The UK Nuclear Industry

A Report for the Japan Atomic Industrial Forum and the Japan Electrical Manufacturers' Association by the NIA

March 2013

Nuclear Industry Association

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Executive Summary

The UK nuclear industry stands at the beginning of a renaissance, with three developers preparing to build 16GWe of new capacity at five sites around the UK. The first of these plants, at Hinkely Point C in Somerset, received planning consent on March 19th.

But there has been a gap of nearly 20 years since the last nuclear plant, the Sizewell B Pressurised Water Reactor in Suffolk, was completed. The purpose of this report is to examine the impact of this gap in construction on the nuclear industry: the nuclear utilities themselves and the industrial supply chain.

The direct decision not to continue with a PWR programme was taken by Nuclear Electric, the nuclear utility that was still at that time in public ownership. But the circumstances that led to that decision were shaped by the policy and market environment after privatisation of the electricity industry. They also have their roots in the history of the UK's Magnox and AGR programmes, characterised by:

- A desire to rely on independent UK reactor design
- limited opportunities to internationalise UK design and industrial capability
- limited standardisation of designs, leading to high construction and operating costs

By time of the construction of Sizewell B many of the problems were already being addressed, and the project had many strengths. It was successfully delivered on time and within its revised budget, and is widely seen to compare well with subsequent Generation III designs. But the project was already becoming more international in character; the design was based on Westinghouse technology under licence to the UK and the reactor pressure vessel was built in France.

The decision not to proceed with the programme after Sizewell B was not taken because of political opposition by Government. In fact the Government of the day supported nuclear power. Rather, the cause was the privatisation of the electricity industry which, in the market conditions prevailing at that time, made it difficult to justify the very large investment required. This was compounded by the low price of gas at the time and high interest rates which made long term investments in nuclear unattractive.

There was undoubtedly a loss of industrial capability as a result of the termination of the new build programme, although some of it has already been lost before Sizewell B. Companies pursued various strategies to diversify into other markets both in the UK and internationally. Although it cannot supply major components of a new nuclear plant, the UK retains industrial capability to supply most of the remainder of the manufactured components and to install them on site and is working to improve capability and capacity.

The decommissioning programme, led by the Nuclear Decommissioning Authority, is recognised as a success and has proved an important way for companies to retain nuclear capability and experience.

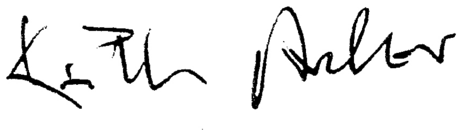
The nuclear Industry has benefited from cross-party political support and favourable public opinion, supported by good stakeholder relations. The UK nuclear industry looks forward to the nuclear renaissance with confidence.

1. Preface

This report has been prepared for the Japan Atomic Industrial Forum and the Japan Electrical Manufacturers' Association by the Nuclear Industry Association (NIA) of the UK.

The report draws on the NIA's expertise and understanding of the UK nuclear industry, as well as research and review by industry colleagues in the UK.

The UK is pleased to have had a strong historical relationship with the Japanese nuclear industry and the NIA looks forward to continued cooperation with JAIF and JEMA to support a successful and growing nuclear industry and the safe operation of nuclear power plants around the world.



Keith Parker

Chief Executive
NIA

2. Overview of Trend Survey of UK Nuclear Industry

2.1 This study covers the history of the UK civil nuclear industry from the mid 1950s until today, but it also includes information on the conditions of the electricity industry before the nuclear programme began.

2.2 The main focus of the study has been on the circumstances leading to the decision not to proceed with a nuclear new build programme after the Sizewell B plant completed in 1995, and the impact this had on the UK nuclear industry. It also examines the development of the industry before the Sizewell B project and the subsequent experience of sustaining the capability of the industry.

2.3 The methodology and approach for this study, and the structure of the report, were agreed with JAIF and JEMA before it commenced. The study draws on

- official sources of data including Government statistics,
- primary research data such as company reports, press reports and Government statements,
- analysis of other reports including academic research and published and unpublished commentaries by industry experts and organisations.

2.4 The study also draws on a series of interviews with leading figures from the industry including:

Bob Hawley	Former Chief Executive, Nuclear Electric
Robert Armour	Former Company Secretary and Legal Counsel, British Energy
Gregg Butler	Former Deputy Chief Executive, BNFL
Grace McGlynn	Former Head of Public Affairs, BNFL
Alain Chevalier	Former PWR Project Manager, NNC and PWR Projects
Bill Bryce	Director of Doosan Power Systems
Adrian Bull	Director of External Affairs, National Nuclear Laboratory
Steve Robinson	Former Chief Executive, The Environment Council

2.5 We are grateful to these individuals and their organisations, and to the many other representatives of the UK nuclear industry who have given advice and assistance with this study.

3. Status of UK Nuclear Industry

(1) Background to Nuclear Power Development in UK

3.1.1 The UK's nuclear programme was one of the earliest programmes to be developed and grew out of the atomic weapons programme. The first research reactor – and the first in Europe - at Harwell in Oxfordshire was opened in 1947 and in the same year the Government began the development of Windscale, a former weapons manufacturing establishment, in Cumbria in the north west of England. The two reactor piles at the Windscale site were intended to produce weapons-grade plutonium for use in the British nuclear bomb.

3.1.2 Later, it was realised that this could also form the basis for electricity generation and the first reactors, with dual military and electricity-generation purposes, began operation at Calder Hall near to Windscale in 1956. This was followed by seven more small (50MWe output) prototype reactors at Calder Hall and at Chapelcross in Scotland. These were all Magnox designs, using natural uranium metal fuel, having a graphite moderator and cooled by carbon dioxide. The choice of natural uranium fuel was made in part to ensure that the UK could be internationally independent in energy supplies, with the fuel being manufactured at the Springfields site in Preston. The military role of the Magnox reactors – production of plutonium for the weapons programme - was eventually transferred back to other sites at Windscale and subsequent reactors were optimised for electricity generation.

