear Power Station Sites and Some Other Existing Civil Nuclear Sites under NDA or BE Ownership

<table>
<thead>
<tr>
<th>Nuclear Licensed Site</th>
<th>Postcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berkeley</td>
<td>GL13 9PB</td>
</tr>
<tr>
<td>Bradwell</td>
<td>CM0 7HP</td>
</tr>
<tr>
<td>Calder Hall</td>
<td>CA20 1PG</td>
</tr>
<tr>
<td>Capenhurst</td>
<td>CH1 6ER</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>DG12 6RF</td>
</tr>
<tr>
<td>Dounreay</td>
<td>KW14 7TZ</td>
</tr>
<tr>
<td>Dungeness</td>
<td>TN29 9PP</td>
</tr>
<tr>
<td>Hartlepool</td>
<td>TS25 2BZ</td>
</tr>
<tr>
<td>Harwell</td>
<td>OX11 0RA</td>
</tr>
<tr>
<td>Heysham</td>
<td>LA3 2XQ</td>
</tr>
<tr>
<td>Hinkley Point</td>
<td>TA5 1YA</td>
</tr>
<tr>
<td>Hunterston</td>
<td>KA23 9QF</td>
</tr>
<tr>
<td>Oldbury</td>
<td>BS35 1RQ</td>
</tr>
<tr>
<td>Sizewell</td>
<td>IP16 4UE</td>
</tr>
<tr>
<td>Springfields</td>
<td>PR4 0XJ</td>
</tr>
<tr>
<td>Torness</td>
<td>EH42 1QS</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>LL41 4DT</td>
</tr>
<tr>
<td>Winfrith</td>
<td>DT2 8WG</td>
</tr>
<tr>
<td>Wylfa</td>
<td>LL67 0DH</td>
</tr>
</tbody>
</table>

Maps illustrating the approximate locations of the nuclear sites listed above can be identified using their postcodes on the Ordnance Survey website at [www.ordnancesurvey.co.uk](http://www.ordnancesurvey.co.uk) and at [www.nuclearsites.co.uk](http://www.nuclearsites.co.uk)
3.4 Preferred development of existing nuclear sites

The very rapid decline of nuclear generating capacity illustrated in Figure 2 that is forecast to take place over the next 12 years implies that around 14 existing nuclear power station sites could potentially become available for redevelopment as the locations for new nuclear power stations. A further 5 existing NDA nuclear decommissioning sites might also be available in principle, although not all of these would automatically be suitable as power station sites for major generation projects. The Association of Electricity Producers suggest that there are approximately 14 coal fired power stations and 46 gas fired power stations in the UK. Implementation of the EC Large Combustion Plant Directive (LCPD) may drive the early closure of some of the 14 coal fired power stations, potentially making some of them available for new nuclear build. Around half of the coal stations may opt out of the LCPD and therefore have to close by 2015\(^{23}\). In many cases these conventional power station sites are likely to already have water and grid facilities for around 2GW of electricity generation. Finally if no other existing sites are available then it may be possible to build a nuclear power station at a completely new location. In the 1980s CEGB identified 7 greenfield sites in the UK that might potentially be suitable for new nuclear build or new coal power station build.

Although in principle a new greenfield site could be chosen to locate a nuclear power station, any new capacity should almost certainly be developed first at one of the existing nuclear sites that are likely to become available for reuse shown in Figure 5. Indeed there are good public policy and economic reasons for making use of existing sites; they already have much of the infrastructure required and grid connections installed and the framework of planning law in the UK generally prefers the expansion of existing facilities rather than development of completely new ones. Local communities may also be more likely to support (or at least accept) expansions of existing facilities if there is a clear benefit to the community such as stability of high quality employment that helps to support the local economy. Communities living near existing nuclear sites are also more likely to have a local nuclear skill base that can be utilised by the company operating the new nuclear power station, helping to reduce shrinkage of the local community from unemployment following nuclear decommissioning.

3.5 Nuclear siting in Scotland and Wales

Although national energy policy is a reserved matter decided by central government at Westminster, some aspects of its implementation have been devolved to the Scottish Executive and Welsh Assembly governments. For example Scottish Ministers have devolved powers under Section 36/37 of the Electricity Act 1989 where a developer must seek the consent and deemed planning permission from Scottish Ministers for building any electricity generating station larger than 50MW. These arrangements mean that in practice the implementation of nuclear new build in Scotland would require permission from Scottish Ministers. Similar powers have not yet been devolved to Welsh Ministers, although the Welsh Assembly government does have powers to issue planning guidance, such as for implementation of energy policy, that must be taken into account by central government for example when deciding on planning consent for any new nuclear power stations in Wales. In practice it is currently unlikely that new nuclear build would be supported in either Scotland or Wales. Scottish Executive policy on new nuclear power is set out in A Partnership for a Better Scotland (Scottish Executive, 2002) which states that "we will not support the further...

\[^{23}\text{See Page 60 of Our Energy Challenge. DTI. 23rd January 2006.}\]
development of nuclear power stations while waste management issues remain unresolved"). Similarly the Welsh Assembly Government would support an extension of the planned lifetime of the only nuclear power station currently operating in Wales at Wylfa, but the Welsh Assembly Government is not in favour of any new nuclear build in Wales. At present Wylfa is due to close in 2010. It is expected that new non-nuclear power station build in Wales (for example in Milford Haven and elsewhere) will supply electricity demand into the future. The economic and waste issues identified in the 2003 Energy White Paper are currently regarded by the Welsh Assembly Government as key factors against new nuclear build in Wales, although there is some support locally to replace Wylfa with a new nuclear plant because of the existing power station’s importance to the local economy.

