

NUCLEAR ENERGY FUTURES PAPERS

The Nuclear Energy Futures Project

The British Nuclear Industry: Status and Prospects

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Abstract

Considerable debate over the future of the United Kingdom's nuclear power industry resulted in publication of a White Paper in January 2008 and ambitious proposals for new build. While nuclear power has met about one-fifth of UK electricity needs in the past decade, about one-third of Britain's total electricity generating capacity is expected to need replacing over the next 20 years, partly because most existing nuclear power stations will close. Concerns about security of supply and climate change frame the UK debate, and while the government has concluded that new nuclear build is a major part of any solution, public opinion remains deeply divided – not least because of the legacy of costly and inefficient former UK nuclear projects. This paper explores the status and prospects of the British nuclear industry, including its history, UK energy strategy and the evolving regulatory framework, and discusses the continuing concerns surrounding the prospective new nuclear build in the UK.



CIGI's Nuclear Energy Futures Project is being conducted in partnership with the Centre for Treaty Compliance at the Norman Paterson School of International Affairs, Carleton University, Ottawa.

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Letter from the Executive Director

On behalf of The Centre for International Governance Innovation (CIGI), it is my pleasure to introduce the Nuclear Energy Futures Papers Series. CIGI is a Canadian-based non-partisan think tank that addresses international governance challenges and provides informed advice to decision makers on multilateral governance issues. CIGI supports research initiatives by recognized experts and promising academics; forms networks that link world-class minds across disciplines; informs and shapes dialogue among scholars, opinion leaders, key policy makers and the concerned public; and builds capacity by supporting excellence in policy-related scholarship.

CIGI's Nuclear Energy Futures Project is chaired by CIGI Distinguished Fellow Louise Fréchette and directed by CIGI Senior Fellow Trevor Findlay, Director of the Canadian Centre for Treaty Compliance at the Norman Paterson School of International Affairs, Carleton University, Ottawa. The project is researching the scope of the purported nuclear energy revival around the globe over the coming two decades and its implications for nuclear safety, security and nonproliferation. A major report to be published in 2009 will advance recommendations for strengthening global governance in the nuclear field for consideration by Canada and the international community. This series of papers presents research commissioned by the project from experts in nuclear energy or nuclear global governance. The resulting research will be used as intellectual ballast for the project report.

We encourage your analysis and commentary and welcome your thoughts. Please visit us online at www.cigionline.org to learn more about the Nuclear Energy Futures Project and CIGI's other research programs.

John English
Executive Director



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Acronyms and Abbreviations

AEA	Atomic Energy Authority	LLW	Low Level Waste
AGR	Advanced Gas-cooled Reactor	LWR	Light Water Reactor (either BWR or PWR)
BERR	Department for Business, Enterprise & Regulatory Reform	MOX	Mixed oxide (fuel fabrication)
BNFL	British Nuclear Fuels Ltd	MW	Megawatts (a million watts)
BNG	British Nuclear Group (a subsidiary of BNFL)	NDA	Nuclear Decommissioning Authority
BWR	Boiling Water Reactor (a type of LWR)	NFFO	Non-Fossil Fuel Obligation
CCGT	Combined-Cycle Gas Turbine	NIA	UK Nuclear Industry Association
CEGB	Central Electricity Generating Board	NII	Nuclear Installations Inspectorate
CNC	Civil Nuclear Constabulary	NLFAB	Nuclear Liabilities Financing Assurance Board
CoRWM	Committee on Radioactive Waste Management	NNL	National Nuclear Laboratory
DTI	Department of Trade and Industry (later replaced by BERR)	NPT	Non-Proliferation Treaty
EDF	Électricité de France	OCNS	Office for Civil Nuclear Security (part of HSE)
EIA	Environmental Impact Assessment	PBMR	Pebble Bed Modular Reactor
ETS	EU Emissions Trading Scheme	PBO	(Sellafield) Parent Body Organisation
FBR	Fast Breeder Reactor	PWR	Pressurized Water Reactor (a type of LWR)
GDA	Generic Design Assessment	RO	Renewables Obligation
GLEEP	Graphite Low Energy Experimental Pile	SEA	Strategic Environmental Assessment
GW	Gigawatts (a thousand million watts)	SMP	Sellafield MOX Plant
HLW	High Level Waste	SSA	Strategic Siting Assessment
HSE	Health and Safety Executive	THORP	Thermal Oxide Fuel Reprocessing Plant
HWR	Heavy Water Reactor	UKSO	UK Safeguards Office (part of HSE)
IAEA	International Atomic Energy Agency		
ILW	Intermediate Level Waste		
INS	International Nuclear Services (a subsidiary of Sellafield Ltd)		

Introduction

“Nuclear power is a tried and tested technology. It has provided the UK with secure supplies of safe, low-carbon electricity for half a century. New nuclear power stations will be better designed and more efficient than those they will replace. More than ever before, nuclear power has a key role to play as part of the UK’s energy mix.”

Gordon Brown, UK Prime Minister, *Foreword to Meeting the Energy Challenge – A White Paper on Nuclear Power*, January 2008 (BERR, 2008a).

Historically, the United Kingdom has met most of its energy needs with domestic sources: until the middle of the 20th century, coal; and since the 1970s, oil and gas from the North Sea. Since the 1950s, nuclear power, fuelled by imported uranium, has generated a significant proportion of UK electricity, in the 1990s reaching a peak of nearly 30 percent of electricity output. Over the past decade nuclear power has met about one-fifth of UK electricity needs. Currently, nuclear power provides approximately 19 percent of UK electricity generation and 7.5 percent of total UK energy supplies and 3.5 percent of total UK energy use (BERR, 2008a: 13).¹

About one-third of the UK’s existing electricity generating capacity is expected to need replacing over the next two decades, since most of the existing nuclear power stations will close along with a number of oil and coal fired electricity power stations. Life extensions to the existing nuclear power stations are possible. However, because of the length of time required to plan and build nuclear power stations, new nuclear generation, if it happens at all, would only make a limited contribution before 2020. Other technologies (e.g. such as gas, renewables and coal) are expected to fill

an “energy gap” during this period. Given these realities, the key question that the UK faces, is whether to build new nuclear capacity for the period beyond 2020.

These early years of the new century have seen considerable debate in the United Kingdom on the future of its nuclear power industry, culminating in the publication of a White Paper² on the issue in January 2008 (BERR, 2008a). It is thus instructive to begin this study with a brief review of the consultation process that led to that White Paper.³ The next section provides a brief overview of the history of UK nuclear power, and its early linkages to the development of the British nuclear bomb. This overview is followed in sections 3 and 4 by two issues that help to frame the debate about nuclear power in the UK. The first is energy strategy, and especially contemporary concerns about climate change and security of supply; second, the UK nuclear regulatory framework, which includes a complex mix of devolved, national, international and inter-governmental agencies, departments and semi-independent bodies. Section 5 explores the UK nuclear fuel cycle, from fuel supplies through to reactor designs and the reprocessing of spent fuel. Section 6 looks at issues of continuing concern associated with prospective new nuclear build in the UK, including: proliferation and security risks, waste management and decommissioning; health and safety; cost, including opportunity costs; skills capacity; the siting of nuclear power plants and related facilities; and differences of opinion on the issue within the devolved governments, especially in Scotland. The report concludes by analyzing the likelihood of new nuclear power stations being constructed in the UK, and if so, when, where and how they might be built.

¹ For a simplified flow diagram of UK energy supply and consumption in 2006 showing the role of nuclear power, see <http://www.berr.gov.uk/files/file43008.pdf>

² The term “White Paper” has no formal definition. However, White Papers generally contain proposals and statements of government policy.

³ For a detailed critique of the consultation process, see Dorfman, 2008.

Author Biography

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before that Programme Manager at another UK-based think tank, Saferworld (1998-2001). He blogs for The Guardian online and is an advisor to the United Nations Association-UK, Saferworld and ISIS Europe (Brussels) and is a member of the Asymmetric Threats Contingency Alliance (ACTA).

The UK Government's 2008 White Paper on Nuclear Power

It was in a 2003 Energy White Paper that the UK government, led then by Prime Minister Tony Blair, first announced that nuclear power remained an option under consideration:

Nuclear power is currently an important source of carbon-free electricity. However, its current economics make it an unattractive option for new, carbon-free generating capacity and there are also important issues of nuclear waste to be resolved. These issues include our legacy waste and continued waste arising from other sources. This white paper does not contain specific proposals for building new nuclear power stations. However, we do not rule out the possibility that at some point in the future new nuclear build might be necessary if we are to meet our carbon targets. Before any decision to proceed with the building of new nuclear power stations, there will need to be the fullest public consultation and the publication of a further white paper setting out our proposals. (DTI, 2003: 12).

In 2006, the UK government published a further Energy Review (DTI, 2006) highlighting the challenges the UK faces in addressing climate change and ensuring security of its energy supplies. This was followed in May 2007 by another Energy White Paper setting out a program of action and a new international and domestic energy strategy, with four goals (DTI, 2007a: 6):

- To put the UK on a path to cutting carbon dioxide (CO²) emissions – the main contributor to global warming – by some 60 percent by 2050, with real progress by 2020;
- To maintain the reliability of energy supplies;
- To promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve UK productivity; and
- To ensure that every home is adequately and affordably heated.⁴

⁴ Fuel poverty – defined as households that spend more than a 10th of their net income on electricity and gas – is on the rise in the UK, with more than 4.5 million households now falling into that category. Despite a legally binding target of eradicating fuel poverty among vulnerable households across the UK by 2018, a number of programs designed to meet this target have been cut. See Brignall, Miles (2008). "Failure to tackle fuel poverty a social disaster, ministers told," *The Guardian*. March 27; and Webb, Tim (2008). "FoE issues fuel poverty ultimatum," *The Observer*. February 24.

UK energy policy, as set out in the second White Paper, is underpinned by the belief that competitive energy markets, with independent regulation, are the most cost-effective and efficient way of generating, distributing and supplying energy.

Also in May 2007, the UK government launched a consultation to examine whether nuclear power could play a role in meeting these long-term challenges, alongside other low-carbon forms of electricity generation (DTI, 2007c). An additional consultation document (DTI, 2007b) was published at the same time and an interactive website enabled people to respond directly online. During the consultation period 3,756 people registered on the site, 2,043 made online submissions and a further 685 responded by email or on paper (BERR, 2008a: 40).

A High Court ruling in February 2007 that the government's earlier process of consulting the public and interested groups was "seriously flawed" prompted this latest consultation. The Department of Trade and Industry (DTI) – subsequently re-organized and renamed the Department for Business, Enterprise & Regulatory Reform (BERR) – was ruled as acting unlawfully because it had failed to keep its promise to carry out the "fullest consultation" before reaching a decision.⁵ Nonetheless, the government's preliminary view remained that energy companies should be given the option of investing in new nuclear power stations.

But halfway through this latest consultation, the Prime Minister Gordon Brown announced to MPs in July 2007 that "We have made the decision to continue with nuclear power." The consensual aim of the process began to further unravel with the withdrawal by Greenpeace, the Green Alliance, the World Wildlife Fund (WWF) and Friends of the Earth on the grounds that it "did not provide fair or balanced information" and "failed to properly consider the alternatives to nuclear power" (Dorfman, 2008: 15).

Between June 25 and November 2, 2007, the UK government also conducted a public consultation to consider the proposed implementation framework for the geological disposal of the UK's higher activity radioactive waste, including the approach to selection of a site for an eventual geological disposal facility (DEFRA, 2007).

⁵ Smith, Lewis, Webster, Philip and Christine Buckley (2007). "Court victory by Greenpeace fails to dampen ministers' nuclear ambition," *The Times*. February 16.

Following the two consultations (the nuclear power consultation involved 2,700 written submissions)⁶, the government published a White Paper on Nuclear Power in January 2008, in which the future of UK nuclear power is clearly tied to meeting two long-term challenges:

- Tackling climate change by reducing carbon dioxide emissions both in the UK and abroad; and
- Ensuring the security of UK energy supplies.

The White Paper concludes that, in summary, nuclear power is:

- Low-carbon – helping to minimize climate change (interestingly, it was described as “carbon-free” in the 2003 Energy White Paper)⁷;
- Affordable – “one of the cheapest low-carbon electricity generation technologies;”
- Dependable – “a proven technology with modern reactors capable of producing electricity reliably;”
- Safe – backed up by a highly effective regulatory framework; and
- Capable of increasing diversity and reducing the UK’s dependence on any one technology or country for its energy or fuel supplies (BERR, 2008a: 5).

These views are not universally shared and the option of nuclear power continues to be controversial and highly contested. The government recognizes this and admits that “significant points” were raised in the consultation regarding:

- The need to combat climate change and ensure secure energy supplies;
- The adequacy of protection in the areas of safety, environmental release of radioactivity and national security;
- The management of radioactive waste and particularly the need to make progress towards a long-term solution;

- The appropriateness of relying on energy companies for the construction, operation and decommissioning of nuclear power stations;
- The risk that cost over-runs in construction, in waste management and decommissioning will undermine the economic case for nuclear and could lead to costs falling to government;
- The perception that investment in nuclear energy will “crowd out” investment in alternative technologies, particularly renewables;
- The argument that the contribution nuclear energy makes to the UK’s overall energy mix is currently quite small, calling into question the materiality of any contribution nuclear might make in the future to tackling climate change and ensuring security of energy supplies;
- The belief that there are better alternatives to nuclear which would also enable the UK to achieve its energy goals and that there should be a greater focus on saving energy; and
- Among those supporting nuclear power, a concern about what was perceived as a growing skills gap in the nuclear industry (BERR, 2008a: 5-6).

In the UK government’s view the nuclear option is one part of an overall approach that includes a range of instruments (as set out in the 2008 White Paper), including measures to save energy and to strengthen the “Renewables Obligation” (see Box 1), and that the majority of the concerns can be met by the regulatory framework or through further policy development. In particular, the government has said that it will:

- Establish a clear strategy and process for medium and long-term waste management;
- Introduce new legislative provisions for a funding mechanism that requires operators of new nuclear power stations to make sufficient and secure financial provision to cover their full costs of decommissioning, and their full share of costs of waste management; and
- Further strengthen the resources of the Nuclear Installations Inspectorate (NII) (BERR, 2008a: 6-7).

Thus, having reviewed all the evidence, the government’s headline decision in the White Paper is that:

The government believes it is in the public interest that new nuclear power stations should have a role to play in this country’s future energy mix alongside other low-carbon sources; that it would be in the public interest to allow energy

⁶ Foreword by the Rt. Hon. John Hutton MP, BERR, 2008a: 5. All written responses to the consultation (except where individuals asked for their response to be treated as confidential) have been published on a government website: www.direct.gov.uk/nuclearpower2007. The government also published an analysis of the consultation responses simultaneously with the White Paper (The Future of Nuclear Power: Analysis of consultation responses, 2008). For an overview of the consultation process, see Section 1 of BERR, 2008a: 38-42.

⁷ Nuclear power is not carbon-free because large amounts of energy are expended in mining and processing uranium ore.

Box 1: The Renewables Obligation

The “Renewables Obligation (RO)” is a UK government initiative introduced in 2002 that requires energy suppliers to source an increasing amount of electricity from renewables: a 10th of overall produced by 2010, rising to a fifth by 2020 or pay a buyout price for any shortfall. It bears an uncanny resemblance to the Non-Fossil Fuel Obligation (NFFO) introduced in the late 1980s as a sweetener for privatization. The NFFO obliged distributors to take a certain proportion of their electricity from non-fossil sources, which at that time meant nuclear power, since there had been little development of renewables.

Since its inception the RO has promoted an increase in UK renewables generation from 1.32 percent of the mix to 4.43 percent in 2006. It operates on the basis of a market mechanism (“renewable obligation certificates”) and has been criticized for failing to provide the same level of certainty that fixed-feed in tariffs for renewables do in continental Europe. The government intends, subject to Parliamentary approval and State Aid clearance from the European Commission, to “band” the RO from April 2009 so that more support is provided to technologies that are further from the market and less to technologies that are close to being competitive with fossil fuel generation.

In addition, as part of the EU target of producing 20 percent of its energy from renewable sources by 2020, the UK has been set a target of 15 percent. The UK government launched a consultation in 2008 on how to achieve this target, and is committed to publishing a renewable energy strategy in spring 2009. However, the UK’s ability to meet this target has been increasingly questioned. See, for example: Macalister, Terry (2008). “Winds of change: Shell ditches renewable stake amid fears of a retreat to carbons,” *The Guardian*. May 1; Webb, Tim (2008). “UK Lags Behind on Eco Energy,” *The Observer*. February 24; and Seager, Ashley (2008). “Britain third worst in EU for use of renewable energy,” *The Guardian*. February 15.

companies the option of investing in new nuclear power stations; and that the government should take active steps to open up the way to the construction of new nuclear power stations. It will be for energy companies to fund, develop and build new nuclear power stations in the UK, including meeting the full costs of decommissioning and their full share of waste management costs (BERR, 2008a: 10).