3.1.3 In parallel, the Government commenced a nuclear naval propulsion programme. This was based on US PWR technology, following a cooperation agreement signed in 1958, and the first nuclear-powered submarine HMS Dreadnought entered service in 1960.

3.1.4 Despite this cooperation on submarine technology (which only came about after the objections of the head of the US naval programme Rear Admiral Hyman Rickover were overcome) the history of nuclear policy in the UK, both military and civil, has been heavily influenced by a desire for UK technology independence. The widespread feeling in Government was that the UK must ensure that the country would not be dependent on US technology that could be withdrawn at some future date, particularly following the 1946 McMahon Act which had ended US-international collaboration in nuclear technology.

3.1.5 There was also a great deal of national pride in the UK's scientific strengths in nuclear technology, leading to a belief that the UK could maintain UK design leadership and indeed offer this to the World.

3.1.6 The other major background factor in the development of nuclear power was the UK's energy policy environment in the decades after 1945. It was recognised that economic recovery would depend on plentiful supplies of cheap energy, but the heavy dependence of the UK economy on coal supplies left it exposed to risks. Civil nuclear power was seen as the main alternative to coal-powered generation and an opportunity to diversify fuel sources.

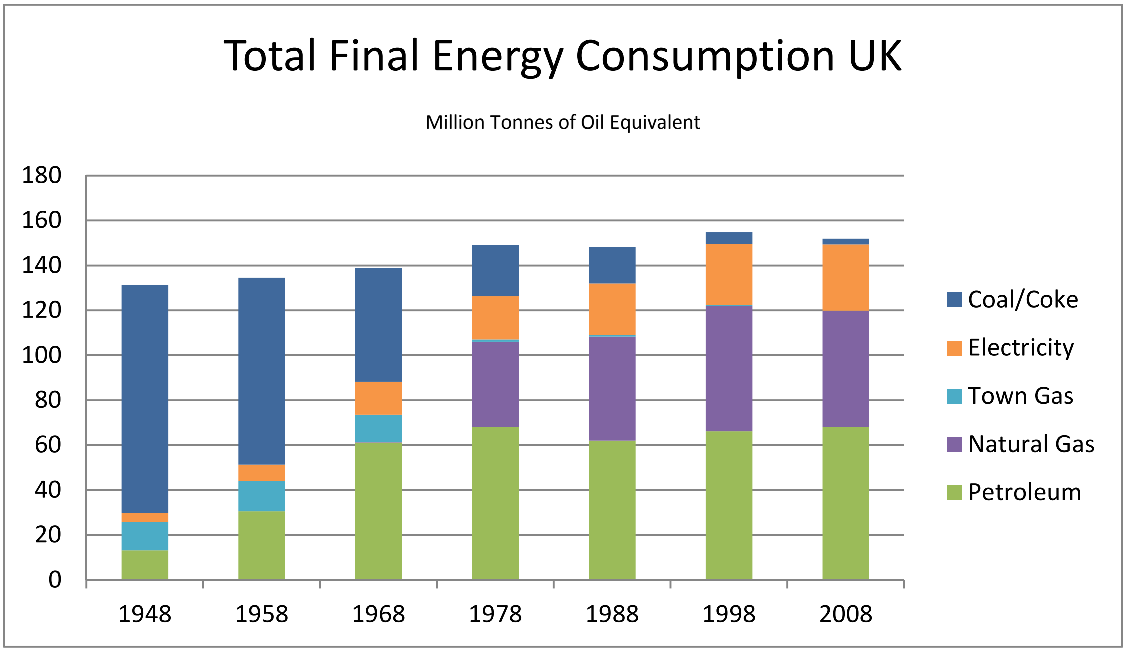
3.1.7 By the mid-1960s, the coal industry came to see nuclear power as a challenge, but this was not how it was seen in these early days. As the Government's White Paper launching the civil nuclear power programme in 1955 said:

> *The provision of enough men for the mines is one of our most intractable problems, and is likely to remain so. Any relief that can come from other sources of energy such as nuclear power will do no more than ease the problem of finding and maintaining an adequate labour force. There can be no question of its creating redundancy. The mining industry will in any case remain one of the major employing industries of the country, but it may hope to be relieved by the advent of nuclear power of the excessive strains which are being put upon it.*

(2) Trend of Energy Demand and Supply in UK

3.2.1 In the period after 1948, the overwhelming majority of energy in the UK came from coal and coke, used in homes, electricity generation and in industrial coke ovens. Almost all of this was sourced domestically in the UK. Coal was also used to manufacture town gas, the main form in which gas was used for heating at that time.

3.2.2 All petroleum was imported at that stage, so coal was critical to UK energy independence. But the dependence on coal also had an important downside: the vulnerability of power generation and the economy generally to the coal industry. This was later to become one of the most important drivers for the UK to develop alternatives sources of power generation including nuclear.



3.2.3 The main transformation in UK energy supply since 1948 has been the decline in coal from being the dominant source of energy to almost zero. In 1948 there were over 1,400 deep coal mines employing 720,000 people. By 2008 there were just 13 mines and employment was down to 6,000.

3.2.4 The other main change has been the emergence of natural gas. From the late 1960s the exploitation of north sea gas from deep water platforms near to the UK led to a rapid growth in natural gas use. Initially this was used only in heat for domestic and commercial premises, but later it was to be used in electricity generation.