3.6 Strategic environmental assessment

In July 2004 new regulations were introduced in England and Wales implementing the EC Strategic Environmental Assessment (SEA) Directive which was adopted in June 2001\textsuperscript{24,25}. The purpose of the SEA Directive is to ensure that the environmental consequences of certain plans and programmes, which would include new nuclear power stations, are identified and assessed during their preparation and before their adoption and implementation. SEA requires all reasonable alternative options to be assessed when all options are open. The intention is that public and environmental authorities can input their opinion in the planning process and all results are taken into account during the course of the planning procedure to select and implement the preferred option. An important aspect of strategic environmental assessment is that options and siting are linked together in SEA\textsuperscript{26}. Alternative options must be assessed to examine both the relative merits of the different management options being considered and also the relative merits of different potential implementation sites. It follows that the selection of sites for building new nuclear power stations would need to be underpinned by a robust Strategic Environmental Assessment.

If the Energy Review concluded that nuclear power should be retained within the UK energy mix and that the government would support new nuclear power stations, an SEA would need to be developed in the future when making decisions on what preferred sites should be selected, although an SEA would not be needed immediately for the White Paper itself\textsuperscript{27,28}. An SEA would not be required for the Energy White Paper because the SEA Directive applies to the implementation of public plans and programmes but not government policies. However an SEA would be required later when developing plans and programmes for implementing those policies downstream following publication of the White Paper. For example the Nuclear Decommissioning Authority published a draft Strategy and Environmental Report in August 2005, some 3 years after the publication of the government’s

NDA White Paper Managing the Nuclear legacy - A Strategy for Action (Cm 5552, July 2002). The strategy and environmental report were driven partly by SEA requirements\textsuperscript{29}. Should new nuclear build be required by government, the early commencement of an SEA following publication of an Energy White Paper might help developers to bring forward proposals for constructing new nuclear power stations at specific sites.

3.7 Nuclear security

The potential security advantages of different site locations were not considered in detail by the DTI expert group and are not discussed in this paper. Any new nuclear power stations must achieve the necessary level of security protection irrespective of their siting locations. The UK civil nuclear industry’s security regulator is the Office for Civil Nuclear Security (OCNS). OCNS specifies the threats that operators must be able to cope with and operators have to ensure that they have security arrangements in place. Nuclear operators are required to produce site security plans that are submitted to OCNS for regulatory approval.

4 Factors affecting site availability and options for action

4.1 Enabling, avoidance and exclusion criteria for nuclear site selection

The process of site selection for a nuclear power station involves striking a reasonable and appropriate balance between several competing factors. For example an ideal power station site would be situated close to areas of greatest electricity demand such as industrial regions, towns or cities but would be far from population centres to reduce the radiological risk to people from a possible reactor accident. Similarly the power station would be located in an isolated area with no adjacent development and existing robust transmission connections to the national electricity grid, but would not be within a National Park, an Area of Outstanding Natural Beauty (AONB), a Site of Special Scientific Interest (SSSI) or the habitat of a rare or protected species. The station would be sited near the coast close to abundant supplies of reactor cooling water but would not be vulnerable to coastal flooding from rises in sea level and storm surges that are predicted to occur more frequently as a consequence of climate change over the next 100 years.

In practice the search for the best overall site (or several sites) involves balancing these difficult issues using enabling criteria which help to identify the strongest candidate sites, avoidance criteria which help to discriminate between sites that are not ideal but still feasible, and exclusion criteria that rule-out unfeasible sites from further consideration. The US-based Electric Power Research Institute (EPRI) has developed a nuclear siting methodology based on enabling, avoidance and exclusion criteria - Siting Guide; Site Selection and Evaluation Criteria for an Early Site Permit Application (EPRI Manual 1006878, March 2002), that could perhaps be adapted to help contribute toward meeting Strategic Environmental Assessment (SEA) requirements for nuclear siting in the UK. Examples of these criteria might include:

- Enabling criteria such as availability of land for nuclear power station development, cost effective access to the electricity grid and availability of cooling water supplies.

- Avoidance criteria such as vulnerability to coastal erosion and flooding, proximity to urban population centres, National Parks, Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest and similar environments protected from development.

- Exclusion criteria such as close proximity to airports and COMAH major accident hazards sites. Avoiding proximity to COMAH sites may be important in the future especially in the light of HSC’s ongoing investigation of the explosion at the Buncefield Oil Depot incident of the 11th December 2005 led by Lord Newton. The siting of residential and industrial premises in the vicinity of COMAH sites may well be an issue raised by the incident investigation conducted by HSC.

These criteria are mainly intended as a general tool to help decision-makers weigh the relative advantages and disadvantages of different candidate sites but they are not intended to be absolutely prescriptive. For example planning consent was given for construction of the Sizewell-B PWR even though the site lies in an Area of Outstanding Natural Beauty. Similarly the Magnox nuclear power station at Trawsfynydd was constructed within a National Park.

30 The Buncefield investigation web site is www.buncefieldinvestigation.gov.uk
In Scotland planning guidance protects areas designated for their national and international heritage value but allows development to proceed in certain circumstances where there are social and economic benefits of national significance and no alternative solutions. Similarly the potential vulnerability of coastal nuclear installations to coastal erosion and storm surges does not automatically rule-out these sites from further consideration, since engineering solutions are available that can mitigate or help adapt to the impacts from climate change.

4.2 Mechanisms to protect the availability of existing NDA sites

If the Energy Review concluded that nuclear power should be retained within the UK energy mix the availability of NDA decommissioning sites for reuse would be strategically important since new nuclear build would probably take place adjacent to an existing licensed site. At present there is some risk that NDA sites might not become available because the NDA's strategic planning tends to favour early site release, although any final decisions on the reuse or lease or sale of an NDA site after clean-up would be made by DTI and Treasury Ministers. Indeed it could be argued that early site release would favour new build, although both the site owners and regulators may wish to avoid the time and resources involved in delicensing and then subsequently relicensing an existing nuclear site.