The government also said that it would carry out further consultations on a number of the actions required to implement this policy, including the “Strategic Siting Assessment (SSA) process,” waste management and decommissioning. In addition, before any nuclear power station is constructed, it would also need to go through the planning system (which the 2008 White Paper also sets out to reform).

Since publication of the White Paper, political momentum in support of the nuclear option has continued to grow. In March 2008, the business secretary John Hutton called for Britain to become a world leader in the development of nuclear power technology and to produce “significantly more” than the 19 percent of electricity nuclear produces already. He also predicted that the benefits to the UK economy would be on a par with North Sea oil in the 1980s and could provide a £20 billion economic bonanza for the country, including 100,000 new jobs.⁸

Second, also in March, an Anglo-French summit included proposals for closer nuclear cooperation. The final communiqué promised to “improve the efficiency and effectiveness of nuclear development projects... to share information on nuclear safety, security and waste management, action which could be extended to other European partners.” While short on details, the announcement was seen in both capitals as an important signal that the French and UK nuclear industries could work closely as Britain prepares to expand its nuclear industry. The UK would be expected to draw on French nuclear industry skills, at least in the initial stage of expansion. It is anticipated that the partnership would facilitate the creation of a skilled British labour force able to work with French counterparts to export nuclear power stations to other countries.⁹

Third, in a speech in June 2008 to an audience of senior figures from the international nuclear industry, John Hutton announced the government’s action plan for enabling a new nuclear build in the UK, including:

- The creation of a new Office of Nuclear Development within BERR, which joins up the approximately 40 staff currently based there with staff from other nuclear-focused teams from across government, with the aim of building more effective cross-government work on nuclear energy;
- The creation of a new Hutton-chaired Nuclear Development Forum, bringing together government and the industry to discuss key issues and maintain momentum as nuclear new build progresses; and
- The publication of the draft criteria for deciding on the siting of new nuclear power stations (the SSA).¹⁰

⁸ Sparrow, Andrew and Patrick Wintour (2008). “Nuclear is UK’s new North Sea oil – minister,” *The Guardian*. March 26.

⁹ Borger, Julian and Patrick Wintour (2008). “More Anglo-French teamwork makes entente formidable,” *The Guardian*. March 28.

¹⁰ BERR News Release (2008). “Hutton Tells Global Nuclear Investors to Build in Britain.” June 12.

Fourth, also in June, a new White Paper entitled *Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal* was published (see the discussion in section 5).

Fifth, in July 2008 the SSA consultation document was published, and Gordon Brown called for Britain to build “at least” eight new nuclear power stations during the next 15 years to replace its ageing plants and contribute to a “post-oil economy.”¹¹ Finally, in September an agreement was reached for *Électricité de France* (EDF) to takeover the UK’s main nuclear power company, British Energy – a deal that Gordon Brown described as “a significant step towards the construction of a new generation of nuclear stations to power the country.”¹²

A Brief History of the UK Nuclear Industry

The UK Nuclear Energy Program (1945-1985): A Tale of Three Acts

The first 40 years of Britain’s nuclear energy program (1945-1985) can be divided into a three-act narrative:

- Act I - Spin-off from nuclear weapons;
- Act II - The AGR *cul-de-sac*; and
- Act III - Sizewell B and the end of the nuclear road?

Act I – Spin-off from nuclear weapons

British scientists were at the forefront of the development of nuclear energy both before and after the Second World War, mainly as a spin-off from their nuclear weapons program. The first UK research reactor – also the first in Europe – the Graphite Low Energy Experimental Pile (GLEEP) at Harwell in Oxfordshire, began operating in 1947, and in the same year work began on two air-cooled plutonium-producing reactors (or piles) at Windscale (later renamed Sellafield) in Cumbria. These began production in 1950 and 1951 respectively, and were designed to produce weapons-grade plutonium for the British nuclear bomb.

The UK Atomic Energy Authority (AEA), set up in 1954, was the initial body responsible for nuclear plants (as well as research). It was the UKAEA that commissioned

the first plants in the 1950s. This role was later taken over by the Central Electricity Generation Board (CEGB) in England and Wales, and the South of Scotland Electricity Board – both government utilities.

Subsequent plutonium-producing Magnox reactors (described in more detail in Section 5) were designed to be dual-use (capable of producing both weapons-grade plutonium for British nuclear weapons and generating electricity) a decision that marked the start of civil nuclear energy in Britain. The Queen opened the first of four reactors, built at Calder Hall near Windscale, in 1956. Four more reactors were constructed at Chapelcross (in Dumfries and Galloway, Scotland) and opened in 1959.

In addition to Calder Hall and Chapelcross (which were closed in 2003 and 2005 respectively), a 1955 White Paper announced the first purely commercial Magnox program. This consisted of nine stations, each comprising two reactors with a combined capacity of over 4,000MW. Construction of the first two, at Berkeley (Gloucestershire) and Bradwell (Essex), began in 1956; the last at Wylfa on the Isle of Anglesey was commissioned in 1971. The first closure came in 1989, and the rest will be closed by 2010. In addition, two Magnox stations were exported (to Japan and Italy) although both are now closed. Research in the UK was also started on fast-breeder reactors.

In 1957 a fire in one of the military plutonium piles at Windscale, caused by poor staff judgment and faulty instruments, released a cloud of radioactive contamination (though small compared with Chernobyl in 1986, it was more life-threatening than the fallout from the 1979 meltdown at Three Mile Island in the United States). The incident marked the end of the early euphoria that had accompanied development of nuclear power in Britain. It also led in 1959 to the creation of what is now the NII, part of the Health and Safety Executive (HSE), as the “independent” government watchdog on the industry.

Act II – The AGR cul-de-sac

By the late 1950s, with the Magnox program still under construction, the UKAEA turned its attention to a successor. Several different research programs were initiated, but the advanced gas-cooled reactor (AGR) was eventually chosen – a design that was unique to the UK and that went against the mainstream trend in the US, France and Japan of building light water reactors (LWRs), either pressurized water reactors (PWRs) or boiling water reactors (BWRs). Seven AGR stations were built in the UK to four different designs and with mixed results. The first, Dungeness B, though ordered in 1965 only began working

¹¹ White, Michael (2008). “Brown calls for eight new nuclear plants,” *The Guardian*, July 14.

¹² Macalister, Terry (2008). “French firm’s £12bn deal starts nuclear revolution,” *The Guardian*, September 25.

properly in 1993 and ran heavily over time and cost – a situation caused in part by the absence of any international experience of solving problems with AGR technology. In 1971, British Nuclear Fuels Ltd. (BNFL) was formed from UKAEA to provide a range of fuel cycle services.

Act III – Sizewell B and the end of the nuclear road?

In the 1980s it was decided to turn to the PWR for the next stage of nuclear development in the UK. The Conservative government under the leadership of Margaret Thatcher originally planned to build ten new large nuclear power stations all to be based on PWR technology. This decision was in part political since it was intended to reduce the influence of the coal mining and transport unions, then the Conservatives' most formidable political adversaries – as confirmed by a leaked Cabinet minute:

...a nuclear program would have the advantage of removing a substantial portion of electricity production from the dangers of disruption by industrial action by coal miners or transport workers (Hall, 1986: 173).

These plans were eventually scaled back to a family of four identical PWRs. However, only one was ever built: the B plant at Sizewell on the coast of Suffolk – the last nuclear power plant to be built in the UK. The planning application for Sizewell B was submitted in 1981, production commenced in 1988 and the plant became operational in 1993. Although planning permission for a second, Hinkley Point C in Somerset, was granted in 1990, production was cancelled soon after because of the uncertainty surrounding the creation of a new electricity market and concerns about nuclear safety following the accident at Chernobyl in 1986.

Privatization and an Uncertain Future

In the ensuing decade after construction of Sizewell B, two significant events affected the nuclear industry: the development of the combined-cycle gas turbine (CCGT) which allowed vast, newly discovered gas reserves to be converted into electricity far more cheaply than had previously been the case; and the introduction of competition into the electricity supply industry (as described in Section 3). Although the nuclear power plants were exempted from the initial wave of electricity privatization in 1989, and remained under state control within a new company, Nuclear Electric; the sector became sufficiently competitive to enable the most modern nuclear power stations to be privatized in 1996 under the name British Energy. The state-owned BNFL took ownership of all the Magnox power stations that were excluded from the privatization package as well as the UK fuel cycle facilities.

However, by the early 2000s British Energy was facing financial problems within the de-regulated energy market. Declining electricity wholesale prices (due to overcapacity as a result of increased gas-fired plants) to a level that was below production cost for British Energy, expensive reprocessing contracts with BNFL, and a newly introduced climate change levy, combined to exacerbate British Energy's financial crisis. In 2003 the company's reprocessing contracts were renegotiated to give some relief, but this decision became contentious within the EU.

During 2003-2005, British Energy was restructured extensively and effectively brought back under temporary state control with the government taking a 64 percent share. In May 2007 the government reduced this to 39 percent, using the £2.08 billion realized in the sale to establish a Nuclear Liabilities Fund to cover future decommissioning of British Energy's eight nuclear plants. Further share sales down to about a 30 percent (or less¹³) holding were envisaged.

However, since the company owns many of the existing nuclear sites where some of the new generation of plants are most likely to be built, private takeover bids for British Energy were tabled by several foreign energy companies during 2008.¹⁴ Europe's biggest power company, EDF, secured a £12.4 billion deal for British Energy in September 2008¹⁵ and promptly indicated that some of the sites would be put up for sale, opening the way for other companies to share in the new nuclear build.¹⁶ The takeover still has to be approved by the European Commission (after a competition investigation)¹⁷ but is expected to be completed by the end of the year. The UK government will raise about £4 billion from selling its holdings in British Energy, to be paid into a fund for future nuclear clean-up costs.¹⁸

¹³ In March 2008, the Business Secretary, John Hutton, suggested that the government might drop its previous commitment to maintaining a minimum 29.9 percent stake in British Energy. Eaglesham, Jean (2008). "Hutton's nuclear future for UK power," *Financial Times*. March 5.

¹⁴ Macalister, Terry (2008). "British Energy shares rise 20% after confirmation of tie-up talks with rivals," *The Guardian*. March 18; and Crooks, Ed, Rebecca Bream and Peggy Hollinger (2008). "Energy rebuffs EDF," *Financial Times*. June 9.

¹⁵ Crooks, Ed (2008). "EDF acquires British Energy," *The Guardian*. September 23.

¹⁶ Crooks, Ed and Peggy Hollinger (2008). "EDF to put sites up for sale," *The Guardian*. September 24.

¹⁷ The merger with British Energy will raise EDF's share of the UK power-generating market from six percent to 25 percent, raising questions about the impact of this concentration on competition and energy prices.

¹⁸ Some reports suggest that the UK government may retain its share of British Energy in order to prevent any "unsuitable" future sale by EDF. See O'Connell, Dominic and Danny Fortson (2008). "Whitehall keeps its say on BE," *The Sunday Times*. September 28. Available at: http://business.timesonline.co.uk/tol/business/industry_sectors/natural_resources/article4837684.ece

A similar complex mix of restructuring and privatization occurred within BNFL, that initially purchased Westinghouse Electric Company in 1999 and other international nuclear engineering and services companies – then sought to off-load most of these acquisitions following a strategy review in 2003. In 2004, BNFL effectively became a two-business company: fuel manufacture and reactor services through Westinghouse and fuel cycle services through its subsidiary, British Nuclear Group (BNG). In turn, BNG became a holding company in 2005 for its three main business units: nuclear decommissioning and cleanup (Project Services Ltd.); spent fuel and engineering (Sellafield Ltd.); and the Magnox nuclear reactor sites (Magnox Electric Ltd.) – the last two as contractors to the government’s new Nuclear Decommissioning Authority (NDA) – discussed in section 4.

The sale of Westinghouse to Toshiba Corporation was completed on October 16, 2006, for the sum of £3.1 billion. As a result, Britain’s only nuclear fuel manufacturing site, Springfield Fuels, is now in the hands of a Japanese company.¹⁹ Efforts to sell-off BNG as a single entity were unsuccessful, and in October 2006 the government gave approval for it to be broken up and sold:

- Magnox Electric Ltd was sold to the US company, Energy Solutions, in June 2007;²⁰
- BNG’s one-third share in AWE Management Ltd., the consortium which runs the Atomic Weapons Establishment at Aldermaston, was put out for tender in July 2007;²¹ and
- Project Services Ltd. was sold to the UK defence and support services company, VT Group plc, in December 2007.²²

However, the prime part of the disposal is the five-year contract with the NDA to run and clean up Sellafield, the site of all of the UK’s “back end” fuel cycle activities. Sellafield Ltd. was accordingly spun off from BNG as a site licence company. The NDA announced in March 2007²³ that six organizations had pre-qualified as bidders

for the Sellafield Parent Body Organisation (PBO).²⁴ In July 2008, the NDA announced that the Nuclear Management Partners (NMP) consortium had won the £6.75 billion (£1.3 billion a year) competition to become the Sellafield PBO for the next five years. Final contract negotiations took place with a view to the contract being awarded in October 2008. Once the contract is finalized, NMP will operate the reprocessing facilities at Sellafield and clean up the remaining sites, although ownership of the assets will remain with the NDA. NMP will own the shares in the site licence company (Sellafield Ltd.), for the duration of the five-year contract with the possibility of periodic extension, up to 17 years in total, subject to performance.²⁵

Sellafield Ltd. also established a subsidiary company, International Nuclear Services Ltd (INS), in which the NDA has a 49 percent share. INS is meant to provide a customer interface, “to manage used fuel reprocessing and MOX supply contracts for more than 20 utility customers and to transport nuclear fuel products to customers.”²⁶ In 2007, the NDA announced that it would fully take over INS from April 2008.

The only part of BNG not for sale is the research and consultancy arm, Nexia Solutions, which will be the basis of a new national nuclear laboratory (NNL) that will include the British Technology Centre at Sellafield. The NNL aims to secure a skills base for the UK’s civil nuclear industry.

Structure of the UK Nuclear Industry Today

There are 23 reactors generating electricity at nine sites in the UK. All are due to be closed by 2035 (see Table 1). See Appendix A for an overview of all the UK nuclear sites as well as a map showing their locations, and section 5 for a more detailed discussion of the various parts of the UK nuclear fuel cycle. According to the UK Nuclear Industry Association (NIA), the sector employs about 40,000 people directly, plus about 40,000 indirectly, and contributes about £3.3 billion annually to the UK’s gross domestic product (GDP).²⁷ The complex public-private restructuring

¹⁹ “BNFL, Toshiba Agree Sale of Westinghouse,” BNFL Press Release, February 6, 2006

²⁰ “BNFL agree to sell Reactor Sites Business to Energy Solutions,” BNFL Press Release, June 7, 2007.

²¹ “BNFL commences sale of its one-third share of AWE Management Ltd.,” BNFL Press Release, July 16, 2007.

²² “BNFL Agrees Sale of its Project Services Business”, BNFL Press Release, December 18, 2007.

²³ “NDA Announces Sellafield Bidders,” NDA Press Release, March 26, 2007.

²⁴ Following the withdrawal of two companies this was reduced to the following four consortia: the US corporation, CH2M HILL; the US Fluor Corporation in partnership with Toshiba; SBB Nuclear, a new consortium set up to bid for the Sellafield contract, consisting of Serco, Bechtel and BWXT; and Nuclear Management Partners (NMP) consortium, consisting of Washington Group, a division of US contractor URS, with British engineering group AMEC and the French company Areva NC.

²⁵ Milner, Mark (2008). “Amec group wins Sellafield contract,” *The Guardian*, July 12.

²⁶ Sellafield Ltd website: <http://www.sellafieldsites.com/page/international-nuclear-services/about-us>.

²⁷ UK NIA website: http://www.niauk.org/component/option,com_easyfaq/Itemid,33/#faq6.

of the last few years has left the following corporate entities at the centre of the UK nuclear industry, and further dispersal and increased multinational ownership is anticipated:

British Energy www.british-energy.com / **EDF** www.edf.com

The British Energy Group plc is a FTSE 100 company²⁸ and the UK's largest producer of electricity (about one sixth of the national total). It employs about 6,000 people across six operating companies, including British Energy Generation (which owns and runs eight nuclear power stations). EDF agreed to a takeover of British Energy in September 2008, is 85 percent owned by the French state. It is a major producer of nuclear energy in France and operates 58 reactors at 19 different sites. In the UK, EDF is already a major energy supplier, with just under eight million gas and electricity customers and 12,000 employees.