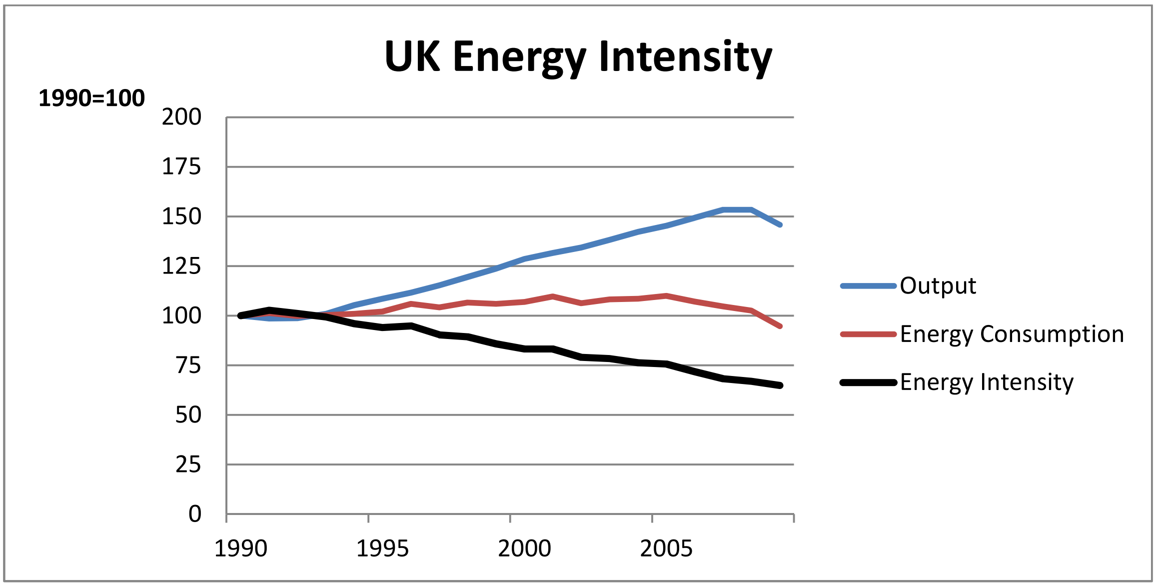
3.2.5 Two other developments are clear from the graph above:

- Growth in the use of petroleum, mainly for transport

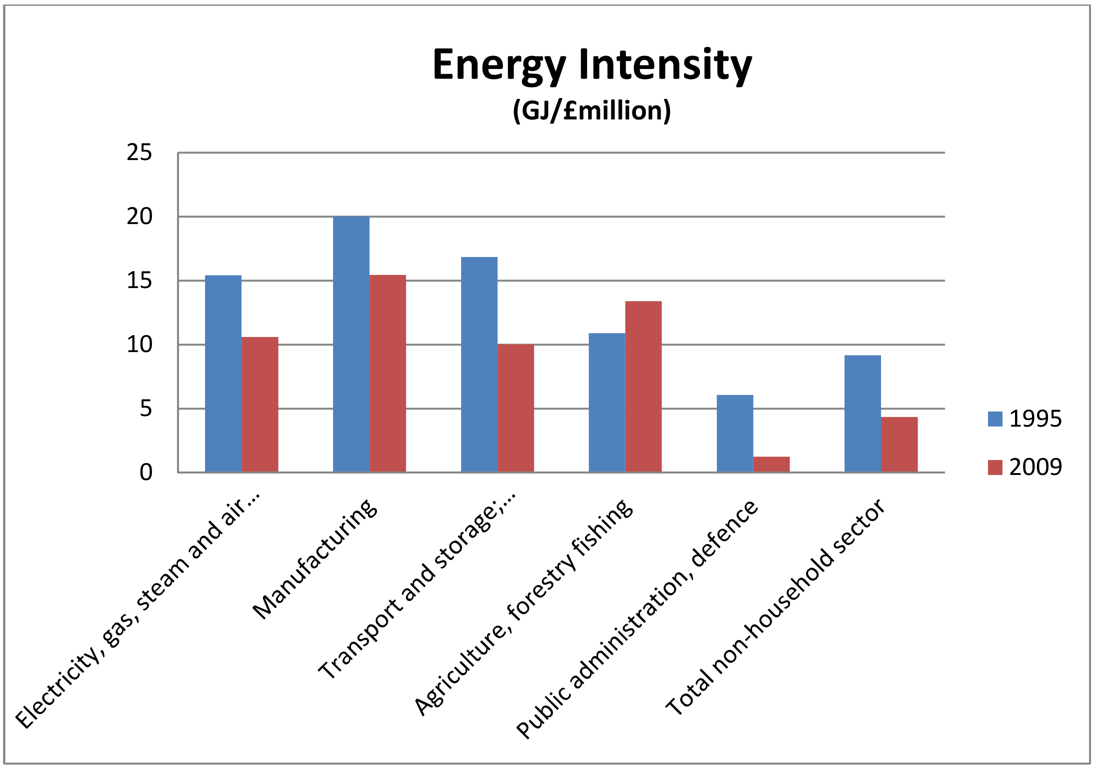
- Growth in primary electricity. Initially this was only from hydroelectric schemes but from the 1950s the share of nuclear also began to grow.

3.2.6 Overall it can be seen that total energy consumption grew for the first three decades after 1948, although not as fast as growth in the rest of the economy. As with other industrialised countries, this is largely because economic growth has shifted towards service sectors. There has been a relative decline in manufacturing industries, especially the heavy engineering industries such as steel production that were once intensive users of coal and coke.