The government published a revised decommissioning policy statement in September 2004 stating that decommissioned civil nuclear facilities may represent a potentially valuable resource and that future uses of the sites should not be foreclosed. The policy statement went on to require the NDA to include an objective in its 5 year strategy on the condition to which each nuclear site would eventually be cleaned-up. For Magnox nuclear power station sites the Draft NDA Strategy, published in August 2005, proposed the decommissioning and release of the site for alternative use in 25 years or less (Draft NDA Strategy, Page 23) implying that former Magnox sites might not automatically be available for the development of new nuclear power stations. After public consultation the NDA Strategy was approved by Ministers and published in final form on 30th March 2006. A key aspiration of the revised NDA Strategy is to accelerate (bring forward) the decommissioning and clean-up of redundant Magnox nuclear sites within 25 years. The NDA plans to develop a business case for accelerating the decommissioning of reactor sites to achieve early site clearance (Approved NDA Strategy, Page 20). The NDA is also considering an alternative option involving the 80-100 year storage of LLW reactor decommissioning waste within the former Turbine Halls of decommissioned Magnox nuclear power stations (Approved NDA Strategy, Page 29). This might indirectly affect the prospects for securing local planning permission for building new nuclear power stations nearby. Moreover because of its clear focus on decommissioning and clean-up the NDA has not yet taken into account potential new build requirements in its strategy, which the NDA regards as an issue clearly outside its remit at present (Approved NDA Strategy, Page 8). The NDA also felt that it would be inappropriate to seek a ban on the development of airports near NDA nuclear facilities, preferring instead to be consulted during the planning process (Approved NDA Strategy, Page 139). The development of a local airport might rule-out an NDA site for new nuclear build.

31 The clean-up objectives for civil nuclear sites are explained in paragraph 6 of The Decommissioning of the UK Nuclear Industry's Facilities. Statement of the UK Government and devolved administrations policy on the decommissioning of nuclear facilities. September 2004.
32 The NDA's proposed strategy over the next 5 years for accelerated (25 year) clean-up of Magnox nuclear power stations was explained in NDA Strategy - Draft for Consultation. 11th August 2005.
The government’s decommissioning policy statement is already sufficiently flexible to allow the reuse of former Magnox stations but nevertheless a statutory Direction from DTI to the NDA could help to clarify the government’s expectations for the availability of Magnox sites for new build and to protect the necessary electricity generation support infrastructure such as maintaining connections to the national grid which would be costly to replace. The NDA would probably need to revise its NDA Strategy to take into account new requirements for ensuring Magnox sites remain available for replacement nuclear reactor build.

The overall prospects for the availability of NDA sites for new build could be improved using a combination of guidance to the NDA and planning development controls, for example:

- By issuing directions from DTI Secretary of State to the NDA using powers under the Energy Act 2004, requiring the NDA to maintain key infrastructure such as grid connections needed for the potential reuse of Magnox nuclear power station sites.

- By issuing Planning Policy Statements and Guidance (PPS and PPG) from the ODPM Secretary of State to Local Planning Authorities in England, limiting building and industrial development adjacent to existing nuclear power station sites.

4.3 Planning policy statements for local authorities and the NDA

The government’s White Paper *Managing the Nuclear Legacy - A Strategy for Action* (Cm 5552, July 2002) acknowledged that the decommissioning of the nuclear industry would result in a gradual reduction of nuclear employment and recognised the need for economic regeneration particularly for isolated communities which relied on the nuclear sector. The Energy Act 2004 subsequently gave the NDA several functions and duties intended to help support the economic life of communities and to consider the effects of the NDA’s decommissioning strategy on local people. Over the next few years as progress is made with planning for the decommissioning and release of former nuclear sites both the NDA and local planning authorities are likely to receive a number of proposals to help regenerate their local economies, for example involving the creation of industrial parks, technology centres and housing developments. Although these developments are highly desirable from an economic standpoint, they could potentially create difficulty or possibly even prevent the reuse of former Magnox sites for new nuclear power stations because of nuclear safety regulatory requirements for reactor licensing explained in Box 4. In essence the safety licensing regime requires the minimisation of any man-made hazards from nearby industrial facilities that might accidentally damage the reactor and also the practical capability to rapidly evacuate members of the local community if a reactor accident did occur for some reason.

The framework of planning law in England is very complex but at national level relies on Planning Policy Statements (PPS) and Planning Policy Guidance Notes (PPG) to set the strategic context for Regional Spatial Strategies and Local Development Frameworks that local planning authorities rely upon when making decisions on planning applications. Planning Policy Statements are issued by ODPM to local planning authorities under the planning hierarchy introduced by the Planning and Compulsory Purchase Act 2004. The land surrounding existing NDA nuclear power station sites could be protected from further development - helping to retain the site for new nuclear reactor build - by issuing Planning Policy Statements and Guidance, for example limiting any housing, industrial and airport development immediately adjacent to existing NDA nuclear power stations.
At present the planning system can also establish land use control mechanisms to protect areas identified for strategic purposes such as marine containerport and airport development. If nuclear power station development is regarded by ODPM as in the national interest then it may be possible to develop a similar planning mechanism for protecting land for nuclear power station development. For example this might take the form of a statute whereby local authorities would be obliged to consult with government on any development proposals with the potential for impact on the protected land use (in this case the nuclear installation).

4.4. Planning policy statements in Scotland and Wales

It is currently unlikely that new nuclear build would be supported in either Scotland or Wales for reasons discussed in Section 3.5 of this paper. The devolved governments have powers to issue their own planning policy statements but Scottish and Welsh planning policy would be unlikely to protect the availability of existing nuclear sites for new nuclear development.