BNFL www.bnfl.com

BNFL's activities cover nuclear site decommissioning and clean-up as well as technology services and solutions across the nuclear fuel cycle. The Group, which employs about 10,000 people, will cease to exist in the near future once the Sellafield contract has been finalized and the NNL established. Currently, BNFL comprises the following two businesses:

- **Sellafield Ltd.** www.sellafieldsites.com: responsible for the delivery of multi-million pound contracts on behalf of the NDA, covering remediation, decommissioning, clean-up, as well as the Thermal Oxide Fuel Reprocessing Plant (THORP) and Magnox reprocessing plant operations, Mixed oxide (MOX) fuel fabrication, waste management and effluent treatment at the Sellafield and Capenhurst sites; and
- **Nexia Solutions** www.nexasolutions.com: provides nuclear technology and R&D services across the nuclear fuel cycle.

Project Services Ltd. www.projects-services.com

Formerly part of BNG, now owned by VT Group plc, this specialist decommissioning and remediation company operates in the UK, continental Europe, the former Soviet Union and Japan. It employs about 750 nuclear experts.

Magnox Electric Ltd. www.magnoxelectric.com

Formerly part of BNG and now a US-owned company, it

²⁸ The FTSE 100 Index is a share index of the 100 most highly capitalised companies listed on the London Stock Exchange. The index is maintained by the FTSE Group, an independent company, which originated as a joint venture between the *Financial Times* and the London Stock Exchange. FTSE 100 companies represent about 80 percent of the market capitalisation of the whole London Stock Exchange.

Table 1: Planned Closure Schedule for UK Nuclear Power Stations

	Commissioning date	Planned closure date
Magnox reactors		
Oldbury-on-Severn	1968	2008
Wylfa	1971	2010
AGRs		
Dungeness B	1985	2018
Hartlepool	1984	2014
Heysham 1	1984	2014
Heysham 2	1988	2023
Hinkley Point B	1976	2016
Hunterston B	1977	2016
Torness	1989	2023
PWR		
Sizewell B	1995	2035

Source: UK Nuclear Industry Association, 2006.

holds the contracts and licences to manage (operate and decommission) ten UK nuclear sites with 22 reactors on behalf of the NDA. It is split into a northern region (carrying out electricity generation on two sites, de-fuelling and decommissioning) and a southern region (undertaking de-fuelling and decommissioning operations).

The generally dispersed and multinational ownership of the British nuclear industry is likely to continue, but with French state-owned groups at the centre. In addition to EDF, the French state-owned group Areva (which manufactures and designs nuclear reactors) is part of the consortium that will soon be running and cleaning up Sellafield, and also one of the leading contenders for the new nuclear build (as discussed in section 5). If EDF does sell some of British Energy's sites, other foreign companies such as Eon and RWE of Germany may also look to build reactors in the UK.

UK Energy Strategy: Climate Change and Security of Supply

The rise, fall and potential rebirth of nuclear power in the UK can only be properly understood in the broader context of UK energy policy, which can be divided into three distinct phases:

- 1945 to late 1980s: state-led solutions (nationalized industries);
- Mid-1980s to 2000: market-led solutions (privatization and de-regulation);
- 2001 to date: reconciling the market with security and environmental concerns (security of supply and climate change).

1945 to late 1980s: State-led Solutions

From the end of the Second World War to the late 1980s, the objectives of UK energy policy were vague, but appeared to be mainly concerned with securing the cheapest energy supplies and helping the nationalized industries break even (Toke, 1990: 4-5). Initial civil nuclear programs in Britain in the mid-1950s led to little public debate were shrouded in secrecy, with little information in the public domain, and were largely the result of a gradual spin-off from military nuclear work. In taking the original decision to establish civil nuclear technology in Britain, the government provided all the necessary back-up, technical and financial research and development, fuel cycle services, insurance, regulation and safeguards. Without the nuclear weapons program, if normal commercial criteria had been applied, it is doubtful that a civil nuclear industry would have ever arisen.

Mid-1980s to 2000: Market-led Solutions

From the mid-1980s to the early years of the new century, energy policy was dominated by privatization (driven by successive Conservative governments) and then a further opening up of the energy markets to competition (under the 1997 New Labour government). The UK gas market was to be privatized in 1986 with a promise that British Gas would have up to a 25 year monopoly of the UK domestic market. But in April 2000, this monopoly was ended and the gas market was opened to domestic competition. In the 20-year period following privatization, average gas prices fell by around 32 percent. These gains are now being eroded by steep rises in gas wholesale prices (which have doubled in the last two years) and growing concerns about security of supply.

The UK electricity industry was privatized in 1989 and the domestic electricity market was fully opened up to competition ten years later. Since privatization, average prices of electricity have fallen by 25 percent and the wholesale price of electricity has dropped by 40 percent. This huge drop in wholesale prices can be explained by falling fuel prices, a generous capacity margin and increased competition in generation.

The structure of the revised electricity industry was designed to encourage competition where feasible, but to regulate prices where natural monopolies existed or where competition required time to emerge. After privatization, there was a major shift from coal to natural gas, and considerable “convergence” (the creation of energy businesses rather than single fuel electricity companies) and “globalization” (takeover activity and foreign ownership). For

example, US companies currently own five of the 12 Regional Electricity Companies, three were purchased by UK generation companies, one by EDF Energy, and two merged with their local water utilities. While PowerGen, National Power and the National Grid remain independent, a large number of other companies are now active in generation and supply. In 1990 there were ten generating companies and 16 suppliers in England and Wales; today there are 32 generating companies and 34 suppliers.

As discussed in Section 2, the nuclear industry remained in state hands until 1996, when the AGRs and Sizewell B were privatized, while the ageing Magnox stations remained in the public sector because of high decommissioning and waste management costs. The main impact on the nuclear industry of having the market “decide” priorities was a complicated roller coaster ride to partial privatization. In general, private investors proved unwilling to underwrite all the uncertainties and hazards associated with nuclear power, effectively leaving the entire nuclear capacity to be gradually phased out – until the nuclear option was resuscitated again in the 2003 Energy White Paper.

Post-2001: Reconciling the Market with Security and Environmental Concerns

In the last century, environmental considerations rarely featured as important influences on UK energy policy. Conversely, the last decade has seen a general recognition that sustainability should be the overriding objective. The UK government and energy sector is only now starting to turn from generalized rhetoric to concrete action.

The underlying belief in a competitive energy market with independent regulation still remains the central plank of UK energy policy today. However, the scope and extent of state intervention in the market is arguably the most contentious aspect of current government policy, especially in the light of concerns about climate change and security of supply. It remains an open question whether a free market in energy, even if attainable, can deliver key environmental and security objectives. Even in the late 1980s, the Select Committee on Energy (1989), with a Conservative majority, was calling for greater state intervention to promote energy conservation.

Security of Supply

It is difficult to predict how energy supply and demand and the electricity generation mix will develop over the very long term. Growth in energy demand, the cost and availability of fossil fuels, and the cost and availability of

emerging low-carbon technologies contribute to this uncertainty (BERR, 2008a: 16-17). The security of energy supply first became a key objective of UK energy planners in response to the oil supply restrictions and price increases imposed by the Organization of the Petroleum Exporting Countries (OPEC) in the 1970s. These concerns soon receded, especially as Britain then met most of its energy needs from domestic sources of coal, oil and gas. However, planned closures of about one-third of UK coal stations and all of UK nuclear power stations by 2023, combined with declining North Sea production of oil and gas, renders Britain once again dependant on oil and gas imports from regions of instability and at a time of rising demand and prices.

Of course, nuclear energy can be conveniently used only to generate electricity in very large base-load stations for distribution by a grid. Increasing reliance on nuclear power therefore implies increasing reliance on grid electricity. There are three elements to electricity security of supply – capacity, diversity and a reliable supply chain.

Energy demand in the UK, as in other countries, fluctuates widely: from around 20GW on a summer night to 60GW on a cold winter evening. Nuclear reactors and large gas-powered plants currently supply the “base load” – the 20GW that the UK uses all the time. As more electricity is required, coal burning power stations and smaller generators are brought online. In addition to reserve capacity in some power plants, 2GW can be imported via a cable between the UK and France and some factories have agreements with the electricity companies to cut their demand when the system comes under strain (in exchange for a rebate). Three hydro “pumped storage” plants also provide additional emergency capacity. One in North Wales, for example, can produce 1.7GW of power for five hours, with fifteen seconds’ notice (Monbiot, 2007: 79-81).

As well as coping with variations in demand, the electricity system must also be able to deal with sudden losses of supply. The UK system is therefore designed to withstand

the loss of the largest operational unit, which currently equals 1.3GW of capacity (Sizewell B nuclear power plant). Sources of current UK electricity generation are shown in Table 2.

While a key element in ensuring sufficient capacity is to address future energy demand, the UK government believes that even if it successfully implements all of its demand-side energy efficiency measures, electricity demand will at best remain stable. It also considers that the new capacity requirements cannot fully be met through renewable sources due to the different types of generation necessary to ensure a flexible, secure mix (BERR, 2008a: 55).

Climate Change

Two recent significant environmental events in the UK were the publication of the Stern Report at the end of 2006 and the launch of a Climate Change Bill in March 2007. Sir Nicholas Stern, the former chief economist at the World Bank was commissioned by the British government to assess the economic implications of climate change. He found that the global cost of a high level of warming during the twenty-first century would be between 5 and 20 percent of global GDP, while the cost of preventing it would amount to only 1 percent (Stern, 2006).

The UK’s international and climate change strategy is built around four main elements, as set out in the Energy White Paper (DTI, 2007a):

- Promoting open, competitive energy markets in the UK and abroad;
- Taking action to put a value on carbon dioxide emissions;
- Promoting investment to accelerate the deployment of low-carbon energy technologies; and
- Putting in place policies to improve energy efficiency.

Under the Climate Change Bill, the UK government commits itself to two binding cuts in greenhouse gas emissions: a 26-32 percent reduction (on 1990 levels) in carbon emissions by 2020 and a 60 percent reduction by 2050. An independent committee will decide whether the goals have been met. Critics of the government policy argue that such targets are too low, inadequately measured,²⁹

Table 2: Sources of UK Electricity Generation (2005)

Fuel type	Percentage of electricity generation
Gas	41
Coal	33
Nuclear	19
Renewable	3
Imports	2
Oil	1
Other fuels	1

Source: DTI, 2005: 15.

²⁹ A recent National Audit Office investigation strongly criticized the government for using two different carbon accounting systems, which raises questions about the credibility of the government’s approach to reducing carbon emissions. See Vidal, John (2008). “Government figures hide scale of CO₂ emissions, says report,” *The Guardian*. March 17.

and are “constantly undermined by weak resolve and conflicting policies,” such as major planned airport and road expansion (Monbiot, 2007: xiv).³⁰ Similarly, energy efficiency standards in UK houses (which consume a quarter of the UK’s electricity) are much lower than in many European counterparts and are not adequately enforced. For example, when the Minister for Housing and Planning, Yvette Cooper, was urged to introduce proper energy efficiency standards for the refurbishment of houses, she said that it would amount to “unnecessary gold plating.”³¹ Finally, the UK’s focus on price regulation has held back greater implementation of renewable energy in the UK. Indeed, many of the subsidies available under the RO and NFFO mechanisms ostensibly designed to support the establishment of renewables, have instead gone to nuclear (Dorfman, 2008: 45).

UK policy is also shaped by developments within the EU. At the Spring European Council in March 2007, an EU energy action plan was agreed upon, underpinned by a number of ambitious climate and energy targets for 2020.³² These included unilateral targets to reduce EU greenhouse gas emissions by 20 percent (compared to 1990), rising to 30 percent in the context of a post-2012 international agreement; a target of 20 percent of the EU’s energy to come from renewable sources; and a target to increase energy efficiency by 20 percent. The Council also underlined the central role of the EU Emissions Trading Scheme (ETS), the first multinational carbon-trading scheme, in meeting the target to reduce emissions. The European Commission announced detailed proposals for meeting the renewables and emissions targets and on the future of the EU ETS in early 2008. It also suggested that the UK’s contribution to the 20 percent renewables target should be to increase the share of renewables in the UK’s energy mix from around 1.5 percent in 2008 to 15 percent by 2020. To this end, a new UK Renewable Energy Strategy is being developed for a planned release in spring 2009.

³⁰ Another example is a planned new coal-fired power station at Kingsworth in Kent, the first to be built in the UK for more than 30 years. The government is expected to give approval for it to be built without insisting that it uses “carbon capture and storage” technology. Although still under development, the technology could reduce carbon emissions from the power station by up to 90 percent. Without it, the power station will be one of the UK’s largest emitters of CO₂. See Vidal, John (2008). “Energy firm wants carbon freedom at new coal-fired plant,” *The Guardian*. February 1. Available at: <http://www.guardian.co.uk/environment/2008/feb/01/fossilfuels.carbonemission>.

³¹ Yvette Cooper quoted in Brown, Paul (2008). “Energy-saving Targets Scrapped,” *The Guardian*. July 18; energy efficiency regulations were first introduced in the UK in 1985 but as at March 2006 there had not been a single prosecution for non-compliance (Warren, 2006).

³² Spring European Council conclusions, March 8-9, 2007.

In conclusion, the UK government now argues that the nuclear power option has several climate change and security of supply benefits, including low carbon emissions (thereby making a material contribution to meeting UK emission targets), and improved security of supply (by ensuring an increased and more diverse mix of generating technologies). It recognizes that uranium supplies are finite but anticipates them lasting a further 85 years based on current extraction rates (BERR, 2008a: 18, 54-58), although critics suggest that known uranium resources are likely to be exhausted much sooner, perhaps by 2030.³³ To encourage private investors to take up the nuclear option a major shake-up of the regulatory framework is envisaged – as discussed next.

The UK Nuclear Regulatory Framework

“The safety and security of nuclear power is of paramount concern and we have an effective regulatory framework in place to ensure that these risks are effectively managed and minimised.”

White Paper on Nuclear Power (BERR, 2008a: 22)

The Current Oversight and Regulatory Mix

The oversight of nuclear power stations in the UK is carried out by a range of different regulatory bodies and agencies at various levels of government: devolved, UK-wide, EU and intergovernmental.

Within the UK, the main regulatory bodies are the NII, a division of the HSE – which administers the 1965 Nuclear Installations Act – the Environment Agency in England and Wales and the Scottish Environment Protection Agency in Scotland. These agencies regulate radioactive discharges from nuclear power stations and have the responsibility to ensure that workers, the general public and the environment are protected against exposure to radioactivity. Nuclear security is the responsibility of the Office for Civil Nuclear Security (OCNS), which has been part of the HSE since April 2007.

The UK government is also committed (BERR, 2008a:154) to establishing a new independent advisory body, the Nuclear Liabilities Financing Assurance Board (NLFAB), which will provide independent scrutiny and advice to

³³ See, for example, an article by former environment minister Michael Meacher, MP: “Bad reactions,” *The Guardian*. May 7.

the Secretary of State for BERR on the financial arrangements for waste management and decommissioning by nuclear operators.

The UK nuclear regulatory framework covers safety, security, environmental, safeguards, transportation and waste management and decommissioning issues, as discussed in greater detail below.

Safety

The NII has statutory responsibility for ensuring that there is an adequate framework for the regulation of safety at UK nuclear sites. This responsibility covers the licensing and day-to-day regulation of nuclear sites and the regulation of work-related health and safety. Licensing applies throughout the lifetime of a nuclear installation from design and construction to eventual completion of decommissioning and site clean-up. The NII carries out inspections of nuclear sites and periodic safety reviews.

Security

The OCNS conducts its regulatory activities on behalf of the Secretary of State for BERR and under the authority of the Nuclear Industries Security Regulations 2003. OCNS also undertakes the vetting of key nuclear industry personnel and transportation plans for nuclear materials. Civil nuclear operators must agree site security plans with the OCNS, covering physical protection features (such as fencing, CCTV and turnstile access, the roles of security guards and the Civil Nuclear Constabulary (CNC) – an armed police force tasked with protection of nuclear material and nuclear sites), the protection of proliferation-sensitive data and technologies and the trustworthiness of the individuals with access to them.

Environmental Regulation

The Environment Agency and the Scottish Environment Protection Agency are the principal environmental regulators in England and Wales and in Scotland respectively. They have a number of regulatory roles in relation to nuclear sites, as legislated by:

- The Radioactive Substances Act 1993 – covering disposals, including discharges to air, water and land, of radioactive wastes off or on nuclear sites;
- The Water Resources Act 1991 – covering abstraction from, and discharges to controlled waters (inland and marine surface waters, and groundwater);

- The Pollution Prevention and Control Regulations 2000/Pollution Prevention and Control (Scotland) Regulations 2000 (as amended) – covering certain installations including, for example, combustion plant used as auxiliary boilers and emergency stand-by power supplies, and incinerators used to dispose of combustible waste; and
- The Environmental Protection Act 1990 – covering disposals of waste by deposit on or into land, including excavation materials arising from construction.

Additionally in England and Wales, local authorities or the Environment Agency usually take responsibility for flood defences. However, at nuclear sites operators take direct responsibility for their local flood defences as part of their safety obligations.