3.2.7 Energy intensity fell by 35.1% between 1990 and 2009, whilst GDP grew by 45.8% in real terms over this period.



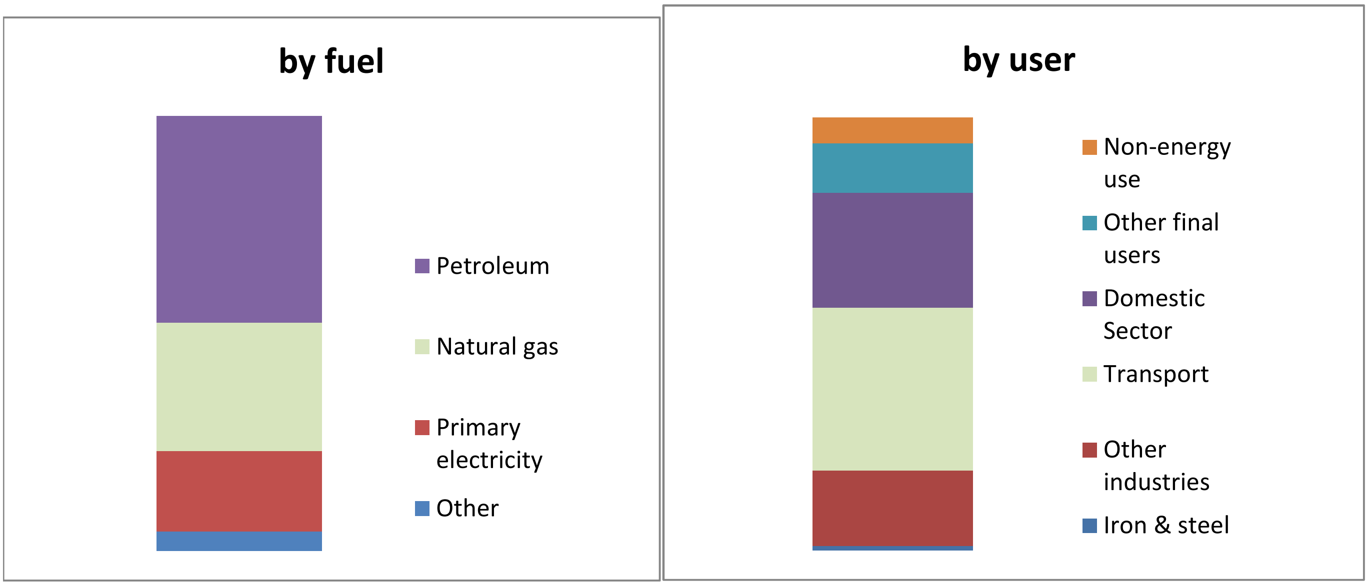
3.2.8 As well as the change in the balance of the economy, there have been improvements in most sectors in the efficiency of energy use with an overall decrease of 52.6 per cent for the non-household sector.



Energy Demand in 2011

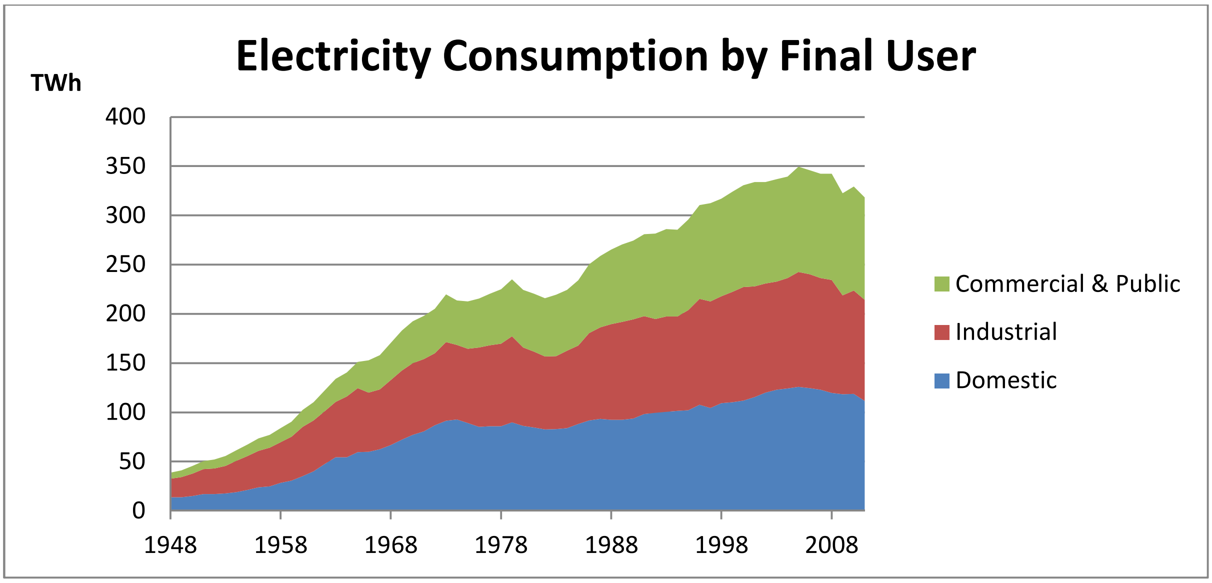
3.2.9 Today, energy demand is roughly evenly split between transport, the domestic sector and industry. Industry users are mainly chemicals (31.5% of industrial use), metal products (12.5%), iron & steel (8%) and food processing (12%). Petroleum is the main fuel, followed by natural gas and primary electricity.