In Scotland the developer of a proposed new nuclear power station would be required to consider Scottish National Planning Policy Guidance, Planning Advice Notes and the planning authority's Structure Plan. New nuclear power station proposals would probably also be subject to strategic environment assessment where in December 2005 the Scottish Parliament approved new strategic environmental assessment law which applies SEA to strategies (Scottish policies) as well as plans and programmes under the Environmental Assessment (Scotland) Act 2005. Power station proposals would also be subject to consideration under the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2000 and the Town and Country Planning (Scotland) Act 1997. These arrangements give considerable decision-making powers to the Scottish Executive.

4.5 Cooling water abstraction and discharge

Nearly all civil nuclear power stations in the UK are located on the coast to take advantage of the availability of seawater for cooling because the UK has no rivers of adequate size to directly cool a large nuclear power station\(^{34,35}\), although it would be possible to utilise rivers for supplying fresh water to cooling towers. For coastal nuclear power stations the intake of filtered seawater is used as once-through cooling water for condensers that are attached to steam turbines that generate electricity from the reactor. The volume of seawater required can be substantial at around 60\(\text{m}^3\) per second for a single reactor or 120\(\text{m}^3\) per second for a twin reactor. It would be possible to site reactors inland and construct cooling towers as used by conventional coal and gas fired generating stations such as Didcot-A and Didcot-B in Oxfordshire, although cooling towers are very large structures which substantially damage the local amenity value from visual intrusion, causing significant difficulties with local public acceptance and obtaining planning consents, as well as adding to the cost of construction of the nuclear power station and reducing the station’s power output by around 3-5\%\(^{36}\).

\(^{34}\) Although most reactors in the UK are located on the coast one exception was the 390 MW Magnox Nuclear Power Station built inland at Trawsfynydd in Wales, which relied on cooling water from lake Trawsfynydd. The reactor was closed in 1991. In continental Europe some PWR nuclear power stations are sited inland using cooling water from large rivers with additional cooling towers.

\(^{35}\) The Royal Commission on Environmental Pollution (RCEP) commented on the unsuitability of rivers for reactor cooling water in its Sixth Report Nuclear Power and the Environment. RCEP 1976.

\(^{36}\) Cooling tower recirculation pumps may consume up to 5\% of the electricity output of the reactor.
Cooling towers potentially have an important environmental advantage in that they require about 98% less water than sea cooling and consequently have much lower abstraction requirements\(^{37}\). However cooling towers also have an environmental disadvantage in that evaporated cooling water is lost to atmosphere and must be replenished from fresh water supplies, whereas no cooling water is lost from sea cooling (it is simply recirculated between the power station and the sea which acts as a cooling sink for waste heat). An ideal coastal site would have inshore deep water and a tidal regime with good heat dispersion. Under less ideal conditions new build at some existing coastal nuclear sites may require cooling towers for example where marine water abstraction is limited for some reason or where there may be difficulty dispersing heat in the sea. For example further nuclear development in the River Severn Estuary or the Blackwater Estuary may require cooling towers because of limited cooling water availability, while further development in Morecambe Bay might require cooling towers because of the potential difficulty of dispersing waste heat within the Bay.

### 4.6 Climate change adaptation and flood defence planning

The need to develop low carbon energy supplies to help mitigate the threat of serious climate change from global warming is recognised as one of the main justifications for building a new generation of nuclear power stations\(^{38}\). In January 2006 Prime Minister Tony Blair described the threat of climate change as the world's greatest environmental challenge\(^{39}\). Despite the attraction of nuclear power as a low carbon energy source, there remains a drawback that most nuclear power stations are sited in low lying coastal locations which may be at risk from coastal erosion and serious flooding as a result of climate change. The UK radioactive waste agency Nirex published a research report in 2005 indicating that many coastal nuclear sites (including nuclear power stations) were vulnerable to the effects of sea level rise from climate change, particularly storm surges which can cause severe but temporary coastal flooding and accelerated coastal erosion\(^{40}\). The sites that Nirex highlighted as at greatest risk were generally located in low lying areas of the South of England where electricity demand from new nuclear capacity is forecast to be greatest. However it is important to remember that risks from extreme weather conditions and flooding are not new and have been taken into account within HSE-NII licensing requirements for nuclear plants since the 1970s\(^{41}\). HSE-NII Safety Assessment Principles P120, P133, P134, P138, P139 and P140 require that nuclear plants are protected to withstand extreme weather events that could occur once in every 10,000 years (although such extreme weather events might now occur more frequently in the future as a result of climate change). For new nuclear build consideration would need to be given to flood protection over the expected 100 year lifecycle of the power station, spanning construction, operation and final decommissioning. This would need to take into account predicted sea level rise including credible extreme weather scenarios and events.

\(^{37}\) Cooling towers need freshwater supplies to replace water lost by evaporation from the cooling towers (make-up water) and during maintenance to remove any build-up of salt deposits (purge water). Typically only about 2% of cooling water recirculation flow is lost by evaporation.

\(^{38}\) *The Role of Nuclear Power in a Low Carbon Economy*. Sustainable Development Commission. March 2006. However the Commission did not support the overall case for new nuclear capacity.

\(^{39}\) Foreword by Prime Minister Tony Blair. *Avoiding Dangerous Climate Change*. Proceedings of the Hadley Centre Exeter Conference on Avoiding Dangerous Climate Change. Published jointly by Defra and Cambridge University Press. 30th January 2006.