Nuclear Safeguards

Nuclear safeguards aim to verify that states comply with their international obligations not to use nuclear materials in nuclear weapons programs. The 1968 Non-Proliferation Treaty (NPT) includes requirements for the application of safeguards by the International Atomic Energy Agency (IAEA). Similarly, the Treaty Establishing the European Atomic Energy Community (the Euratom Treaty) includes requirements for the application of safeguards by the European Commission. Nuclear operators are required to provide the European Commission with design information on installations and accountancy reports for nuclear materials, and the Commission's inspectors are meant to have access at all times to all civil nuclear places, data and personnel in order to verify the safeguards information.³⁴

Responsibility for overseeing compliance with the UK commitment to these regimes belongs to the UK Safeguards Office (UKSO), which is part of the Nuclear Directorate of the HSE. It does this by (BERR, 2008a:185):

- Working with the UK nuclear industry and others with safeguards reporting requirements, and safeguards inspectors from the European Commission and the IAEA, to make sure that the safeguards measures applied are both effective and efficient;
- Ensuring that safeguards measures do not place unreasonable demands on, or result in unnecessary commercial disadvantage to the UK organisations involved;

³⁴ In 2004, the European Commission launched legal proceedings against the UK for failing to provide proper access over a five-year period for nuclear inspections to an area of Sellafield nuclear plant known as "pond B30." "EC Court Challenge to Sellafield." *BBC News Online*. September 3, 2004.

- Helping to negotiate facility-specific safeguards reporting and inspection arrangements with the European Commission and/or the IAEA;
- Assisting UK operators, especially those unfamiliar with the subject, in meeting safeguards requirements;
- Implementing the UK's Additional Protocol; and
- Providing support to safeguards officials in BERR on safeguards policy issues that arise from the work of HSE (UKSO).

BERR is responsible for the UK government input into the development of the international nuclear safeguards regimes.

Transportation of Nuclear Materials

Spent fuel from UK power stations is transported in specially designed flasks by rail, while spent fuel from overseas is carried by specially equipped ships. The UK has a number of international obligations and commitments in relation to transportation of nuclear and radioactive materials, including three European Directives³⁵ and the IAEA's Standard for the Safe Transport of Radioactive Material. The security for the transportation of nuclear material is regulated by the OCNS, which also receives terrorist threat intelligence briefings. The Department for Transport under The Carriage of Dangerous Goods and the Use of Transportable Pressure Equipment Regulations 2007, regulates the safety of nuclear transport (and security of less sensitive nuclear material). The UK is a party to the 1980 Convention on the Physical Protection of Nuclear Material,³⁶ which it ratified on September 6, 1991, and the 2005 amendment.

Waste Management and Decommissioning

Between 1978 and 2004, the UK government was advised on nuclear waste matters by the Radioactive Waste Management Advisory Committee, replaced in 2004 by another "independent"³⁷ Committee on Radioactive Waste Management (CoRWM). This new committee, described by the government as an "Advisory Non-Departmental Public Body" (BERR, 2008a: 186), was charged with again

reviewing the options for long-term storage and disposal of high- and medium-level radioactive wastes.

At the end of 2001 the government announced that it would set up a new authority to handle "the clean-up of the legacy created by the early years of Britain's military and civil nuclear programs." In 2002 the DTI published a White Paper, *Managing the Nuclear Legacy* (DTI, 2002) and the NDA was eventually set up and funded under the 2004 Energy Act. It is charged with cleaning up the UK's legacy of nuclear wastes on 20 sites, including 39 reactors and five fuel reprocessing plants, as well as other fuel cycle and research facilities. These were the responsibility of BNG (the decommissioning and clean-up arm of BNFL) and the UKAEA, but in April 2005 NDA took over all designated liabilities and assets from those bodies. As discussed in section 2, BNG became manager and contractor to the NDA.

Proposed Deregulation: Facilitating New Nuclear Build

The government believes it is important to further revise the regulatory framework in order to "give confidence to investors" that might be considering financing new nuclear build. Proposals for action "designed to reduce the regulatory and planning risk associated with investing in new nuclear power stations," especially in the pre-construction period, were set out in the White Paper on Nuclear Power (BERR, 2008a: 34-35). These include two major sets of reforms:

Improving the Planning System for Major Electricity Generating Stations

The intention is to establish a framework for "development consent" for new electricity generating stations (including nuclear power stations) in England and Wales (Scotland has opted out – see section 6), that gives full weight to policy and regulatory issues that have already been subject to debate and consultation at a national level. This could take the form of a National Policy Statement, consistent with proposed planning reforms (DEFRA, 2007) that entail:

- Running an SSA process to develop criteria for determining the suitability of sites for new nuclear power stations and taking further the consideration of the high-level environmental impacts of new nuclear power stations through a formal Strategic Environmental Assessment (SEA) in accordance with the EU SEA Directive³⁸ – although applicants for specific

³⁵ Council Directive 94/55/EC of November 21, 1994 on the approximation of the laws of Member States with regards to the transport of dangerous goods by road; Council Directive 96/49/EC of July 23, 1996 on the approximation of the laws of Member States with regards to the transport of dangerous goods by rail; and Council Directive 86/618/Euratom of 27 November 1989 on informing the general public about health protection measures to be applied and steps to be taken in the event of a radiological accident.

³⁶ See <http://www.iaea.org/Publications/Documents/Conventions/cppnm.html>.

³⁷ For a skeptical view on the independence of CoRWM see <http://www.nuclear-spin.org/index.php/CoRWM>.

³⁸ Directive 2001/42/EC of June 27, 2001 on the assessment of the effects of certain plans and programs on the environment (O.J. L197, 21.7.2001: 30).

proposals would still need to carry out a full Environmental Impact Assessment (EIA);

- Running a process of “Justification” (in accordance with the Justification of Practices Involving Ionizing Radiation Regulations 2004), to test whether the economic, social or other benefits of specific new nuclear power technologies outweigh the health detriments; and
- Assisting the nuclear regulators to pursue a process of Generic Design Assessment (GDA) or “pre-licensing” of industry-preferred designs of nuclear power reactors to complement the existing site-specific licensing process. This would consist of an assessment of the safety and security of power station designs and their radiological discharges to the environment (see further discussion in section 5).

Under the SSA process, third parties will be invited to nominate potentially suitable sites, that will be assessed against siting criteria developed and consulted on by government. A list of the SSA criteria was published in summary draft in June 2008 together with an assessment timetable (BERR, 2008b). These formed the basis of a consultation document published on July 22, 2008 (BERR, 2008c), together with a study of the potential environmental and sustainability effects of the siting criteria (BERR, 2008d). The consultation will run until November 11, 2008.

Three types of criteria are outlined in the consultation document: exclusionary, discretionary (as shown in Table 3) and local. Exclusionary criteria are those criteria that for safety, regulatory, environmental or other reasons will categorically exclude a site from further consideration in the SSA. Discretionary criteria are those criteria (such as flood risk, proximity to protected sites or access to suitable cooling) that the government considers, either singly or in combination, to make a site unsuitable for a new nuclear power station but which need to be considered in order to come to a conclusion as to the site’s strategic suitability. Local criteria will be assessed as part of detailed site-specific investigations and data.

The proposed SEA will consider the high level environmental impacts of applying the SSA criteria. However, the initial environmental study (published alongside the SSA criteria consultation) found that the discretionary nature of some of the criteria mean that “adverse environmental and sustainability impacts cannot be wholly ruled out” (BERR, 2008d: 5).

Table 3: SSA Proposed Criteria

Criteria related to nuclear safety		Status
1.1	Seismic risk (vibratory ground motion)	Exclusionary
1.2	Capable faulting	Exclusionary
1.4	Flooding	Discretionary
1.5	Tsunami, storm surge and coastal processes	Discretionary
1.7	Proximity to hazardous industrial facilities and operations	Discretionary
1.8	Proximity to civil aircraft movements	Discretionary
1.10	Demographics	Exclusionary
1.12	Proximity to military activities	Exclusionary and Discretionary
Criteria related to environmental protection		
2.1	Internationally designated sites of ecological importance	Discretionary
2.2	Nationally designated sites of ecological importance	Discretionary
Criteria related to societal issues		
3.2	Areas of amenity, cultural heritage and landscape value	Discretionary
Criteria related to operational requirements		
4.1	Size of site to accommodate construction, operation and decommissioning	Discretionary
4.2	Access to suitable sources of cooling	Discretionary

Source: BERR, 2008b: 8.

Some planning reforms are proving controversial, especially the proposal for a new independent Infrastructure Planning Commission that would decide on all new nuclear power stations, road schemes and airport runway extensions. The government has already made a number of concessions in order to try and smooth passage of the draft Planning Bill. First, MPs are to be given the opportunity to vote on new national infrastructure strategies, including nuclear energy, before referral to the Commission for decision. The strategy on nuclear power stations will say how many will be required, where they will be sited and how much they will cost. Second, people whose homes could be blighted by such developments will automatically have the right to compensation. In the nuclear context, however, the cost of this concession is likely to be marginal, especially if the new nuclear power stations are built at existing sites.³⁹

Increasing Transparency and Certainty in Liability Costs

The government is committed to “delivering legislative arrangements to ensure that operators meet their full decommissioning costs and their full share of waste management and disposal costs.” Currently, nuclear operators

³⁹ Hencke, David (2008). “MPs get veto on nuclear power, motorway and airport schemes,” *The Guardian*. May 30.

have to maintain insurance or other financial security to cover liability for personal injury and property damage under the Nuclear Installations Act 1965.⁴⁰ The government intends to consult on amending this Act to include “new heads of liability, such as the cost of measures of reinstatement of impaired environment” (BERR, 2008a: 65). The requirement for insurance or other financial security will also then be extended to cover these new liabilities. Certain potential liabilities associated with nuclear events are expected to continue to fall to the government, as set out in its May 2007 consultation document (DTI, 2007b: 61-62).

Any changes are expected to enhance both investor confidence (by giving greater certainty about how they will be expected to meet their liabilities) and taxpayer protection (by ensuring that private sector operators of nuclear power stations securely accumulate the funds needed to meet the full costs of decommissioning and waste management). A number of experts from the nuclear, insurance and banking industries will be invited by the government to sit in on a NLFAB, which will monitor the companies’ decommissioning funds.⁴¹ This new legislative arrangement would need to be agreed upon before proposals for new nuclear power stations could proceed.

Conclusions

The four decades of nuclear power in the UK have seen a transition from self-regulation (through the UKAEA) to institutional regulation (via the NII) to the current complex mix of regulatory and advisory bodies. The UK government believes that the regulatory process is capable of overseeing existing facilities as well as any new nuclear power stations irrespective of who owns and operates them. A recent review by the IAEA concluded that the HSE’s regulatory arrangements are mature and transparent, with highly trained and experienced inspectors (IAEA, 2006).

To strengthen the UK’s regulatory regime, the government has authorized the HSE to increase the salary levels of its nuclear inspectors to ensure that it can “recruit staff of the necessary calibre” (BERR, 2008a: 22), but nonethe-

less concludes that, “Whilst there can be no room for complacency, the UK has a strong safety record with no events relating to a civil nuclear power station with off-site consequences or where all the safety barriers that are an inherent part of the design were breached” (BERR, 2008a: 75).

UK Nuclear Fuel Cycle

From the outset, the UK has sought to be self-sufficient in conversion, enrichment, fuel fabrication, reactor design, reprocessing and waste treatment. Uranium is imported. Each stage of the UK’s nuclear fuel cycle and its current status is discussed below.

Fuel Supplies

The UK currently relies on imports of uranium (mostly from Australia) for its existing nuclear power stations. The NDA owns around 51,000 tonnes of uranium, which could be converted into uranium-based fuel or could be combined with the UK’s 86.5 tonnes of plutonium and used to make MOX fuel. A recent report commissioned for the NDA (2007), estimates that the UK stocks of uranium and plutonium could fuel up to three 1,000-MW reactors for 60 years.

In addition, the government White Paper on the Future of Nuclear Power (BERR, 2008a: 29) cites a number of “authoritative reports” (including House of Commons Trade and Industry Committee, 2006; Euratom Supply Agency, 2007; World Energy Council, 2007; and IEA 2007) as evidence that sufficient imports of uranium will be available to fuel a new UK program of nuclear power stations.

Conversion, Enrichment and Fuel Fabrication

A uranium conversion plant producing 6,000 tonnes per year operates at Springfields in Lancashire and is managed by Westinghouse under contract to the NDA. In 2005, the Canadian corporation, Cameco (the world’s largest uranium producer) signed a 10-year agreement for the supply of conversion services from the Springfield plant. With feed from Cameco’s Blind River refinery in Ontario, the agreement is expected to utilize over 80 percent of the uranium conversion capacity at Springfields.

The European energy company Urenco (which is part owned by the British government, although its 33 percent stake is up for sale) undertakes enrichment at the Capenhurst site near Chester in the north-west of England.

⁴⁰ This implements the special international regime set out in the Paris Convention on Third Party Liability in the Field of Nuclear Energy of July 29, 1960 and the Brussels Supplementary Convention of January 31, 1963 regulating liability for personal injury and third party property damage caused by incidents involving nuclear matter in the course of carriage to or from, or on a licensed site.

⁴¹ Bream, Rebecca (2008). “Companies to foot nuclear clean-up bill,” *Financial Times*. February 22. Available at: <http://www.ft.com/cms/s/0/70bd3824-e0d4-11dc-b0d7-0000779fd2ac.html>.

Parts of the site dating back to 1976 were originally used to enrich uranium for military purposes. The site currently operates three plants based on the gas centrifuge process for producing enriched uranium and employs around 300 people.

Fuel fabrication of Magnox, AGR and PWR fuel is undertaken at Springfields, while additional PWR fuel is bought on the open market. The last batch of Magnox fuel was made in 2007 and will be loaded in 2009-2010. MOX fuel fabrication for export is undertaken at the Sellafield MOX plant.

Reactor Designs

The global nuclear industry classifies its reactors according to “generations.” There are no Generation I reactors in operation today anywhere in the world, although the UK was the last to close theirs, and was still operating eight of these Magnox (the name is derived from the magnesium alloy casing surrounding the fuel rod) plants as recently as 2004. Britain also specialized in two unusual Generation II reactor designs, both of which are still currently in use: an upgraded Magnox air cooled-graphite-moderated, natural uranium reactor, and the AGR. Neither of these two designs included secondary containment vessels, so both have a potential for large radioactive releases (Caldicott, 2006: 117). The third type of reactor currently in use in the UK, of which there is only one, the PWR, is also a second-generation reactor.⁴²

Magnox Reactors

The first eight Magnox reactors (Generation I) were small prototypes and initially dual-purpose, combining power generation with plutonium production for military purposes. When the latter function was taken over by other facilities at Windscale (later renamed Sellafield), these Magnox reactors were reconfigured to provide only power. Subsequent Magnox reactors (Generation II) were progressively scaled up and optimized for continuous electricity production. Twenty-six were built in the UK, two were sold to Japan and Italy, and similar units were built in France. Originally licensed for 30 years, some were extended to 50 years, although the last four in operation – two each at Wylfa and Oldbury – are due to close by 2011 and 2008 respectively.

AGR

The AGR is based on a prototype developed at Windscale in 1962 and adopted two years later as the UK standard. Graphite moderated and carbon dioxide-cooled, they use enriched oxide fuel that is burned at low levels (relative to LWR fuel). Fourteen were built at seven sites from 1976-1989. Each pair was a unique design so there was little standardization, and operational problems were significant. Like the Magnox units, they were designed and built for the CEBG by private industrial nuclear power consortia as complete power stations. Some of the construction delays beggar belief. The AGR power station Dungeness B, for example, took 22 years before producing any power (Myddelton, 2007: 95).

In 2006 British Energy closed four AGRs on account of boiler degradation in the non-nuclear part of the plants and approval was only given to restart them in May 2007 (operating at about 60 percent capacity). In December 2007 the company announced that it was investing £90 million on a five-year life extension for these four units (which would keep them operating until 2016) with a further extension to be considered in 2013. Life extensions for other AGR plants are to be considered at least three years before the scheduled closure of each unit. However, further corrosion problems were found in the structures of two other AGRs towards the end of 2007 and these, plus two similar plants were closed pending fuller assessment.⁴³ The technical problems continued into 2008, with 10 of British Energy's 16 plants out of action in May 2008 (including its PWR, discussed below).⁴⁴

PWR

In 1978 the decision was made to build an initial PWR at Sizewell B in Suffolk and the resulting Westinghouse reactor started up in 1995. It is typical of much of the current global fleet, but newer and more complex than most PWRs using water as both coolant and moderator. Water is pumped under high pressure (to prevent boiling) through the core of the reactor, reaching a high temperature. It is then used to boil other water in a separate circuit to make steam.

⁴² This discussion on UK reactor designs draws heavily on information on the World Nuclear Association's briefing “Nuclear Power in the United Kingdom,” January 2008. Available at: <http://www.world-nuclear.org/info/inf84.html>.