Final Energy Consumption 2011

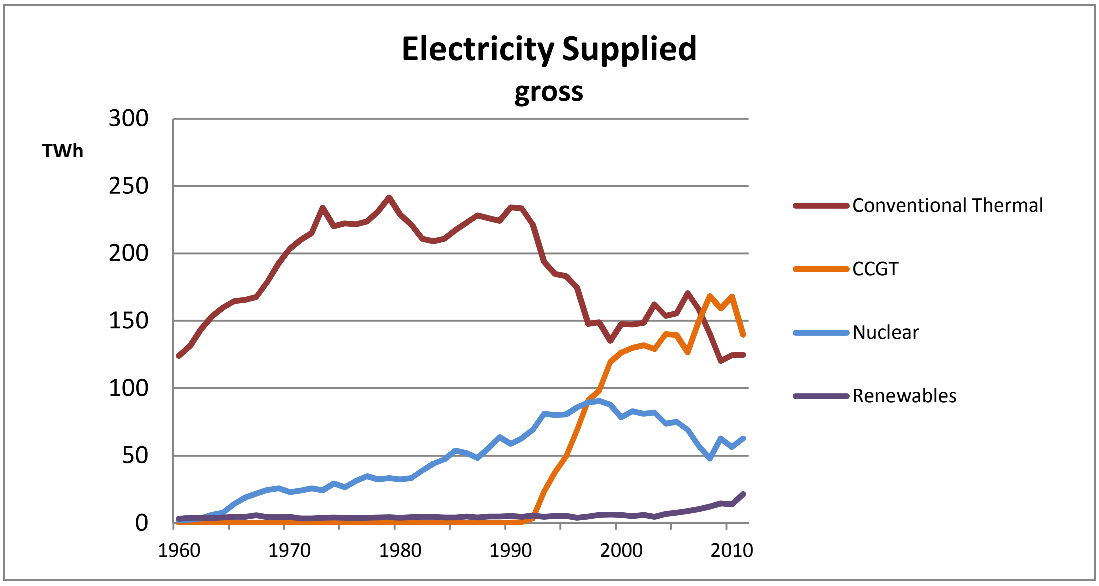


Electricity Supply and Demand

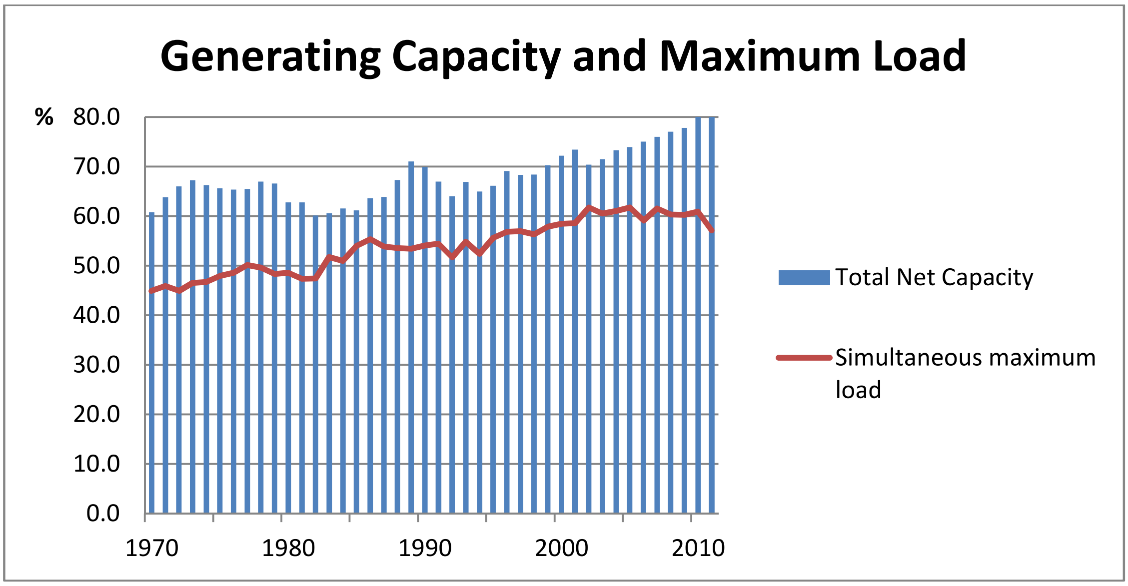
3.2.10 In 1948, almost half of electricity consumption was by industry. Today, the shares of industry, commercial (shops and offices) and domestic use are roughly similar, but industry is now the smallest share of the three. All sectors have seen growth in consumption, following the path of growth in GDP.



3.2.11 There has been a very significant shift in the sources of primary energy used in electricity generation. The contribution of nuclear grew steadily from the early 1960s as the new nuclear power plants came on stream, but the major change has been that the dominant role of coal has given way to a rapid increase in gas-fired CCGT plants from 1990.



3.2.12 A further 11GWe of coal capacity will be closed before the end of 2015 as a consequence of the implementation of the EU Large Combustion Plant Directive. These are mainly older and larger coal plants which are not suitable for fitting equipment for the abatement of sulphur dioxide and nitrogen oxide emissions. This loss of capacity – almost 15% of generating capacity - will lead to a reduction in the capacity margin in the electricity generating network from 14% of to just 4%.



3.2.13 There has been a transition to fewer, larger power plants, with more than two thirds of generating capacity now in plants of over 1000 MWe and more than 89% in plants over 500MWe.

(3) History of Energy and Nuclear Policy in UK

3.3.1 For several decades, energy policy in the UK was largely stable and there was a consensus on the objectives of policy which was shared across parties and by different governments. Energy policy was seen as having a primary objective of supporting economic growth and prosperity. In a growing economy the main concerns were about the sources of energy and how it could be delivered at low cost to domestic customers and industry.

3.3.2 Whilst Governments did not worry that there would be a shortage of energy per se, there were concerns about the security of energy supply, principally where to obtain reliable supplies of oil and, later, natural gas, on international markets. And all governments worried about the dependence of the UK on coal. One consequence of these concerns was that capacity margins for all forms of energy were generally kept at high levels to avoid the danger of energy shortages or blackouts (losses of electricity supply).

3.3.3 The first oil crisis in the 1970s had an impact both in the transport sector, where the effect was mainly through prices with the higher costs being absorbed through the economy, and in electricity, where a lot of investment in the UK had, as elsewhere, gone into oil-burning generation.

3.3.4 In 1972 and 1974 there were national strikes by the National Union of Mineworkers – for the first time since the 1920s – leading to power cuts and heightened political concern about dependence of the electricity industry on coal.

3.3.5 However, throughout these events and, at time, crises, the objectives of energy policy were still largely shared across the political spectrum. Differences between political parties were mainly about which party could deliver the objectives most effectively, and in particular which could best maintain stable industrial relations in the mining industry.