Sensible planning would dictate that the construction of a new nuclear reactor may require some upgrading of existing sea defences or protection of stretches of coastline that were previously relatively unprotected. The sea defences near a new build nuclear power station would probably need to be sufficient to protect any new power station over its 100 year lifecycle. Adapting to the impacts of climate change would not automatically rule-out new nuclear build in coastal locations because civil engineering solutions would be possible to strengthen sea defences near coastal power station sites, although these might add to the capital cost of construction of the station depending on whether either the Environment Agency or the nuclear site developer was responsible for funding flood defence. The Environment Agency funds some flood defence schemes but is not responsible for funding the flood defence of industrial developments.

The Environment Agency’s climate change publication *Time to Get Ready* (EA, May 2005) estimates in *Putting A Price on Climate Change* that at present adapting to climate change costs £400 million per year and will cost the UK from £22 to £75 billion over the next 80 years. Some individual coastal flood defence schemes have cost from £18 to £40 million. Recent research by the Environment Agency suggests that the costs of providing a high level of protection for a site with high tidal and wave exposure are around £10,000 per metre.

Conservatively assuming an overnight capital build cost of £1.2 billion per station for building a series-of-four AP1000s or EPRs42, climate adaptation costs could represent from 1.5% to 3.3% of capital build costs, with a central value perhaps around 2% of capital build costs. Viewed from an economic perspective, climate adaptation costs alone are therefore not likely to significantly influence location decisions on nuclear power station siting.

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42 In economic forecasting the overnight capital build cost of a nuclear plant is the cost of a plant if the plant were built and paid for overnight, without inflation and interest costs. Overnight costs are the sum of all costs without considering the time-value-of-money. They are expressed as if all costs occurred instantly or ‘overnight’. Overnight costs are particularly useful for analysing the underlying costs of building nuclear plants because nuclear plants may take several years to build and bring into operation, during which time inflation and interest rates can have a significant escalation effect on the final cost of the plant, making economic comparisons between nuclear plants difficult. In June 2005 the Westminster Energy Forum (WEF) estimated the typical overnight build cost of a modern PWR as about £1.2 billion per plant assuming that a series-of-four units were built, and allowing first-of-a-kind costs of +30% and a further +25% contingency costs. See *Nuclear New Build: Key Investment Issues & Implications for Strategic UK Energy Policy* by Chris Lambert and Nigel Hawkins. Westminster Energy Forum. 23 June 2005. www.westminsterenergy.org
4.7 Grid connection and transmission

In the liberalised competitive electricity supply market in the UK a principal economic requirement for the development of a new nuclear power station is the need for good access to the existing electricity transmission infrastructure. Siting a nuclear power station close to areas of demand reduces the need for long-distance power transfers that in turn reduce losses from the electricity grid, improving the efficiency of the network and reducing supply costs. Sufficient transmission capacity would be needed to export generation from the nuclear power stations to electricity consumers connected to the grid. Moreover an important factor is the ability of the grid system to accept power infeed at a particular site location without requiring costly and time-consuming reinforcement.

In principle it is possible to connect any generator at any site to the electricity grid. However in practice the specific location of an electricity generator has a major impact on the costs of connection to the grid and on the costs of then transporting the electricity generated to areas of demand. The key drivers of cost are the size of the connection needed (MW); the transmission distance to the grid (km); the need to strengthen the grid to receive and distribute the electricity generated; the local landscape through which transmission lines must pass through; and the costs of electricity transport to areas of demand. Some of these costs can be avoided if the necessary connection and transmission infrastructure is already partially or fully in place. Replacing old plant with new is thus the best way to minimise cost, but adding new capacity at a site which already has a grid connection can also offer significant cost savings compared with new build in a completely greenfield location.

The energy markets regulator Ofgem has pointed out that the costs associated with connecting new nuclear power stations to the national electricity grid can be regarded from two different perspectives - the partial cost to the nuclear developer for connecting to the grid and the total cost to the UK economy for reinforcing the transmission network. Ofgem point out that transmission reinforcement costs can be significant. For example in 2004 Ofgem authorised infrastructure investment by National Grid plc of £560 million to reinforce the transmission network in Scotland to support the development of renewable generation.

These long term grid investment costs are shared collectively between all users of the electricity grid. The grid operating company National Grid plc (‘National Grid’) recovers its investment by charging an overhead cost to the electricity generating companies. In essence National Grid levies two main charges on electricity generators - an annual connection charge for joining the network (‘connection charge’ £/year) and a separate usage charge for utilising the transmission network (‘use-of-system’ charge £/kW/yr/year).

The use-of-system charge varies regionally throughout the UK depending upon geographic variations between electricity supply and demand explained below. In broad terms use-of-system charges are higher in the North of the UK and lower in the South of the UK, reflecting the greater demand for electricity in London and Southern England (see Figure 6).

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43 Discussion and correspondence between Jackson Consulting and Ofgem. 21st April 2006.
44 £560 million at 2004 prices. The investment would be spread over a 40 year period.
45 Connection charges enable National Grid to recover, with a reasonable rate of return, the costs involved in providing assets that afford connection to the GB transmission system. Costs are recovered via an annual charge. The charges assume a rate of return of 6% over 40 years plus RPI.
Figure 6
Proximity of Existing Nuclear Power Station Sites and Some Other Nuclear Sites to Zones of Grid Connection Opportunity Forecast by National Grid plc