⁴³ Macrae, Fiona (2007). “Power cuts warning as energy chiefs shut down half our nuclear power stations,” *Daily Mail*. October 24. Available at: http://www.dailymail.co.uk/pages/live/articles/news/news.html?in_article_id=489362&in_page_id=1770

⁴⁴ Milner, Mark and Terry Macalister (2008). “Shutdowns and plunging profits cast doubt on nuclear future,” *The Guardian*. May 29.

Fast Breeder Reactors

The UKAEA operated a fast neutron (breeder) reactor program at Dounreay in Scotland, from 1957 until the government withdrew financial support in 1994. Three reactors were constructed, two of them fast breeders and the third a heavy water moderated research reactor used to test materials for the program. Fabrication and reprocessing facilities were also constructed on site. All the facilities at the site are now closed. Decommissioning and clean-up is scheduled to bring the site to an “interim care and surveillance state” by 2036 and a “brownfield site” (to enable re-use) by 2336, at an estimated cost of £2.9 billion.

Generation III and IV Reactors and Future UK Reactor Designs

The Generation III reactors are generally modifications of the light water Generation II reactors. Only three commercial Generation III reactors are in operation in the world at present (in Japan) with another under construction (in Finland). However, four of these “new” reactor designs have been certified for use in the United States. A number of potential sites are under consideration for the construction of at least two of these. About 20 additional designs for Generation III reactors are also under development (Greenpeace International, 2005). While the UK does not have any Generation III reactors currently under development, it did develop a prototype of the Pebble Bed Modular Reactor (PBMR) in the late 1980s. A high-temperature, gas-cooled reactor, the PBMR operates at 900 degrees centigrade and is cooled by helium gas circulating at high pressure (Caldicott, 2006: 119-121).

Generation IV reactors are “revolutionary” in that they rely on fuel and plant that have not yet been tested. For example, many of these designs require metals to resist corrosion levels far in advance of those experienced to date. There are also demands, especially in the United States, for Generation IV reactors to “close” the nuclear fuel cycle (see discussion on reprocessing below). Britain is part of the Generation IV International Forum, a group of countries chartered since July 2001 to lead the collaborative efforts to develop next generation nuclear energy systems. There are currently 12 countries involved, plus Euratom.⁴⁵

The Generic Design Assessment (GDA)

As discussed in Section 4, the UK government proposed a GDA (or pre-licensing) process to at least give the appearance of “competition” in the market for new nuclear reactors (Dorfman, 2008: 46). Having invited applications on a “contingent basis” during the consultation period, four applications were received:

- From the French energy companies, Areva and EDF for the European Pressurized-water Reactor (EPR), a new Generation III 1,660 MW PWR, one of which is currently under construction in Finland, with another plant planned in Normandy, France;⁴⁶
- From Westinghouse Electric Company for the AP1000, a 1,117 MW PWR with passive safety systems and extensive plant simplifications that are said to improve plant operation and maintenance while reducing construction cost (although these cost-cutting features mean that it has no secondary containment)⁴⁷ – the company secured a US contract in April 2008 to build two of these reactors for an estimated \$13bn (£7bn);⁴⁸
- From GE-Hitachi, for the Economic Simplified Standard Boiling Water Reactor (ESBWR) a 1,55 MW Generation III+ reactor incorporating simplified design features and fewer components, which is claimed would allow faster construction, lower operating costs and enhanced safety;⁴⁹ and
- From Atomic Energy of Canada for the Advanced CANDU Reactor (ACR) 1000 Limited (AECL) – an evolutionary, Generation III+, 1,085 MW class heavy water reactor, which is designed for a 2016 in-service date, with extensive pre-licensing review and feedback from Canadian regulators.⁵⁰

Britain’s largest defence contractor, BAE Systems, is also looking to break into the civil nuclear market and claims to have had talks with “at least one” of the four companies that have submitted proposals.⁵¹ BAE Systems sees the civil nuclear program as both a business opportunity and a means to protect its core capability in building nuclear

⁴⁵ The twelve countries are: Argentina, Brazil, Canada, France, Japan, Korea, South Africa, Switzerland, UK, and US. For further details see: <http://www.gen-4.org/>. In February 2008, the UK also joined the US-led Global Nuclear Energy Partnership (GNEP), although the significance of this is unclear since, other than signing the Statement of Principles, nothing is currently being asked of member states. See <http://www.eurekalert.org/features/doe/2008-02/ddoe-udo022908.php>.

⁴⁶ For further details, see the company website: <http://www.areva.com>.

⁴⁷ See the company fact sheet: <http://www.energetics.com/pdfs/nuclear/ap1000.pdf>.

⁴⁸ Macalister, Terry (2008). “Westinghouse wins first US nuclear deal in 30 years,” *The Guardian*. April 10.

⁴⁹ For further details, see http://www.gehgenericdesignassessment.co.uk/document_download.jsp.

⁵⁰ For further details, see <http://www.aecl.ca/Reactors/ACR-1000.htm>.

⁵¹ Pfeifer, Sylvia (2008). “Civil role beckons for nuclear expertise,” *Financial Times*. April 23.

submarines. The UK aircraft engine maker, Rolls-Royce, also announced similar plans to spin off from nuclear submarines into the civil nuclear market, and is said to be working on projects with both Areva and Westinghouse.⁵² These moves revive the prospect, albeit unlikely, of a return to stronger synergies between the civil and military nuclear sectors in Britain.

On July 5, 2007, BERR announced that all four applicants (none of whose designs are proven commercially) had met the criteria set down in the consultation document. In August 2007 the UK regulatory agencies – the NII, OCNS and the Environment Agency – commenced the initial stages of the GDA for all four designs.⁵³ Steps 1 and 2, a preparatory stage and a safety overview, have already been completed, and the HSE and the Environment Agency jointly announced in March 2008 that they had provisionally reviewed all four designs and could find no fault with them.⁵⁴ Subsequently, the Canadian ACR1000 was withdrawn from the GDA process. The official explanation was that the company wanted to focus on the Canadian market, although it was always anticipated that no more than three designs would proceed to the next phase, in part because of resource constraints among the regulators.

On June 12, 2008, HSE and the Environment Agency announced that they were starting the next, more detailed assessment stage of the GDA process – referred to by HSE as Step 3 – for the remaining three designs. This third phase is expected to run until 2010-2011.

The ultimate aim is to sanction designs that are most capable of being licensed and operational in the UK within the 2016-2022 timeframe (BERR, 2008a: 144-146). Informed opinion suggests that the French EPR with its relatively recognizable design will emerge as the “only show in town” (Dorfman, 2008: 48), especially given the March 2008 announcement of Anglo-French nuclear cooperation.

Reprocessing of Spent Fuel

“Spent” nuclear fuel consists of about 96 percent unused uranium, one percent plutonium and about three percent highly active waste products (“fission products”) and

heavy metals. There are two broad options – either the spent fuel can be stored with a view to disposal or it can be reprocessed into its separate components. In theory, reprocessing reduces the amount of fresh uranium that has to be mined, so extending the lifetime of uranium reserves and also cutting the volume of highly radioactive material for eventual disposal.

But this “plutonium economy” also involves the use of chemicals and reprocessing plants that become contaminated with radioactivity, causes emission of radioactive materials into the environment, and is expensive. It also produces plutonium which can be used in nuclear weapons – and, indeed, this was the initial rationale for most reprocessing programs. It was also initially assumed that plutonium would be needed to fuel a growing number of fast breeder reactors, but this has not proved to be the case due to technical complications and excessive costs with these reactors. Instead, the industry goal has switched to the conversion of plutonium into MOX fuel, which can be used in PWRs as an alternative to fresh uranium fuel. Several countries have licensed reactors to use MOX fuel, notably in France where over 20 reactors operate in this way.

The UK is one of a small group of countries, France being the main competitor that offers a reprocessing service to other countries through BNFL’s facility at Sellafield. In all contracts signed with BNFL since 1976, the country that owns the fuel is supposed to take back (and store) all waste products, as well as the reusable uranium and plutonium. The fact that this is not done is symptomatic of the UK reprocessing story: a lesson in nuclear hubris and over-confidence of the highest magnitude.

Sellafield houses two state-owned reprocessing works and a MOX plant. Britain first began reprocessing spent Magnox fuel at a plant in Windscale/Sellafield in the mid-1960s, partly since this fuel could not be stored indefinitely because of corrosion problems. Although the plant is due to shut down in 2012 after closure of the last Magnox reactors, reprocessing is currently behind schedule and it may need to be kept open longer. The NDA’s 2005 three-year plan had expected 2,520 tonnes of fuel to be processed but the facility only managed 1,230 tonnes.⁵⁵

In the 1970s, the grand vision of the UK nuclear establishment was of a different order: the vision of a “plutonium economy” that would fuel a new generation of fast breeder reactors to supply the majority of Britain’s energy needs. Contracts to reprocess 1,500 tonnes of oxide fuel were

⁵² Bream, Rebecca (2008). “Rolls-Royce plans civil nuclear expansion,” *Financial Times*. July 16.

⁵³ A new website has been set up jointly by HSE and the Environment Agency which gives information on the new reactor assessment process. Available at: <http://www.hse.gov.uk/newreactors/index.htm>.

⁵⁴ The regulators have published a series of reports on the initial assessment of the four designs. Available at: <http://www.hse.gov.uk/newreactors/assessmentreports.htm#ArevaEDF>.

⁵⁵ Milner, Mark and Terry Macalister (2008). “Shutdowns and plunging profits cast doubt on nuclear future,” *The Guardian*. May 29.

Box 2: The Sellafield Complex: An Ongoing Technical and Financial Disaster

Vitrification and evaporator plants

For more than 40 years HLW has been stored at Sellafield in liquid form in special tanks. In 1990, a £240 million plant was built to convert 1,355 cubic metres of this liquid waste, which requires constant stirring and cooling to stop radioactive elements combining and causing an explosive reaction, into 8,000 much safer glass blocks. Because of technical difficulties and a growing backlog of waste, another vitrification plant was built (at a cost of £320 million) and came on line in 2003. Overall in its first 11 years the vitrification plant throughput should have been 6,600 glass blocks or “cans,” but it only made 2,400. In the subsequent five years to March 2008, 4,500 cans of vitrified waste should have been produced, but the total was only 1,956. To compound matter, the three evaporators (which concentrate the liquid so that it can be stored in readiness for turning into glass blocks) have also not worked properly and a fourth has been ordered at a cost of £90 million, but will not be completed until 2011. The NII continues to express concern at the failures of the vitrification and evaporator plants (Paul Brown, 2008: 9-13).

THORP

Designed to deal with spent fuel from Britain’s AGRs and PWRs elsewhere in the world, the government claimed in 1990 that the plant would make £500 million profit for the UK economy by reprocessing 7,000 tonnes of fuel in the first 10 years. However, it dealt with only 5,729 tonnes in its first 11 years⁵⁶ and has experienced a series of technical problems, the most serious in May 2005 when a substantial leakage of radioactive spent fuel led to the plant’s closure for two years. BNG was fined £500,000 in October 2006 for what the Chief Inspector of nuclear installations

acknowledged as a major operational lapse. The NDA also fined BNG £2 million for failing to meet safety standards. Soon after re-opening in late 2007 the plant was closed again, in February 2008, and received a damning report from the NII, which described safety procedures at THORP as “not fully adequate.”⁵⁸

THORP is now well behind its reprocessing schedule, having reprocessed only half of the 2,160 tonnes of AGR fuel that it is contracted to reprocess. As of mid-2007, 1,500 tonnes of AGR fuel was scheduled to be reprocessed at the plant, and an additional 4,500 tonnes arising to the end of the AGR operating lifetimes was due to be stored. THORP could also reprocess the 1,000 tonnes of fuel from the PWR at Sizewell B, but has not been contracted to do so.⁵⁹

SMP

Although construction of the SMP was meant to cost £265 million, that rose to £490 million by 2004, according to the National Audit Office. The MOX activities were further discredited when Japan sent back fuel made in a demonstration facility following the falsification of quality-control documents. The return of the fuel cost the British taxpayer £113 million, while overall the SMP accumulated losses of £600 million by 2004.⁶⁰ In February 2008, the energy minister Malcolm Wicks admitted in parliament that the plant had only produced 2.6 tonnes in 2007 and a total of 5.2 tonnes since it opened in 2001, despite promises it would produce 120 tonnes a year.⁶¹

The combined annual cost of subsidising the Sellafield complex has been estimated at £100 for every taxpayer in the country or £3 billion in total (Paul Brown, 2008: 4).

negotiated with Japan and Germany, among others. To carry out the work BNFL set out a £1.2 billion plan to build THORP at Sellafield. Despite huge controversy, construction went ahead in the 1980s, but the economic justification proved illusory. As William Walker (1999: 137) concluded in his study of THORP:

One of Britain’s largest facilities was being turned on to provide plutonium that was no longer needed or wanted, and whose stockpiling was considered by many to endanger international security.

In the mid-1990s, with a decision pending on whether to make the plant operational (and the construction costs having almost doubled to £2.3 billion)⁵⁷, the goal posts were

moved from reprocessing for fast breeders to a MOX program. BNFL/BNG constructed a MOX facility adjacent to THORP (Walker, 1999: 117). Neither of these two facilities works as they were meant to and both have experienced huge technical problems and cost overruns, as has the entire Sellafield complex (see Box 2). Slow progress in reprocessing has also caused a huge backlog of spent fuel and a major storage issue at Sellafield.

⁵⁶ *Ibid.*

⁵⁷ *Ibid.*

⁵⁸ Lean, Geoffrey (2008). “Shambolic’ Sellafield in crisis again after damning safety report,” *The Independent*. February 3.

⁵⁹ World Nuclear Association website, fact sheet: “Nuclear Power in the United Kingdom.” February 2008. Available at: <http://www.world-nuclear.org/info/inf84.html>.

⁶⁰ Milner, Mark and Terry Macalister (2008). “Shutdowns and plunging profits cast doubt on nuclear future,” *The Guardian*. May 29.

⁶¹ Macalister, Terry (2008). “Minister admits nuclear fuel plant produces almost nothing,” *The Guardian*. March 3.

A June 2007 report (NDA, 2007) focused on the three options for dealing with the 100 tonnes of reactor-grade plutonium and 60,000 tonnes reprocessed and depleted uranium⁶² that will be need to be managed by 2012. The three options are:

- Treating the materials as wastes destined for deep geological disposal;
- Long-term storage; or
- Using them as fuel (or selling for this purpose)-the energy content is enough to run 3 GW of new PWR reactors for 60 years, or 12 GW of fast reactors for 700 years.

The NDA report makes no recommendations but notes that the waste option provides the lowest undiscounted cost. However, the Royal Society (2007), the UK's national academy of science, recommended in a separate study that the 100 tonnes of plutonium be used as MOX fuel. This would either be burnt in the proposed new generation of nuclear power stations, or, if there is no new nuclear build, by burning some in a modified Sizewell B and converting and storing the rest as MOX fuel pellets in a deep underground repository.

The French company Areva (which is part of the NMP consortium that will soon be running and cleaning up Sellafield and is also one of the leading contenders in the GDA process for the new nuclear build) also favours this approach, but wants to build a new MOX plant at Sellafield modelled on the one at its Melox plant near Avignon.⁶³

For the proposed new nuclear power stations, the UK government, while not favouring reprocessing of the spent fuel, does not rule it out in the future:

Our view remains that in the absence of any proposals from industry, new nuclear power stations built in the UK should proceed on the basis that spent fuel will not be reprocessed. (BERR, 2008a: 30).

Waste Management and Decommissioning

Radioactive waste is categorized into three types of waste according to the levels of radiation it contains:

- Low-level waste (LLW), which includes items that might be contaminated with traces of radioactive materials such as used protective clothing;

- Intermediate-level waste (ILW), which consists of solid and liquid materials from nuclear power stations and from fuel reprocessing; and
- High-level waste (HLW), which is the concentrated waste produced when nuclear fuel is reprocessed.

Until 1982 some LLW and ILW were disposed of in deep ocean sites. In 1993 the government accepted an international ban on this and currently all UK nuclear waste is stored on the surface in managed, monitored and retrievable form. The industry is confident it can continue to be safely stored in this way for many decades, although there are growing doubts as to the storage capacity for HLW at Sellafield (Brown, 2008: 19-23). Different storage solutions apply to the different categories of waste:

- LLW is compacted and stored in drums and placed in engineered storage, mostly at Drigg, near Sellafield;
- ILW is similarly stored in stainless steel containers and placed in engineered storage, at the site where it is produced; and
- HLW nearly all arises at Sellafield where it is stored in liquid form in stainless steel tanks before vitrification (turned into glass blocks) and encapsulation into welded stainless steel containers.

In 2004, the newly established CoRWM was charged with again reviewing the options for long-term storage and disposal of high-activity wastes. After three years' consultation with stakeholders it recommended deep geological disposal as the "best available approach" for the long-term management of Britain's 470,000 cubic metres of HLW and ILW, despite the fact it was the same solution the government had already rejected three times over the last 30 years.⁶⁴ It also explored the implications of possibly treating plutonium and depleted uranium as wastes, and of possibly abandoning any reprocessing of used fuel (CoRWM, 2006).