Structure of the Electricity Supply Industry Before Privatisation

A single national structure was created for the electricity supply industry in 1947, amalgamating multiple smaller bodies. Power generation and distribution were kept separate. A single generating body was created for England and Wales, which from 1957 became the Central Electricity Generating Board (CEGB). There were separate generating companies in Scotland: the South of Scotland Electricity Board (SSEB) and a hydro-electric business, the North of Scotland Hydro-Electric Board.

These generating companies did not supply electricity directly to customers, other than to a few very large companies, but instead distributed it to 14 Area Boards in England, Wales and Scotland which in turn supplied it to customers.

The Market Experiment

3.3.6 The principal break with the past and with these shared objectives was the market experiment introduced by the conservative governments in the 1980s. Privatisation began in other sectors and only came to the energy sector with the sale of British Gas in 1986.

3.3.7 It had previously been thought that major utilities such as energy were natural monopolies which were not suitable for competition and the operation of market forces. In these early days of privatisation, the Government accepted that competition could not be introduced – this was only to come later – and relied instead on regulation in place of market forces. It was thought that regulation, combined with the financial discipline from private ownership, would create the incentives to improve efficiency that, in other parts of the economy, would come from market forces.

3.3.8 The form of regulation introduced for the privatised British Gas, and later copied in the electricity industry, relied on price caps for customers, set for fixed regulatory periods. These allowed the utility to make an agreed rate of return, but it also meant that, if the utility achieved improvements in efficiency, it could keep the benefit as additional profit for its shareholders.

3.3.9 Price controls for the subsequent regulatory periods would then be set at a level that took the improved efficiency improvements into account, allowing some of the benefits to be delivered, ex-post, to customers.

3.3.10 Overall the system appears to have been successful in driving improved productivity. In British Gas, labour productivity rose by 6% a year in the early 1990s and employment fell by a quarter in the eight years after privatisation. However, it was only as regulation was tightened after the first regulatory period that the benefits started coming through. Moreover, prices would still depend heavily on movements in fuel prices.

Electricity Privatisation

3.3.11 In the wake of what were generally considered to have been successful privatisations of the telecommunications, gas and water industries, the electricity industry, apart from nuclear, was privatised in 1990. Whereas British Gas had been sold off as one unit, it was recognised that electricity would be more complex and the generation and transmission businesses were sold off separately from the supply of electricity to customers.

3.3.12 In generation, the fossil fuel interests of the CEGB were split into two separate companies – National Power and Powergen - to create competition. The Area Boards supplying electricity to customers were turned into Regional Electricity Companies (RECs).

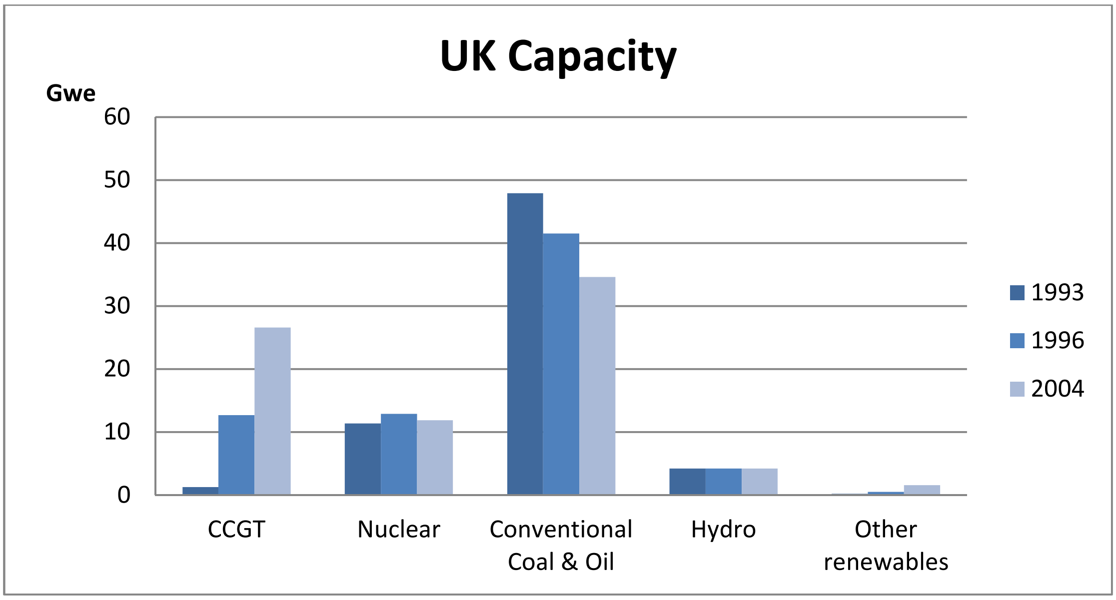
3.3.13 At first the RECs were regulated businesses, having a monopoly over customers in their region and being subject to a system of price caps similar to that in the gas industry. In time, competition was introduced, allowing customers to choose between suppliers, starting with the larger industrial customers and steadily being extended until it covered all customers by 1999.

3.3.14 A wholesale market was created – the electricity pool – into which the generators would offer electricity. These bids would be for 30 minutes slots and all generators would receive the same price for electricity supplied into the pool for that period. The intention was to create some market tension within the industry.

3.3.15 RECs and generators could, however, also enter into bilateral contracts and in time more than 90% of electricity was supplied through these bilateral deals.

3.3.16 Privatisation was intended to improve productivity and to reduce prices for consumers. It also had a major impact on the way investment decisions were made, with high interest rates at the time making it difficult to justify capital-intensive projects and therefore focusing attention on securing returns over short term investment time-frames.

3.3.17 The most significant outcome was a large expansion of combined cycle gas turbine plants, which had low capital costs and, with gas prices being low at the time, short investment pay-back periods. A change in EU regulation allowed gas to be used in power generation for the first time and the "dash for gas" had begun. The first CCGT was commissioned in 1991 and by 2004 gas accounted for more than a quarter of electricity capacity.