Source: Adapted from Figure E.12 GB Generation Connection Opportunities published in Opportunities for New Generation and Demand in Great Britain Seven Year Statement National Grid Company plc (May 2005)
National Grid is required by its Ofgem transmission licence to propose use-of-system charges that are cost reflective, reflecting the additional costs to the transmission network of siting generation remotely from demand. These economic signals to the market ensure that new transmission assets that might not have a strong economic case are not developed\(^46\). National Grid's market assessment of available connection and demand opportunities over the next 7 years is shown in Figure 6, which indicates that demand and connection opportunities are very limited in the North of the UK and greatest in the South of the UK. The availability of existing grid connections is important for new nuclear build because the upgrading (reinforcement) of transmission and the construction of new connections and transmission pylons is very costly at typically £0.5 million per km (2001 prices). For example a study published by Cumbria County Council in March 2006 estimated that the total grid connectivity costs for construction of an AP1000 at Calder Hall at Sellafield would be in the range from £66 million for a single AP1000 to £223 million for a twin AP1000 assuming that a new 80km transmission line would be built from Calder Hall to the grid connection at Carlisle\(^47\). The cost of upgrading Calder Hall's single transmission circuit would be £66 million but the cost of installing a second circuit needed for a twin reactor would be much higher at £157 million (£223 million total). The cost escalation for a second transmission line is mainly due to the need to bury parts of the line underground. Underground cabling is useful for constructing transmission lines across environmentally sensitive areas but costs around 20 times higher than overhead transmission pylons. Note that these cost estimates are specific to Calder Hall and different costs would apply for grid connection and reinforcement at other nuclear sites situated elsewhere in the UK that would need to be assessed individually.

The construction of new electricity transmission pylons and cables also requires planning permission that can be difficult to obtain, especially if the network connections cross National Parks or other environmentally sensitive environments that are protected by development controls under planning law. Nevertheless it is important to note that planning policies do not automatically rule-out transmission lines from being built in protected areas, especially if there is a compelling social or economic benefit judged to be of national importance. For example the Trawsfynydd Magnox nuclear power station was granted planning consent even though it was located in a National Park. The Planning Inspector specifically asked his Minister to decide whether electricity production or the restriction of development in a national park should take precedent. Similarly the nuclear site at Sizewell lies in an Area of Outstanding Natural Beauty (AONB) but planning permission was granted for development of the Sizewell-B PWR. On the other hand it has taken National Grid nearly 10 years to obtain planning consent for a second grid transmission line in Yorkshire.

\(^46\) Reply to Q476 and Q479 Environmental Audit Committee Inquiry Keeping the Lights On - Nuclear, Renewables and Climate Change. Oral evidence by Mr Nick Winser Group Director National Grid and Mr Louis Dale Regulatory Strategy Manager National Grid. 16 November 2005.

Several NDA and BE sites are situated in strategically desirable locations in the south of the UK where increase in electricity demand is forecast by the National Grid Company to be greatest over the next 7 years, particularly in London (Zone 14. Very High. 3 GW), the Midlands (Zone 11. High. 2GW), Southern England (Zone 16. High. 2GW) and South West England (Zone 17. High. 2GW). Figure 6 shows the proximity of these NDA and BE sites to zones of future electricity demand forecast by National Grid. National Grid divided the UK into 17 study zones and five broad demand opportunity groups; very low, low, medium, high and very high. The opportunity groups indicate the ability to connect new generation without an associated need for major transmission reinforcement, that could be expensive and require planning consents. National Grid comment that new generation located in the South is far less likely to incur the need for major transmission reinforcement than new generation in the North. Moreover because powerflows to the Midlands through the Scottish and English grid systems would require significant reinforcement it is unlikely that applications for new generation in Scotland or the North of England can be accommodated by the grid within the next 7 years. At present National Grid is considering an unprecedented number of 150 new applications to connect 10GW of new wind generation in Scotland to the grid. In effect any new nuclear development would probably have to join the back of the applications queue, and reinforcement would be unlikely to be available before 2016 unless some wind generation projects were cancelled. Another difficulty is that at present it is not possible to reserve (or ‘bank’) a grid connection at a particular site for a new nuclear power station. Thus it would be possible for another non-nuclear generator to build a gas fired power station sooner, perhaps adjacent to the nuclear site or within the same generation zone, and connect to the grid system more quickly than the much longer timescale needed to construct and bring the nuclear station into operation. This could then have a significant negative effect on the economics of the nuclear station, affecting the generation tariff and the need for further costly reinforcement of the grid.

The availability of the national grid both to connect to and receive power from new nuclear power stations could have a considerable impact on the sequencing and timing of new build. An important factor is the ability of the grid system to accept power infeed at a particular site location without requiring costly and time-consuming reinforcement. From a grid perspective the simplest option may be to bring new nuclear generation online immediately after old nuclear generating plant was shut-down, taking advantage of existing grid connections and transmission capacity. However in practice nuclear generators worldwide are now extending the lifetimes of their existing nuclear plant assets where this can be achieved safely. The business driver for British Energy, the main nuclear generator in the UK, is to maximise profits by extending the lifetime of its existing stations through Plant Life Extension (PLEX) stretching the closure dates of stations into the future. Lifetime extension would offer the government more flexibility over the timing of new nuclear build but the downside is that it might not be possible to connect significant new nuclear build to the grid in the near term. The impact of grid connectivity on the timing of new nuclear build is shown in Figure 7.

48 Figure E12. GB Generation Connection Opportunities published in *Great Britain Seven Year Statement*. National Grid Company plc. May 2005. The 7 year statement is a comprehensive 175 page forecast of future demand trends intended to assist existing and prospective new users of the GB electricity transmission system in assessing opportunities available to them for making new or additional use of the GB transmission system in the electricity market.