CoRWM also recommended that the repository location should be on the basis of community agreement, with incentives provided to encourage volunteers. It acknowledged that actually commissioning a repository could take decades. The government accepted CoRWM's key recommendations and new members of CoRWM were then appointed in October 2007 to give continuing advice on implementing them. As part of its work CoRWM also put

⁶² The uranium is of three kinds: UF₆ depleted uranium tails from enrichment (25,000t), Magnox depleted uranium from reprocessing Magnox used fuel (30,000t) and normal reprocessed uranium from reprocessing oxide fuels (5000t).

⁶³ Bream, Rebecca (2008). "Push for 'closed cycle' reprocessing," *Financial Times*. June 9.

⁶⁴ In 1997, for example, the UK government refused permission for UK Nirex Ltd to construct an underground rock laboratory to investigate the suitability of strata near Sellafield for deep geological disposal.

Table 4: UK Radioactive Waste and Materials Inventory, 2007

Materials	Notes	Packaged Volume		Radioactivity (At April 1, 2040)	
		Cubic Metres	%	Terabequerels	%
HLW	1, 2, 3, 5	1,400	0.3%	36,000,000	41.3%
ILW	1, 2, 5	364,000	76.3%	2,200,000	2.5%
LLW (not for LLWR)	1, 2, 5	17,000	3.6%	<100	0.0%
Spent nuclear fuel	1, 4, 5	11,200	2.3%	45,000,000	51.6%
Plutonium	1, 4, 5	3,300	0.7%	4,000,000	4.6%
Uranium	1, 4, 5	80,000	16.8%	3,000	0.0%
Total		476,900	100	87,200,000	100

Source: DEFRA, 2008a: 20.

together an indicative “Baseline Inventory” of higher activity wastes for geological disposal – as shown in Table 4.

However, the Scottish Executive announced on June 25, 2007 that it did not endorse the decision by the UK government and other Devolved Administrations to seek to develop a geological disposal facility and instead declared its support for long-term “near surface near site” storage facilities.

The specific problems associated with decommissioning power reactors are discussed in Appendix B, but estimates of the total overall cost of civilian nuclear clean-up in the UK have now reached £73 billion. The Sellafield and Drigg sites represent about half of that estimated cost, the Magnox reactors about a quarter and Dounreay about a tenth. The rest is split across other UKAEA sites. The waste management portion is slightly greater than the decommissioning share. The NDA has an annual budget of £2.8 billion per year, with over £1 billion of this offset by operational revenue. In February 2008, however, the NDA had to seek a further £400 million funding top-up from the government, partly because its commercial income was not as high as expected. A subsequent report by the cross-party business and enterprise committee of MPs in April 2008 described the current funding model as “unsustainable,” adding:

Nuclear decommissioning is too important to be left to the mercy of changing priorities in the Treasury and uncertain commercial income... a new system of funding is needed, and work on this needs to begin urgently (Business and Enterprise Committee, 2008: 11).

In October 2006, the government announced that NDA would take over responsibility for ILW from Nirex⁶⁵ and in March 2007 it also assumed responsibility for developing a national strategy for the disposal of LLW. Thus, the NDA is now responsible for all nuclear waste activities in the UK.

In April 2007, the NDA established the Radioactive Waste Management Directorate to devise “a safe, environmentally sound, publicly acceptable, geological disposal solution” for the UK’s HLW and some ILW, both civil and military. This could eventually develop into the site licence company and implement geological disposal (expected to cost £7.5 billion from conception to closure in 2100) once a suitable repository site has been selected with public participation.

To this end, the government launched a new consultation in June 2007 called “Managing Radioactive Waste Safely: A framework for implementing geological disposal” (DEFRA, 2007). The consultation, which included “partnerships with potential host communities that allow issues and opportunities to be fully discussed and evaluated” closed at the beginning of November 2007. An analysis and summary of the responses was published in January this year (DEFRA, 2008). Overall the analysis suggests that there was general agreement with the government’s proposals, including that of seeking a voluntarism and partnership approach, although there continues to be some opposition to geological disposal more generally.

In June 2008, the government issued a new White Paper, *Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal* (DEFRA, 2008a), setting out the implementation framework for delivering geological disposal of the UK’s higher-level radioactive waste. Such facilities could take some decades to complete, but are expected to provide the means to dispose of both legacy and new waste. In summary, the White Paper:

- Keeps open the option of “extended retrievability” of the waste in the planning, design and construction phases;
- Favours a single geological disposal facility (for both legacy and new waste) provided it can be developed to provide suitable, safe containment for the “Baseline Inventory” of waste;
- Endorses a flexible “voluntarism and partnership” approach to site selection;
- Outlines the “engagement packages” (and potential future “benefits packages”) that will be available to

⁶⁵ UK Nirex Ltd. (originally the Nuclear Industry Radioactive Waste Management Executive) was formed in 1982 to develop an ILW disposal facility, with shares held by British Energy, BNFL, the UKAEA and the government. In 2003, the government took control of Nirex and gave it independence from the nuclear industry as part of wider reforms, including the establishment of the NDA, to deal with legacy nuclear installations and sites.

communities⁶⁶ that declare an Expression of Interest in hosting a geological disposal facility and, if appropriate, subsequently agree a Decision to Participate in a Community Siting Partnership; and

- Provides guidance on the site assessment process from the point at which a community makes an Expression of Interest.

With publication of the White Paper, the government also formally invited communities to express an interest in opening up “without commitment discussions” on the possibility of hosting a geological disposal facility. A dedicated website (www.defra.gov.uk/mrws) has been set up to assist in this process.

Proposed New Nuclear Build: Issues of Concern

As the UK government admits in the 2008 White Paper on Nuclear Power, the option of building a new series of nuclear power stations continues to be controversial and highly contested. There are seven main issues of concern: proliferation and terrorism risks; waste and decommissioning; health and safety; cost, including opportunity costs; skills capacity; location; and the Scottish opt-out. These concerns are reviewed below.

Proliferation and Terrorism

The UK is a nuclear weapon state party to the Non-Proliferation Treaty (NPT) having signed and ratified in 1968 and under which a safeguards agreement has been in force since 1972. The Additional Protocol to the UK's agreement was signed in 1998 and entered into force on April 30, 2004.⁶⁷ IAEA safeguards are applied to all UK civil nuclear activities. While it can be argued that all civil nuclear programs carry a nuclear proliferation risk, the government takes the view that new reactors are likely to be unattractive as a source of nuclear proliferation. This is because the “design of any new nuclear power stations would require fuel that needs considerable further treatment before it could be used in weapons” (BERR, 2008a: 78).

⁶⁶ The White Paper identifies three types of communities: “Host Community” – the community in which any facility will be built (e.g. a town or village); “Decision Making Body” – the Local government decision-making authority for the host community; and “Wider Local Interests” – other communities that have an interest in whether or not a facility should be built in the Host Community (e.g. a neighboring district or a community on the local transport routes to the Host Community).

⁶⁷ The Protocol only entered into force in the UK after similar implementing measures had been taken within the EU, or more precisely, within the Euratom Community (Santamaría and Prieto, 2006).

A number of broad security concerns were raised in the consultation process, ranging from the security of any new nuclear plant to the security of the transportation of nuclear materials, with a particular emphasis on the terrorist threat to the civil nuclear industry. Greenpeace commissioned a series of three reports in the wake of the 9/11 attacks that examined potential scenarios arising from an aerial attack by terrorists on the nuclear complex at Sellafield (comprising nuclear reactors, re-processing plants and high-level waste storage tanks containing 1550 cubic meters of liquid waste and tens of tons of separated plutonium). Their worst-case disaster scenario envisaged 3.5 million fatalities. Frank Barnaby, a former nuclear scientist at Aldermaston, concluded that the deliberate crashing of a jumbo jet onto the Sellafield plant could cause a radioactive fireball over a mile high and would likely release 25 times as much radiation as was emitted in the Chernobyl disaster (Caldicott, 2006: 105).

The government and the nuclear industry consider such conclusions to be unsubstantiated, and, based on confidential impact studies, believe that bulk shielding and containment at Sellafield would not be breached by an aircraft crash. An independent parliamentary analysis of the evidence of the risk of terrorist attacks on nuclear facilities concluded that:

There is sufficient information in the public domain to identify ways terrorists might bring about a release of radioactive material from a nuclear facility, but not to draw conclusions on the likelihood of a successful attack, or the size and nature of any release (POST, 2004).

Waste and Decommissioning

As discussed in section 5, the UK government has accepted CoRWM's recommendation that geological disposal, coupled with safe and secure interim storage of the UK's higher activity “legacy” radioactive waste is the best available approach. The government also confirmed its support for exploring an approach based on voluntarism and partnership with local communities. The government also believes that new waste should be dealt with in the same way as legacy waste, although operators of new nuclear power stations will be required to provide and pay for the interim storage facilities and set aside sufficient funds to cover decommissioning costs.

Critics argue that without any firm plans for the long-term disposal of UK legacy waste after nearly 30 years of consultations and policy reviews, creation of new waste simply compounds the problem. But while the government accepts that creating new waste “raises ethical issues,”

on balance it concludes that “not taking action now on climate change, by allowing energy companies to invest in new nuclear power stations, raises more significant inter-generational challenges in terms of climate change related CO² and ongoing security of energy supplies, than does the management of radioactive waste” (BERR, 2008a: 27). Some continue to question whether responsibilities and burdens are being fairly and equitably distributed:

The UK needs to act on its ethical responsibilities to mitigate climate change, but should not be achieving this by giving the major burden to a handful of isolated and dependent nuclear host communities. Action should rather be focused on the heartlands of demand and consumption. There are better and fairer ways of distributing responsibility to reduce carbon that do not pose an irresponsible and unethical burden of radioactive waste on future generations (Dorfman, 2008: 54).

Health and Safety

One indisputable fact about nuclear power stations around the world is that they all leak radiation into the environment. The long-term health effects of living near nuclear power stations are highly contested,⁶⁸ although there are real concerns that infants and children living near nuclear facilities may be subject to greater cancer and leukaemia risk. In the UK, in addition to the routine “safe”⁶⁹ emissions into the air and sea from nuclear power stations, concerns have periodically arisen about more serious levels of pollution at specific sites (especially the Sellafield complex)⁷⁰ and as a result of nuclear waste “dumping” scandals (for example, at the power plant at Dounreay on the north coast of Scotland)⁷¹.

In relation to the proposed new builds, concerns were specifically raised in the consultation process that the private sector might sacrifice health and safety standards

in the pursuit of profits. The recent leak from a nuclear treatment plant run by Areva in southern France will add to those concerns, especially given the growing involvement of French companies in the British nuclear industry.⁷² However, the government believes that new nuclear power stations would pose very small risks to health and safety, and that the UK’s regulatory framework “ensures that these risks are minimised and sensibly managed by industry” (BERR, 2008a: 22).

Costs

There are three concerns regarding cost: capital costs of supply (building and operating the power stations); the cost of decommissioning and clean-up (which is a major component of the capital costs); and opportunity costs (the argument that nuclear power will financially crowd out other options). The capital costs involve a range of factors, including investment decisions, pricing structure, tax policies and market strategy. One critic of Britain’s previous nuclear programs (Myddelton, 2007: 104) estimates, “as a minimum,” total “losses” of £32 billion:

These are not the total costs of providing civilian nuclear power – they are losses. This figure does not include the substantial cost of Magnox construction overruns; it almost certainly understates the cost of AGR overruns; and it ignores THORP.

The author attributes the principal causes of Britain’s “disastrous experience with nuclear power” as the “three interacting state monopolies, supported by an interventionist state,” which “severely distorted the incentives facing managers in the industry.” In his view, the key factor was the absence of market forces – something that successive government have sought to address through privatization over the last two decades. Will greater use of market mechanisms ensure that future cost projections are met?

There are at least four reasons for thinking that the faith in cost forecasts by nuclear enthusiasts may again be misplaced. First, the only nuclear power station currently being built anywhere in the world without government money, the Olkiluoto 1,600 MW reactor in Finland, has faced severe cost overruns and delays. Originally due to be completed in 2009 at a cost of about £2.2 billion, it is now reported to be 25 percent over budget and the start

⁶⁸ For example, see the contrasting discussion on research into cancer clusters around UK and German nuclear power stations in the White Paper on Nuclear Power (BERR, 2008a: 78-79) and Dorfman (2008: 55-58).

⁶⁹ The UK government and the EU base their policies on safe levels of exposure on International Commission on Radiological Protection data. Currently, an acceptable “dose limit” is 20mSv/y for workers and 1mSv/y for members of the public.

⁷⁰ In 2003, for example, European Commission inspectors discovered a pond containing 1.3 tonnes of plutonium, which had been sitting there, unacknowledged and unchecked, for 30 years. (Edwards, Rob (2004). “Uranium Pond at Sellafield Sparks Court Threat by EU.” *Sunday Herald*. March 28). And in 2005, leaking pipes were found to have spilled nitric acid containing around 20 tonnes of uranium and 160 kilograms of plutonium. “Legal Threat Over Sellafield Leak,” *BBC News Online*. June 12.

⁷¹ Ross, David (1998). “Dounreay Admits Shaft Error,” *The Herald*. May 22; and Arlidge, John (1998). “Fresh Scare on Nuclear Waste,” *The Guardian*. February 2.

⁷² Hollinger, Peggy (2008). “France orders probe at all nuclear sites,” *Financial Times*. July 17.

of commercial production has slipped to 2012.⁷³ There have also been suggestions that the plant is being built as a “loss leader” by the French company Areva, in order to create the impression that the technology is commercially viable (Monbiot, 2007: 93).

Second, this would seem to confirm the arguments of nuclear critics (see, for example, the alternative economic modelling undertaken by Greenpeace, 2007) that nuclear power always relies on subsidies of one kind or another

Box 3: Subsidizing UK Nuclear Power

Past:

- £73 billion waste and decommissioning costs;
- Nuclear power generation was protected by subsidy from the NFFO up to 1998, which obliged distributors to take a certain proportion of their electricity from non-fossil sources; and
- Financial aid packages for British Energy: in 2002 the government lent the company £650 million and a further £184 million in 2005.⁷⁴

Present:

- Limits on the insurance liability that nuclear operating companies have to take on: for example, the state provides insurance cover for extreme accidents that commercial insurers refuse to cover (BERR, 2008a: 62-63);
- The special armed nuclear police provided at public expense; and
- The priority given to nuclear power as a base load provider: nuclear power stations only operate economically at full power, so they have to be given priority to sell their electricity to the grid to the exclusion of other power sources that may be cheaper.

Future:

- New nuclear-build may require a long-term government-backed financial indemnity (Hawkins, 2008: 35);
- Electricity suppliers – as part of their licence requirements – may be required to sign up to a long-term nuclear purchasing obligation (NPO) (Hawkins, 2008: 36-37);
- Provision of sea defences for the new stations (if built on vulnerable coastal sites): will the nuclear industry or the taxpayer-funded Environment Agency pay these costs?; and
- Transmission costs. The new nuclear power stations are going to require new investment in the National Grid.

and that nuclear generation costs are typically underestimated. Even some pro-nuclear analysts admit that new nuclear build is not possible in the UK without the government speeding up the planning process and giving financial guarantees so the taxpayer covers the risk of cost overruns (Hawkins, 2008). Thus, despite having a deregulated market in electricity, the government continues to subsidize the nuclear sector. Some of the new subsidies will only become apparent as terms and conditions are negotiated with potential builders, but examples of past, current and potential future subsidies are shown in Box 3.

Similarly, future decommissioning and waste costs may also be understated. The estimate for existing clean-up costs stands at £73 billion, an increase of 30 percent since 2003, and there is a risk that costs may rise further, especially since the UK is only just starting to come to grips with decommissioning and waste management (Public Accounts Committee, 2008: 3). While it is the government’s stated intention to ensure that operators build up funds to cover the costs of decommissioning, doubts were expressed during the consultation process that operators would actually accumulate sufficient funds. Indeed, a committee of MP’s with oversight of the public accounts recently concluded that BERR “is unable to provide complete assurance that the costs of decommissioning new nuclear power stations will not fall back on future taxpayers” (Public Accounts Committee, 2008: 4).

Third, the government believes that large project management techniques have improved over the past 25 years and that the prospect of genuine international tendering should restrain costs. However, the potential novelty of reactor designs that might be used in the UK and the political and regulatory risks attached to them could mean that the chances of cost overruns are higher than the chances of achieving cost savings. It was a lack of standardized designs and program build that plagued past British reactor designs, especially AGRs.