3.3.18 The main impact of the dash for gas was on coal generation, but the drive to higher productivity and the focus on short investment pay-back periods also had implications for nuclear.

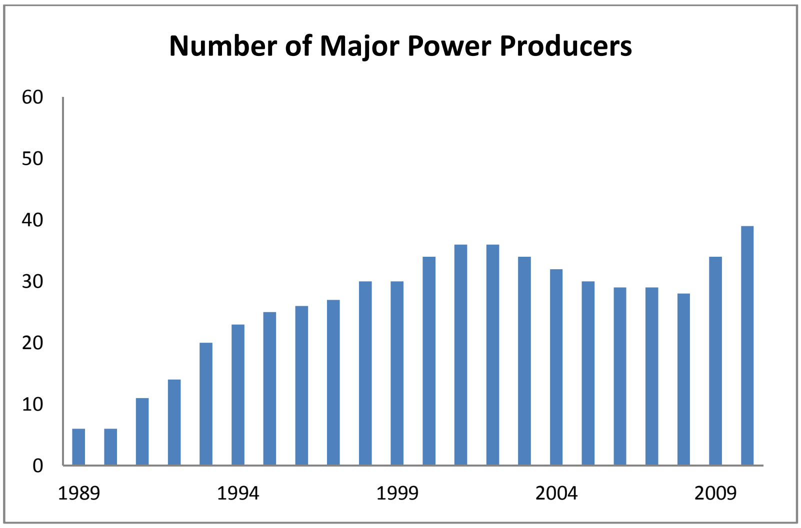
3.3.19 The primary objective of privatisation was to increase the efficient use of existing assets rather than new investment. However, some 20Gwe of capacity was added in ten years after privatisation, half of it in the first two years. The additional capacity included 500MWe of gas-fired CCGTs built by RECs.

3.3.20 New entrants entered the market, some of them building new CCGT plants, others buying up the 10GWe of capacity disposed of by the two major generators.

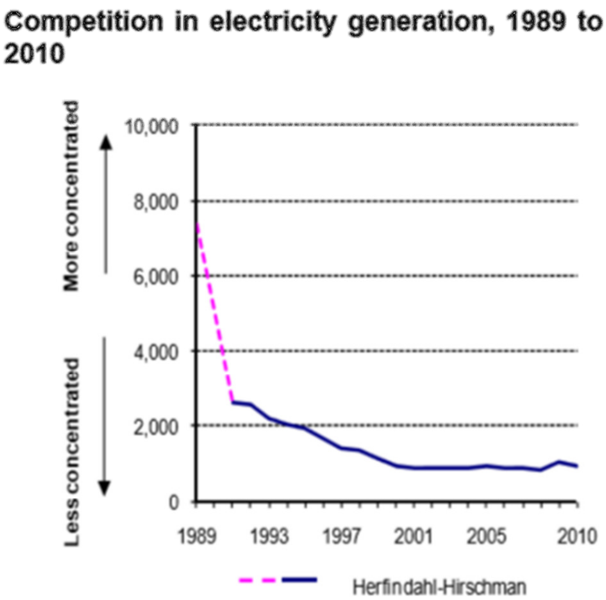
3.3.21 The electricity pool was criticised for being ineffective and for allowing market domination by the major power generators. Initially, generator prices rose, helping the generating companies to increase their margins. Prices then began to fall substantially, but the pool price was still above the charges of the new entrants, which were mainly operating gas-fired CCGTs with long term power purchase agreements. These criticisms led to reform of the pool system and replacement by the New Electricity Trading Arrangements (NETA) in 2001 which relies more on bilateral contracts between generators supply companies and which led to sharp falls in the wholesale prices paid to electricity generators.

Effects of the Market Experiment

3.3.22 Privatisation was intended to increase competition and drive down prices. On top of the effects of privatisation there has also been an increase in the number of producers, leading to additional competition. One way of measuring the extent of competition in electricity generation is by considering the market shares of each company in the electricity generation market. The number of companies has increased from six at the time of privatisation in 1990 to 39 today.



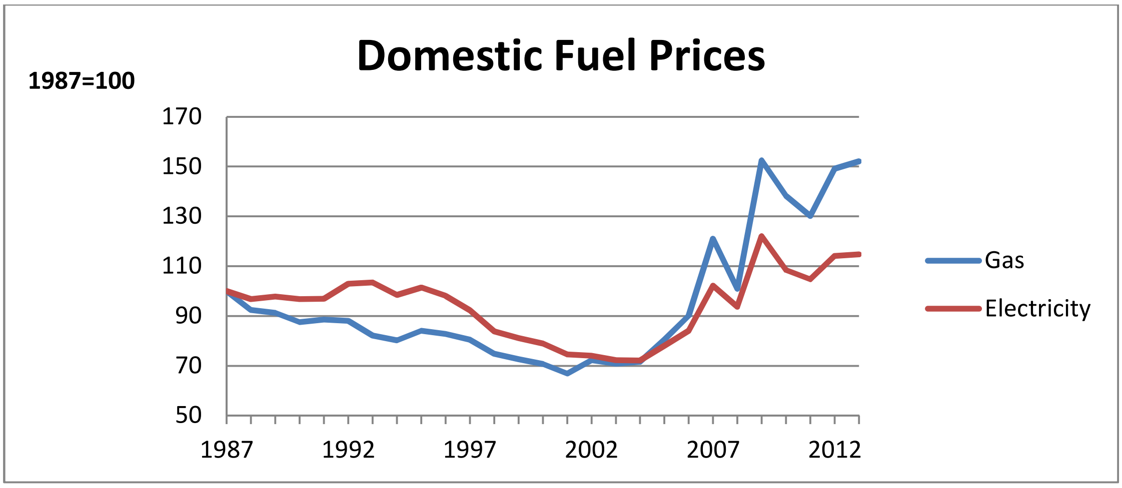
3.3.23 Whilst market shares are not evenly distributed between the 39 companies generating electricity in 2010, the overall market became considerably less concentrated, particularly between 1992 and 2000, with increased diversity of suppliers. A measure of market concentration is provided by the Herfindahl-Hirschman index (see chart) which shows that the market in electricity generation has become less concentrated since privatisation.