Figure 7 summarises the overall suitability of existing sites for new build, based on a simple traffic light assessment of their development potential, considering each site in relative isolation. Ofgem has pointed out that in practice there could be transmission barriers if some of the ‘green’ sites were co-developed together in a new nuclear programme. Such combined development might result in the need for extensive transmission reinforcement. This is especially the case when other potential (non-nuclear) generation developments in the same region are taken into account. Significant additional costs of the order of £100 million per year may also be necessary to balance the power system to cope with the risk of losing larger generation infeeds than currently provided for by the network. The electricity network is protected against the largest single loss that could occur on the grid if a single generating plant shut-down unexpectedly. At present the largest single potential loss is based on the 1,200MW output of the largest nuclear power station Sizewell-B but this balancing arrangement may need to increase if a larger 1,600MW EPR station was built (although the network risk could be reduced by building twin stations maintaining one in standby mode).

In summary the costs for connecting a new nuclear power station to the national grid and for reinforcing the grid to distribute electricity to areas of demand can substantially affect the overall economics of siting. But the economic impact can be regarded from two different standpoints; (1) from the perspective of grid connection costs (up to £223 million) paid for by the nuclear developer and (2) from the wider perspective of total costs to the UK economy for transmission reinforcement that are shared between all users of the grid (up to £500 million). For nuclear sites remote from areas of demand, the cost of grid connection could range from around £66 million (single reactor) to £223 million (twin reactor). These indicative cost estimates for grid connection by the Cumbria Partners Study (March 2006) are generally similar to costs ranges of £50 million to £200 million estimated by National Grid. Note that these costs are for connection only and exclude the costs of grid reinforcement.

Conservatively assuming an overnight capital build cost of £1.2 billion per station for building a series-of-four AP1000s or EPRs, grid connection costs could represent between around 5.5% and 18.6% of capital build costs, with a central value perhaps around 10% of capital build costs. Thus grid connectivity factors can significantly affect overall project economics (greater than 10% of estimated capital costs for new nuclear build). Viewed from an economic perspective, grid costs are probably likely to influence siting decisions.

Grid connection costs for siting more closely to areas of demand would probably be much lower and hence more economically favourable. Studies by BNFL suggest that the costs of grid connection for an ‘average’ site might be only around 5% of the capital build cost.

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50 National Grid operates a trading market for network balancing services where generating companies are paid to produce extra electricity if the output from another generator shuts-down unexpectedly. The total system balancing cost is about £400 million per year. National Grid estimate that balancing costs for a single large 1600MW reactor would be around £100 million per year (see below).


52 The typical overnight build costs of a modern PWR are explained in Footnote 42.
5 Development potential of existing nuclear power station sites

A preliminary assessment by the DTI expert group of the development potential of existing nuclear power station sites for new nuclear build identified 12 sites potentially suitable for a new single reactor (1,100MW to 1,600MW) and 10 sites potentially suitable for a new twin reactor (2,200MW to 3,200MW). The assessment findings are summarised in Figure 7 below and were based on discussion and expert judgement informed by the conclusions of some previous studies and existing knowledge of the sites by their owners BE and the NDA.

Figure 7
Preliminary Assessment of Development Potential of Existing Nuclear Power Station Sites

<table>
<thead>
<tr>
<th>Existing Nuclear Power Station</th>
<th>Land Owner</th>
<th>New Single Reactor</th>
<th>New Twin Reactor</th>
<th>Expected Date Available</th>
<th>Comment on Site Development Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinkley Point</td>
<td>BE &amp; NDA</td>
<td>Green</td>
<td>Green</td>
<td>Now</td>
<td>3200 MW twin reactor may need planning consent for additional transmission line and investigation of grid stability. Possible conflict with potential windfarm development near site.</td>
</tr>
<tr>
<td>Sizewell</td>
<td>BE &amp; NDA</td>
<td>Green</td>
<td>Green</td>
<td>Now</td>
<td>3200 MW twin reactor may need planning consent for additional transmission line and investigation of grid stability.</td>
</tr>
<tr>
<td>Bradwell</td>
<td>BE &amp; NDA</td>
<td>Green</td>
<td>Amber</td>
<td>Now</td>
<td>Limited cooling water availability at Gloucester Estuary for twin reactor because of environmental sensitivity and limited on abstraction capacity. Planning consent may be needed for transmission line upgrade.</td>
</tr>
<tr>
<td>Dungeness</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Twin reactor would need planning consent for additional transmission line towards London. Environmentally sensitive location.</td>
</tr>
<tr>
<td>Hinkley Point</td>
<td>BE &amp; NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>2011 +</td>
<td>Limited grid connection opportunity in Scotland means twin reactor connection only realistic after closure of existing AGR in 2011 or later if AGR extended. 1800 MW single or twin may need planning consent for new transmission line.</td>
</tr>
<tr>
<td>Hartlepool</td>
<td>BE</td>
<td>Green</td>
<td>Amber</td>
<td>2014 +</td>
<td>Limited grid connection opportunity in NE means near reactor connection only realistic after closure of existing AGR in 2014 or later if AGR extended. 3200 MW twin would need upgrade of transmission line from 275kV to 400kV.</td>
</tr>
<tr>
<td>Torness</td>
<td>BE</td>
<td>Green</td>
<td>Amber</td>
<td>2015 +</td>
<td>Limited grid connection opportunity in Scotland means new reactor connection only realistic after closure of existing AGR in 2015 or later if AGR extended.</td>
</tr>
<tr>
<td>Wylfa</td>
<td>NDA</td>
<td>Green</td>
<td>Amber</td>
<td>2011 +</td>
<td>Limited grid connection opportunity in Wylfa means new reactor connection only realistic after closure of Wylfa in 2011 or later if extended. 2300 MW or 3200 MW twin would need planning consent for new transmission line.</td>
</tr>
<tr>
<td>Heysham</td>
<td>BE</td>
<td>Green</td>
<td>Amber</td>
<td>2014 +</td>
<td>Limited grid connection opportunity in Wylfa means new reactor connection only realistic after closure of Heysham-1 in 2014. Twin station would have limited cooling water availability because of local development in Morecambe Bay.</td>
</tr>
<tr>
<td>Cumbra</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Reserves planning consent for lengthy new transmission line avoiding Lake District National Park and limited grid connection opportunity.</td>
</tr>
<tr>
<td>Cloca</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Limited cooling water availability at Sellafield because of environmental sensitivity and limits on abstraction capacity. Same grid reinforcement necessary.</td>
</tr>
<tr>
<td>Chaplain Garden</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>2015 +</td>
<td>Cooling towers and freshwater reservoir necessary because no assewered cooling. Limited grid connection opportunity in Scotland and 30 km because of many current applications for connection of wind generation to the national grid.</td>
</tr>
<tr>
<td>Barroway</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Requires planning consent for new transmission line. Existing grid connection disallowed. Very limited cooling water availability in upper Severn Estuary because of environmental sensitivity and limits on abstraction capacity.</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>NDA</td>
<td>Amber</td>
<td>Amber</td>
<td>Now</td>
<td>Cooling towers and freshwater reservoir necessary because no assewered cooling. Requires planning consent for cooling towers in Snowdonia National Park.</td>
</tr>
</tbody>
</table>