Fourth, a number of other complex contracting relationships have floundered across the UK public-private divide, including Network Rail, Metronet, the national ID card scheme and the NHS computer initiative. All have been expensive failures and give similar cause for concern in the nuclear case, which could be described as a “capitalist redefinition of state-financed activities.”⁷⁵

⁷³ Milner, Mark (2007). “Delays to Finnish plant fuel UK nuclear debate,” *The Guardian*. December 29; and Gow, David (2008). “New-generation Finnish nuclear reactor hit by fourth delay,” *The Guardian*. October 18.

⁷⁴ Brown, Paul (2005). “Taxpayers’ £184m Aid to Private Energy Firm,” *The Guardian*. July 18.

⁷⁵ Jenkins, Simon (2008). “The state is utterly clueless on the public-private divide,” *The Guardian*. February 20. Available at: <http://www.guardian.co.uk/commentis-free/2008/feb/20/northernrock.banking1>

The attempt at “corporatizing” the nuclear industry has certainly had a bumpy path, and some of the regulatory bodies (such as the NDA) have also in effect become “not-for-profit holding company boards.”⁷⁶ The balance sheets of the “private” nuclear companies continue to depend on government contracts containing price guarantees and risk-limiting clauses.⁷⁷ The Treasury believes that “efficiency savings” and “risk transfer” made these deals worthwhile, yet the risk is seldom transferred. The nuclear companies have the potential to walk away with huge profits without delivering lasting solutions to Britain’s energy insecurity and nuclear waste management problems.

Finally, the opportunity costs of new nuclear build are likely to be considerable. Put simply, if an energy company (with or without government subsidies) decides to build a nuclear power station on vacant land it owns, the opportunity cost is the value of the benefits forgone of the *next best thing* that might have been done with the land and construction funds instead. This assumes that both economic and political capital for energy projects is finite, a deeply contested claim, but there is evidence that nuclear power has “crowded out” investment in other forms of energy production, especially renewables. In the mid-1980s, for example, a potential alternative technological trajectory – wave power – was closed off as a result of decisions by key UK nuclear institutions and networks.⁷⁸

The legacy of those decisions is not only the lost opportunity for a much larger indigenous renewable energy sector, with its own employment and export benefits,⁷⁹

but also the continued support for disastrous nuclear projects like the THORP program (Schofield, 2007) and the crippling cost of decommissioning. For example, almost half of the entire budget-over £1.5 billion in 2008 (equivalent to an extra 1 penny on the pound on income tax)⁸⁰ – of the UK government department responsible for business development (BERR) is currently being spent on decommissioning the UK’s old reactors and nuclear facilities. Given that all power plants have long lead and operating times, often stretching for several decades, it seems highly likely that the nuclear revival is once again drawing in limited energy investment while indirectly or directly reducing or closing off alternative technological choices.

Skills Capacity

While the government acknowledges that the supply of both skilled people and equipment will be constrained at times and that action is required to retain skills and train a new workforce, it concludes that “the situation is manageable” (BERR, 2008a: 30). To address the skills shortage, a new £25 million Centre for Nuclear Energy Technology has been announced for Manchester University, to train present and future nuclear workers and conduct nuclear research.⁸¹ A National Skills Academy for Nuclear has also been established, with a Head Office in West Cumbria and a network of Regional Training Clusters. The Academy aims to start 1,200 apprentices and 150 foundation degree learners in the next three years, while simultaneously providing 4,000 shorter courses for developing the skills of current workers and engaging with higher education to ensure an adequate supply of graduates.⁸²

However, the current shortage of nuclear safety inspectors, in particular, may yet lead to a slippage in the new build timetable. As many as a 100 new inspectors will have to be hired over the next four years in order to assess new reactor designs and to keep checking existing nuclear plants. There are currently 168 nuclear inspectors in post, and 13 of these have already been allocated to the GDA program for new reactors. Around 30 more are needed to assess the four proposed reactor designs.⁸³

⁷⁶ Ibid.

⁷⁷ For example, consumers may face higher electricity bills to cover the future decommissioning costs of the new nuclear power stations. While the government is expected to collect a fee from the companies for each unit of electricity used in British homes to build up a decommissioning fund, it is also anticipated that this extra fee will be passed on to consumers in the form of higher bills. Also, if the fund does not cover the full decommissioning costs, the shortfall would also likely fall to the taxpayer. Finally, the taxpayer will also foot the bill of nearly £1bn to compensate the community eventually chosen to host the permanent nuclear waste repository, as well as the cost of security at potential sites, the transport of waste and the extra cost of any required increase in the size of transmission lines for the national grid. Vidal, John (2008). “Consumers may foot nuclear bill,” *The Guardian*. January 7. Available at: <http://www.guardian.co.uk/environment/2008/jan/07/nuclear-power.alternativeenergy>.

⁷⁸ In 1984, researchers at the nuclear research centre at Harwell put the price of wave power at 9.8 pence per kilowatt hour (current estimates are 4-5 pence) leading to the cancellation of the UK’s pioneering research into wave power. See the discussion in Schofield (2007).

⁷⁹ A comparison of employment statistics in the UK nuclear industry and German renewables sector is illustrative. While the UK nuclear industry is thought to employ around 80,000 (directly and indirectly), a study commissioned by the German government found that in 2006 the country had some 259,000 direct and indirect jobs in the renewables sector. The number is expected to reach 400,000-500,000 by 2020 and then 710,000 by 2030. Renner, Michael. “Jobs in Renewable Energy Expanding,” Worldwatch Institute Briefing. Available at: http://www.worldwatch.org/node/5821?utm_campaign=vsonline&utm_medium=email&utm_source=green_jobs.

⁸⁰ Webb, Tim (2008). “Clean-up slows down at Britain’s obsolete reactors,” *The Observer*. May 18.

⁸¹ Turner, David (2008). “Nuclear centre aims to fill training gap,” *Financial Times*. February 25. Available at: <http://www.ft.com/cms/s/0/ba151bae-e32c-11dc-803f-0000779fd2ac.html>.

⁸² See the website of the National Skills Academy for Nuclear for further details: <http://www.nuclear.nscademy.co.uk/index.html>.

⁸³ Edwards, Rob (2008). “Shortage of safety inspectors could delay nuclear plans,” *Sunday Herald*. January 13; and Pagnamenta, Robin (2005). “Skills shortage threatens Britain’s nuclear drive,” *The Times*. July 22. Available at: http://business.timesonline.co.uk:80/tol/business/industry_sectors/utilities/article4375481.ece.

Any slippage in the timetable caused by a shortage of regulators would further undermine the government's security of supply and climate change rationale for nuclear power. Based on current policies, no new nuclear electricity is likely before 2020 even if an order were placed today (Sustainable Development Commission, 2005: 40). However, since new nuclear build is being suggested to fill an anticipated "energy gap" from 2020 onwards, any slippage in the timetable could have important consequences. (The government's indicative timetable for new nuclear build is discussed further in section 7).

Location

The issue of the location of new generating plant will also be critical. While there are no plans to restrict new nuclear power plants to the vicinity of existing sites, this nonetheless seems the most likely outcome. In addition to acquiring British Energy, EDF has been buying land around existing nuclear sites in England and Wales on the assumption that these will also be the sites of new nuclear power stations.⁸⁴ There are a number of reasons why the industry has indicated that these are the most viable sites: the economics are healthier, connection to the grid is already established (although some upgrading may be needed), obtaining land ownership is likely to be relatively simple, the locations are "known" by the regulatory authorities and it is assumed the local community will be more sympathetic to new-build having already lived with nuclear power, but this is by no means certain. However, all the existing sites are vulnerable to future coastal flood risk and would likely face long-term dependence on expensive sea defences (Dorfman, 2008: 51).

The suitability of sites will be assessed through the forthcoming SSA process (discussed in section 4). In addition to the SSA, any developer wishing to construct a new nuclear power station would also need to obtain relevant environmental, health and safety authorizations as well as development consent. Goodman and Hulson (2006) review some of the likely pitfalls in the consenting procedure and policy guidance for improving the system. Consultations are taking place on the criteria for assessing suitable sites and are then expected to take place on a draft list of sites.

⁸⁴ Crooks, Ed and Rebecca Bream (2008). "EDF adds to its UK nuclear options," *Financial Times*. May 8.

The Scottish Opt Out

The power to consent to the construction of power stations greater than 50MW capacity has been devolved to Scottish Ministers and is also devolved in Northern Ireland. The Scottish government has made clear its opposition to the UK government's proposals on new nuclear power (and on replacement of the UK's Trident nuclear weapon system, which is based in Scotland, but is a reserved matter for Westminster⁸⁵). The Scottish government has also indicated that while any proposal to build a new nuclear power station would be considered on its individual merits, it is unlikely that it would find favour.

In June 2007, the Cabinet Secretary for Finance and Sustainable Growth, John Swinney announced that the Scottish Government would consult on a Climate Change Bill to set a mandatory target of cutting emissions by 80 percent by 2050. In January 2008, the Scottish government published such a consultation document, with a closing date of April 23, 2008 (Government of Scotland, 2008). The difference in emphasis between the Scottish government's approach and that of Westminster is highlighted by the fact that nuclear power is mentioned only once in the entire consultation document – and only then in the context that increasing renewable capacity, improving energy efficiency and reducing energy demand may mean "fewer new fossil fuel (or nuclear) power stations in the UK, avoiding future emissions from construction and technological lock in" (Government of Scotland, 2008: 39).⁸⁶

Conclusions: The Construction of New Nuclear Power Stations: If, When, Where and How?

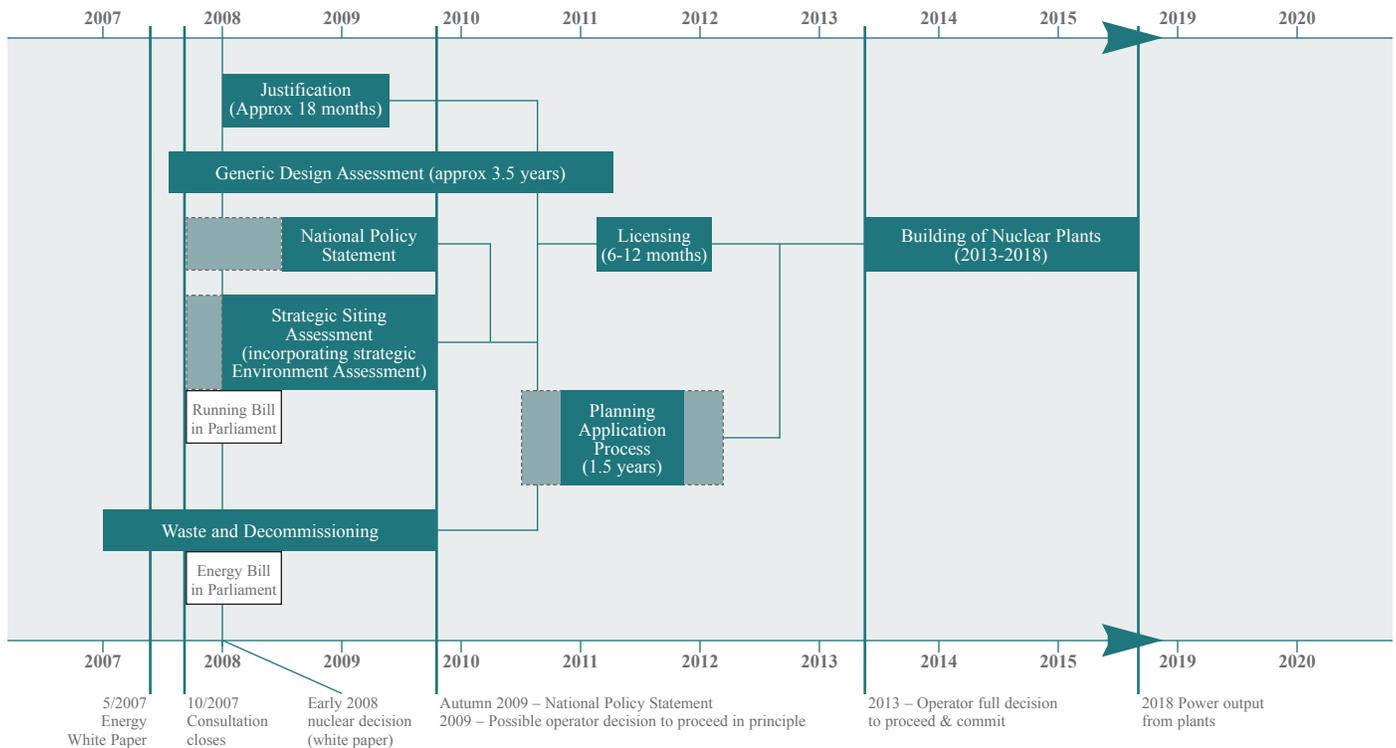
The discussion of nuclear power is charged with more anger than any other... every fact is fiercely contested. However much reading you do, you still don't know what or whom to believe.

George Monbiot (Monbiot, 2007: 89)

⁸⁵ See Walker, William (2007). "Scotland could go nuclear over the retention of Trident," *Financial Times*. March 9; and Jack, Ian "When is a nation not a nation? When it can't say no to Trident," *The Guardian*. October 9.

⁸⁶ A report published by Scottish ministers in September 2008 suggests that up to 128 new hydroelectric dams and scores of smaller schemes powered by the natural flow of a river could be built across the western and southern Highlands, generating enough electricity for a quarter of Scotland's homes. See <http://www.scotland.gov.uk/Resource/Doc/917/0064958.pdf>.

Chart 1: Indicative Pathway to Possible New Nuclear Power Stations



Source: BERR, 2008a: 36.

Several reputable organizations have published reports showing that there is no need to build new nuclear power stations, because a combination of renewable energy, greater energy efficiencies and other technologies (such as combined heat and power) can fill the gap as the old nuclear plants become redundant (see, for example, New Economics Foundation, 2005; Greenpeace UK, 2005; and the Sustainable Development Commission, 2005). This is also the view of the Scottish government.

Nonetheless, despite its historic problems, the UK government has concluded that nuclear power is one of the best ways to cut the pollution that is disrupting the climate (even though its own estimates suggest that the contribution of nuclear to CO² reduction is only likely to comprise around 4 percent of total UK CO²) while meeting UK demand for energy. Since the fundamental principle of UK energy policy is that competitive energy markets, with independent regulation are the most cost-effective and efficient way of generating, distributing and supplying energy, investment decisions on new nuclear power stations are largely being left to the energy companies in the private sector to make (although the government is seeking to soften the regulatory framework to help facil-

itate the nuclear option). Thus, the economics of nuclear power will be at the centre of the ongoing debate about new nuclear build in the UK.

The now infamous US Atomic Energy Commission boast in the mid-1950s that nuclear-generated electricity would soon become “too cheap to meter”⁸⁷ was quickly undermined by serious cost overruns, construction delays and operating problems that went on to bedevil all three of the previous UK nuclear programs. Would a new generation of UK power stations fare any better? And will energy companies want to invest in new nuclear build given that the process for obtaining consent looks set to be long and arduous, despite the government’s commitment to make life easier for them?

⁸⁷ The origin of the phrase “too cheap to meter” is a speech by the chairman of the US Atomic Energy Commission, Lewis L. Strauss, to the National Association of Science Writers in New York in 1954. The context of the speech is important. While Strauss did say that “our children will enjoy in their homes electrical energy too cheap to meter” he did not specifically say that it would be generated by nuclear power and, in the same futuristic speech, he also predicted an end to disease, hugely extended human lifetimes and world peace. However, the phrase has entered into popular UK usage and is often attributed to one of the British nuclear pioneers, Walter Marshall, but without any clear source references.

As discussed in section 5, three energy companies have already come forward with proposals for new nuclear power stations now being considered under the GDA process. The government has established an indicative timetable (see Chart 1) showing the fastest practical route to the building of new nuclear power station and believes that it can deliver a framework that would enable energy companies to begin construction of the first new nuclear power station in the period 2013-2014 (BERR, 2008a: 35-36). It also anticipates completion of the building schedule and power output by 2018, but previous British experience with untried nuclear designs suggests it could be much longer.

British Energy has said that it would support all three GDA applications and is conducting its own review of these reactor designs. It controls many of the likely sites for new plants and believes all of them would be suitable for new build, even considering possible sea level rise due to climate change. It has made transmission connection agreements with the National Grid for possible new nuclear plants at Sizewell, Dungeness and Bradwell (in the densely populated southeast of England) and Hinkley (in the southwest). The agreements will facilitate appropriate grid connections for a range of possible reactor types to be in place from 2016 onwards.⁸⁸

The government also claims that, after many decades of incoherence, UK radioactive waste management policy is making progress, with the decision that wastes from new plants likely to end up in a single national repository. However, there is a great deal still to be done and the challenge of legacy waste alone is enormous. And the shambles at THORP continues to cast a huge shadow over any claims of increased UK competency in the backend of the nuclear cycle.