Source: Adapted from Preliminary Assessment of Development Potential for Single and Twin Reactors by DTI Expert Group (April 2006)

The development potential has been assessed by members of the DTI Expert Group using a simple traffic light system. The assessment assumes that a new nuclear power station built in the UK would generate between 1,100 - 1,600 MW for a single station or between 2,200 - 3,200 MW for a twin station. It may be feasible to build smaller capacity (e.g. 110 MW-190 MW) reactor stations at a wider range of locations. * BE cars cross arm is adjacent to the NDA’s Belcham reservation.
### Glossary of terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AGR</td>
<td>Advanced Gas-cooled Reactor, operated by British Energy Group plc</td>
</tr>
<tr>
<td>AP1000</td>
<td>Advanced-Passive PWR nuclear reactor, developed by Westinghouse</td>
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<tr>
<td>BE</td>
<td>British Energy Group plc, commercial nuclear power station operator</td>
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<tr>
<td>BEPO</td>
<td>British Experimental Pile Zero, an early British nuclear research reactor</td>
</tr>
<tr>
<td>BNFL</td>
<td>British Nuclear Fuels plc, public sector Magnox nuclear power station operator</td>
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<tr>
<td>CEBG</td>
<td>Central Electricity Generating Board</td>
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<tr>
<td>COMAH</td>
<td>Control of Major Accident Hazards Regulations, regulated by HSE and EA/SEPA</td>
</tr>
<tr>
<td>CoRWM</td>
<td>Committee on Radioactive Waste Management, Defra</td>
</tr>
<tr>
<td>Defra</td>
<td>Department for Environment, Food and Rural Affairs, UK government</td>
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<tr>
<td>DTI</td>
<td>Department of Trade and Industry, UK government</td>
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<tr>
<td>EA</td>
<td>Environment Agency, environmental regulator in England and Wales</td>
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<tr>
<td>EPR</td>
<td>European Pressurised-water Reactor, developed by Framatome and Siemens</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System, mapping software allowing queries by postcode</td>
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<tr>
<td>GLEEP</td>
<td>Graphite Low Energy Experimental Pile, an early British nuclear research reactor</td>
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<tr>
<td>HSE</td>
<td>Health &amp; Safety Executive, UK safety regulator</td>
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<tr>
<td>HSC</td>
<td>Health &amp; Safety Commission, body overseeing the executive work of HSE</td>
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<tr>
<td>LLW</td>
<td>Low Level Waste, radioactive waste from reactor decommissioning</td>
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<tr>
<td>NAO</td>
<td>National Audit Office</td>
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<tr>
<td>NDA</td>
<td>Nuclear Decommissioning Authority</td>
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<tr>
<td>NG</td>
<td>National Grid plc, UK electricity grid operating company</td>
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<tr>
<td>NII</td>
<td>Nuclear Installations Inspectorate, part of HSE</td>
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<tr>
<td>Nirex</td>
<td>An executive body responsible for radioactive waste disposal planning in the UK</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>OCNS</td>
<td>Office for Civil Nuclear Security, UK nuclear industry security regulator</td>
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<tr>
<td>ODPM</td>
<td>Office of the Deputy Prime Minister, UK government</td>
</tr>
<tr>
<td>Ofgem</td>
<td>Office of Gas and Electricity Markets, UK energy markets regulator</td>
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<tr>
<td>PBMR</td>
<td>Pebble Bed Modular Reactor, a small reactor design developed by Eskom</td>
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<tr>
<td>R2P2</td>
<td>Reducing Risks Protecting People, HSE’s risk management policy</td>
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<tr>
<td>RAF</td>
<td>Royal Air Force</td>
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<tr>
<td>RCEP</td>
<td>Royal Commission on Environmental Pollution</td>
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<tr>
<td>SAPs</td>
<td>Safety Assessment Principles for Nuclear Plants, developed by HSE</td>
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<tr>
<td>SDC</td>
<td>Sustainable Development Commission, advisory body to UK government</td>
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<tr>
<td>SEA</td>
<td>Strategic Environmental Assessment, an EC Directive requirement</td>
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<tr>
<td>SRD</td>
<td>Safety and Reliability Directorate of the UKAEA during the 1960s-1980s</td>
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<tr>
<td>SEPA</td>
<td>Scottish Environment Protection Agency, environmental regulator in Scotland</td>
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<tr>
<td>TOR</td>
<td>Tolerability of Risk from Nuclear Power Stations, developed by HSE</td>
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<tr>
<td>UKAEA</td>
<td>United Kingdom Atomic Energy Authority</td>
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