UK public and parliamentary opinion also seems largely favourable to “new nuclear” being part of a future UK energy mix, although public opinion on the issue in particular tends to fluctuate depending on the prominence and framing of core concerns (especially waste, safety, costs and competition with renewables). An opinion poll in 2002 by MORI on behalf of Greenpeace, showed large support for wind energy and a majority for putting an end to nuclear energy if the costs were the same.⁸⁹

⁸⁸ World Nuclear Association, Web Information Paper, “Nuclear Power in the United Kingdom,” February 2008. Available at: <http://www.world-nuclear.org/info/inf84.html>; and Bream, Rebecca (2008). “British Energy in talks on reactors,” *Financial Times*. February 14. Available at: <http://www.ft.com/cms/s/0/88e5f764-da9f-11dc-9bb9-0000779fd2ac.html>.

⁸⁹ “Renewable Energy Wins Support From British Public,” Ipsos MORI. July 31. Available at: <http://www.ipsos-mori.com/polls/2002/greenpeace-energy.shtml>

However, in November 2005 a YouGov poll conducted by management consultants Deloitte & Touche found that 36 percent of the UK population supported the use of nuclear power, though 62 percent would support an energy policy that combines nuclear along with renewable technologies (i.e. government policy).⁹⁰ And an online opinion poll in *The Guardian* in March 2008 was almost evenly split on the question “Should nuclear power play a part in the UK’s energy policy?”⁹¹ With the main opposition Conservative party supporting the use of nuclear power,⁹² and only the Liberal Democrats, Greens and Nationalists critical, the political path seems relatively clear (in England and Wales at least).

At every turn in the 2008 White Paper on Nuclear Power, the concerns that were raised during the consultation are eventually dismissed, with the balance of the argument always resting on the government’s side. It is hard not to see the whole consultation as a massive public relations exercise created to fit the policy – an “exercise in managed consent” as one Scottish critic put it.⁹³ In a detailed analysis of the form and function of the nuclear consultation, another group of nuclear experts concluded:

To access true public opinion about such a high-stakes issue, the public consultation should have been clear, integrated, independent, and conducted over a long enough time-frame. Failure to do so has left the government vulnerable to legal challenge and may lead to hostility and mistrust of any future energy policy decision (Dorfman, 2008: 6).

Instead, the mantra throughout the consultation was that new nuclear power stations could make a positive contribution to maintaining a diverse energy mix in the UK and no contradictory evidence was allowed to stand in the way of this “fact.” More recently, the extravagant claims by ministers that new nuclear power stations will generate not only the energy the UK needs, but also 100,000 new jobs have emerged. But there are few details as to when and how these jobs will be created, and where they will be located (most could be in France rather than the UK, for example, were a French reactor design to be chosen).

⁹⁰ “62% would support inclusion of nuclear in future UK energy policy – but only as part of a diversified portfolio including renewable energy,” Deloitte Press Release. December 2005. Available at: http://www.deloitte.com/dtt/press_release/0,1014,sid=2834&cid=102273,00.html.

⁹¹ Only a small majority (50.9 percent) registered “No,” which is quite surprising for a largely left-leaning and anti-nuclear readership. See: <http://www.guardian.co.uk:80/environment/poll/2008/mar/06/nuclearpoll>.

⁹² Eaglesham, Jean “Drive to fasttrack nuclear reactors backed,” *Financial Times*. June 13.

⁹³ Macwhirter, Iain (2008). “Showdown over Trident could yet bring regime change in Scotland,” *Sunday Herald*. February. Available at: <http://www.sundayherald.com/oped/opinion/display.var.1201125.0.0.php>.

Rather than a “gateway to a new nuclear renaissance across Europe,”⁹⁴ the decision to build a new generation of nuclear power stations seems likely once again to take the British economy down a costly technological cul-de-sac. The problematic history of nuclear power in the UK suggests that a much more prudent path would see a stronger focus on delivering more sustainable methods of generating electricity, and on absolute reductions in UK energy demand, along the lines of what is being proposed in Scotland. A more radical option would have seen Ministers seek to ensure energy security by reducing demand to a level that could be met fully by renewable energy sources. Diversity could have been obtained within the renewable energy mix by including new imported sources (such as geothermal energy from Iceland and concentrating solar energy from North Africa)⁹⁵ as well as promoting innovative indigenous projects such as a Severn Barrage and other projects for tidal power and wave energy.⁹⁶

As David Edgerton (2008: xiii) argues, alternatives exist for nearly all technologies. However it seems likely that these renewable technologies will be crowded out (as they were in the past), by the obsession with nuclear power. Malcolm Wicks, the UK energy minister, while acknowledging only recently that Britain needs a “revolution” in green technologies, continues to insist that the country is showing “leadership” in the area. The facts, however, show Britain as the third worst in the EU for the use of renewables.⁹⁷ By pressing the green button on a nuclear revival, the UK government may once again be unwittingly raising the stop sign on viable alternatives.

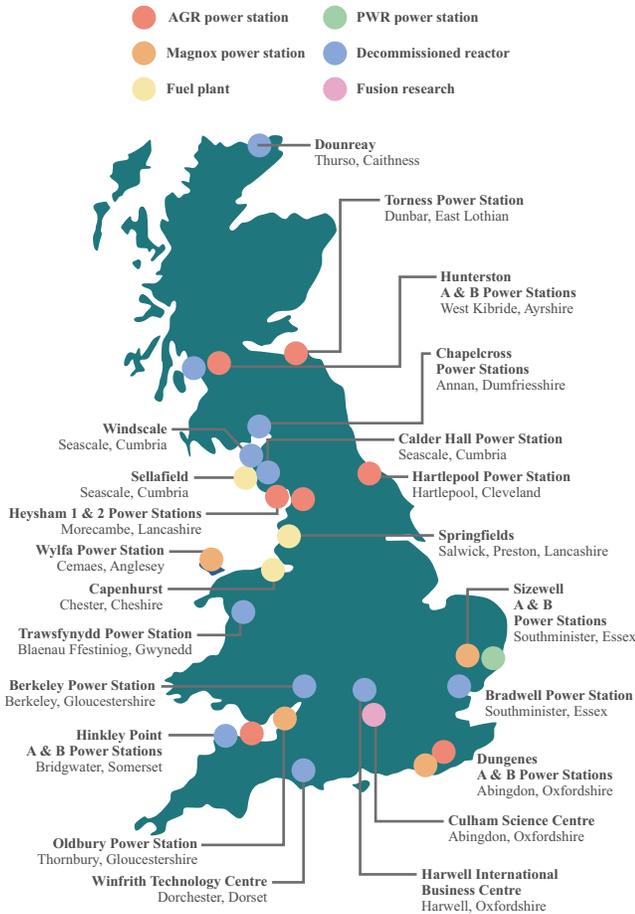
⁹⁴ Sparrow, Andrew and Patrick Wintour (2008). “Nuclear is UK’s new North Sea oil – minister,” *The Guardian*. March 26.

⁹⁵ Jha, Alok “Saharan sun to power European supergrid,” *The Guardian*. July 22. Available at: <http://www.guardian.co.uk/environment/2008/jul/22/solarpower.windpower>.

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⁹⁷ Seager, Ashley (2008). “Britain third worst in EU for use of renewable energy,” *The Guardian*. February 15. Available at: <http://www.guardian.co.uk/environment/2008/feb/15/renewableenergy.solarpower>; and Seager, Ashley (2008). “Reasons to see red over green energy – Government apathy sabotages Britain’s shift to a low-carbon economy,” *The Guardian*. February 18. Available at: <http://www.guardian.co.uk/environment/2008/feb/18/energy.economy>.

Appendix A: UK Nuclear Sites – An Overview



Source: BERR, 2008a: 36.

Calder Hall

Located on the Sellafield site in Cumbria. The world's first commercial nuclear power station started generating electricity in 1956 and ceased in 2003. Calder Hall Power Station is licensed to BNG Sellafield Ltd.

Capenhurst

Located near Ellesmere Port in Cheshire, adjacent to Urenco and has an area of 32 hectares covered by the nuclear site licence. It was home to a uranium enrichment plant and associated facilities that ceased operation in 1982. Capenhurst is licensed to BNG Sellafield Ltd.

Chapelcross Power Station

Located near Dumfries in southwest Scotland and has an area of 96 hectares covered by the nuclear site licence. The first nuclear power station in Scotland. Electricity generation started in 1959 and ceased in June 2004. Chapelcross Power Station is licensed to Magnox Electric Ltd.

Culham JET

The Joint European Torus (JET), located at Culham in Oxfordshire, is the world's largest fusion research machine. The JET facilities occupy 35 hectares of the 73 hectare UKAEA owned Culham Science Centre. JET is operated by UKAEA through a contract placed by Euratom under the framework of the European Fusion Development Agreement (EFDA). Culham is not a nuclear licensed site and the JET Facilities are currently not designated to the NDA. JET operations are expected to end at the end of December 2008.

Dounreay

Located in Caithness, Scotland and has a total site area of 55 hectares. It was established in the mid-1950s as a research reactor site with fuel production and processing facilities. There were three reactors, the last of which ceased operation in 1994. Dounreay is licensed to UKAEA and, after Sellafield, is the UK's second largest site.

Dungeness A

Located at Dungeness in Kent and with an area of 20 hectares covered by the nuclear site licence, Dungeness A Power Station started generating electricity in 1965. It is licensed to Magnox Electric Ltd. The area around the site is environmentally sensitive and is home to the largest shingle peninsula in Europe. Continuous shingle replenishment is in progress to maintain the reactor site and British Energy's Dungeness B power station.

Harwell

Located in Oxfordshire and was established in 1946 as Britain's first Atomic Energy Research Establishment. The campus, of which the designated site forms a part, is home to a wide range of research organisations and businesses. The NDA has responsibility for 110 hectares of land – approximately one-third of the total area. The nuclear site licence is held by UKAEA.

Hinkley Point A Power Station

Located at Hinkley in Somerset and has an area of 19 hectares covered by the nuclear site licence. It started electricity generation in 1965 and ceased operations in 2000. Hinkley Point A Nuclear Licensed Site is licensed to Magnox Electric Ltd.

Hunterston A Power Station

Located in Ayrshire, South West Scotland and has an area of 15 hectares covered by the nuclear site licence. It started electricity generation in 1964 and ceased production in 1989. Hunterston A Power Station is licensed to Magnox Electric Ltd.

The LLW Repository, Drigg

Located near Drigg in Cumbria and has an area of 98 hectares covered by the nuclear site licence. It has operated as a disposal facility since 1959. Wastes are compacted and placed in containers before being transferred to the facility. The LLWR is licensed to British Nuclear Group Sellafield Ltd.

Oldbury Power Station

Located at Oldbury in Gloucestershire and has an area of 51 hectares covered by the nuclear site licence. It started electricity generation in 1967. Oldbury Power Station is licensed to Magnox Electric Ltd.

Sellafield

Located in Cumbria and has an area of 262 hectares covered by the nuclear site licence. It is a large, complex nuclear chemical facility that has supported the nuclear power program since the 1940s, and has undertaken work for a number of organisations including UKAEA and MoD. Operations at Sellafield include processing of fuels removed from nuclear power stations; MOX fuel fabrication; and storage of nuclear materials and radioactive wastes. Sellafield is licensed to BNG Sellafield Ltd.

Sizewell A

Located at Sizewell in Suffolk and with an area of 14 hectares covered by the nuclear site licence, Sizewell A power station started generating electricity in 1966. Sizewell A Nuclear Licensed Site is licensed to Magnox Electric Ltd.

Springfields

Located near Preston in Lancashire and has an area of 81 hectares covered by the nuclear site licence. It manufactures nuclear fuel and fuel products for the UK's nuclear power stations and for international customers. The site is licensed to Springfields Fuels Ltd.

Trawsfynydd Power Station

Located at Trawsfynydd in the Snowdonia National Park in North Wales and has an area of 15 hectares covered by the nuclear site licence. It started electricity generation in 1965 and ceased generating in 1991. Trawsfynydd Nuclear Licensed Site is licensed to Magnox Electric Ltd. The NDA also has designated powers to manage and operate the Maentwrog hydro-electric power station, which was opened in 1928 and is situated near the site.

Windscale

A separate licensed site located on the Sellafield site in Cumbria. The site area is 14 hectares. It comprises three reactors, two of which were shutdown in 1957. The third was closed in 1981. Windscale is licensed to UKAEA. A fire damaged one of these reactors (Pile 1) in 1957, making its decommissioning a significant challenge.

Winfrith

Located near Poole in Dorset and has a total site area of 88 hectares. It was established by the UKAEA in 1958 as an experimental reactor research and development site. Winfrith is licensed to UKAEA.

Wylfa Power Station

Located on Anglesey in North Wales and has an area of 21 hectares covered by the nuclear site licence. It was the last and largest power station of its type to be built in the UK. It started electricity generation in 1971. Wylfa Power Station is licensed to Magnox Electric Ltd.

Appendix B: Decommissioning of UK Power Reactors

Part of the long-term clean-up problem in the UK is that costs for decommissioning gas-cooled reactors are much higher per unit of capacity than for LWRs. This is due to the large volume of material and the need to dispose of a lot of graphite moderator. Decommissioning waste volumes per unit capacity for Magnox are ten times those for western LWRs.

The government (through the NDA) is responsible for about 85 percent of the UK's nuclear liabilities, including:

- the nuclear sites and facilities which were developed in the 1940s, 1950s and 1960s to support government research programs, and the wastes, materials and spent fuels produced by these programs; and
- the Magnox nuclear power stations built in the 1960s and 1970s and plant and facilities at Sellafield used for the reprocessing of Magnox fuel; and all associated wastes and materials.

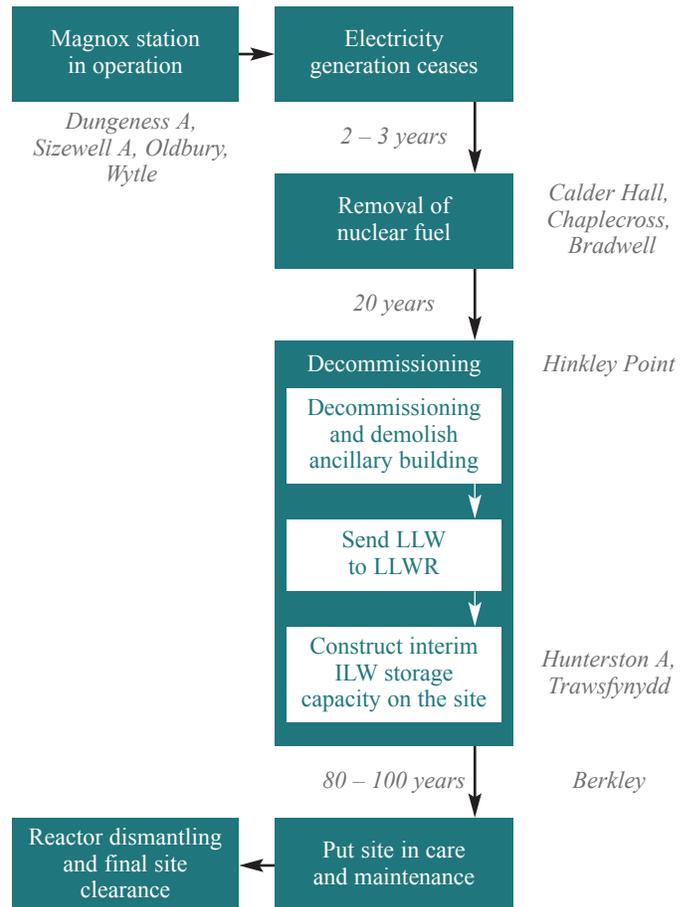
Seven Magnox stations are at various stages of de-fuelling (removing the fuel from the reactors) or decommissioning. De-fuelling and sending it to Sellafield for reprocessing removes 99 percent of the radiological hazard from the site. Apart from work related to dealing with operational ILW and the arrangements for the disposal of LLW, most of the remaining work is concerned with decontaminating and dismantling buildings and other structures. The current approach to decommissioning the Magnox plants is shown in Diagram 1.

Responsibility for decommissioning the AGRs and the sole PWR rests with British Energy and a Nuclear Generation Decommissioning Fund was set up to ensure a secure source of funds for eventual decommissioning of those nuclear power plants. In 2001 the Trustees of the Fund reported that its value matched its liabilities. When British Energy was privatized, the Fund received £228 million on account of the decommissioning liabilities of the company's predecessors and in recognition of sums that CEBG and Nuclear Electric had paid to the Treasury for that purpose. In March 2004 the Fund was worth £440 million and British Energy estimated the undiscounted cost of decommissioning its plants as £5.1 billion.

Following the re-organisation of British Energy in 2004 the Fund's assets were transferred to the new Nuclear Liabilities Fund, which is administered by the NDA and is

primarily for cleaning up UK's legacy wastes as described above. British Energy makes both fixed payments and pays 65 percent of its annual net cash flow into this latter fund.

Diagram 1: Current Magnox Decommissioning Approach



Begins when the only significant buildings left on site are the reactor buildings and an ILW Store – these will be removed at the dismantling stage

Source: NDA, 2006: 27.

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