3.3.24 The break-up of the nationalised power suppliers into smaller privatised companies produced an immediate impact on the Herfindahl-Hirschman measure of concentration. A further decrease occurred once new companies began to build their own CCGT stations after 1992, but after 2000 there was a levelling off of the concentration measure. Although new power producers appeared, others were taken over or bought power stations to add to their portfolio.

3.3.25 As a result, the share of the top three companies in generation terms remained at around 40% between 2004 and 2010.

3.3.26 The effects of the increased competition were therefore mixed. Prices remain dominated by the major players, and heavily influenced by fuel prices, principally the price of gas on international markets. Domestic prices fell in the period after privatisation but have then risen again, very sharply after 2005.

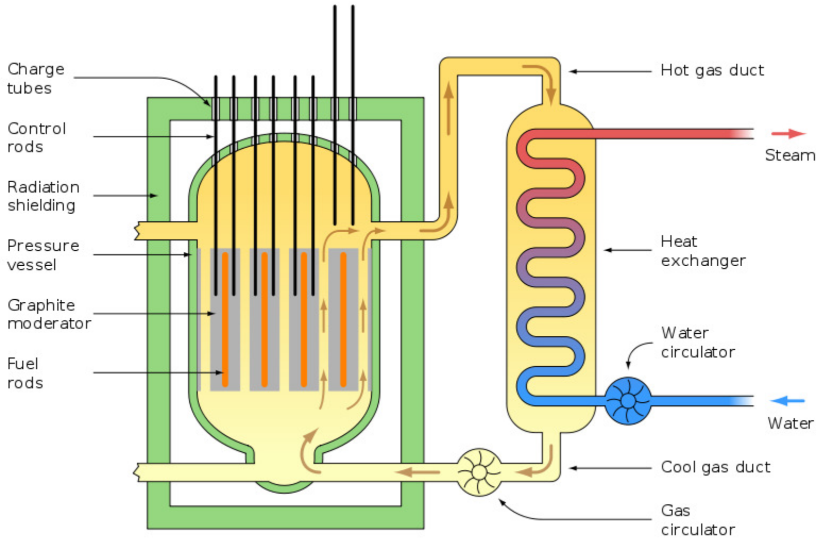


(4) Transition in Nuclear Power Plants in UK

The Magnox Programme

3.4.1 Around the same time as the opening of the first reactor at Calder Hall, built with dual military and power-generation the Government announced plans for a commercial programme of nuclear power development, with the construction of 1400 to 1800 MWe of Magnox capacity by 1965. Shortly afterwards, the planned nuclear programme was expanded to between 5000 and 6000 MWe when the Suez crisis led the Government to favour a large expansion of new electricity generation. The Government also commenced plans to investigate the future use of fast breeder reactors.

Magnox Plant schematic diagram



Note that the heat exchanger is outside the concrete radiation shielding. This represents an early Magnox design with a cylindrical, steel, pressure vessel.

3.4.2 It is interesting to note that cheap power was not at the time considered to be the objective of the Magnox stations. The Duke of Edinburgh, on opening Berkeley and Bradwell stations in 1962 said:

> "The importance of these nuclear power stations far outweighs the immediate cost of the power they produce. The very steep rise in demand for electricity brought about largely by this weather, the practical limits on the use of coal above a set amount, the practical and economic disadvantages of relying too heavily on oil fuel – all these make it quite plain that nuclear power is going to play an increasingly important part in the British energy programme of the future".

3.4.3 This initial period of enthusiasm for nuclear power was, however, qualified shortly afterwards by the accident at Windscale in 1957 when a fire in one of the military plutonium piles led to a release of radioactive contamination. The subsequent review led to the transfer of responsibility of regulation of nuclear safety from the UK Atomic Energy Authority (UKAEA) to an independent Nuclear Installations Inspectorate, part of the Health and Safety Executive. The culture of secrecy that had been inherited from the military programme, however, continued to pervade the civil industry and it would be several decades before it took seriously the need to engage with local communities and other stakeholders.

Forming Industrial Consortia

3.4.4 The Government decided to encourage the setting up of industrial consortia to deliver the Magnox projects, as recommended by the UKAEA which, as well as managing the Government's nuclear facilities, acted as its advisory body in the commercial new build programme. The intention was to ensure that the projects could be delivered by contractor organisations that were strong enough, technically and financially, to undertake the design and construction of complete power stations and, in time, to sell these overseas. It was also thought that this was the best way of ensuring that UK industry had a share of the new nuclear power market.

3.4.5 Ultimately, five consortia were established and these became responsible for delivering 18 Magnox reactors in the UK and two overseas – in Japan and Italy.

3.4.6 Critically, the consortia were invited to compete in undertaking research, development and design for their projects. The UKAEA stipulated that natural uranium rods and a graphite moderator should be the basis of the design but the detailed design to take this to a commercially viable form for large scale electricity generation was left to the consortia. Not surprisingly, given the different make-up of the consortia, a variety of designs were utilised. The UKAEA acted as advisor to both the Government and to the contractors and also took the role of design safety authority.

3.4.7 Each of the consortia established engineering R&D teams based at the member companies' manufacturing facilities and in some cases setting up separate laboratories for the consortium itself. These worked closely with the UKAEA and with the Government-owned utility – the Central Electricity Generating Board - created as the customer for the projects.

3.4.8 In the end, 26 Magnox plants were built at 11 sites with about 4200 MWe of capacity. The last of these to be built, and the largest, were in Wylfa in north Wales. Wylfa 1 is still operating and is scheduled to be closed in 2014.

UK Magnox reactors			
Reactor	**MWe net**	**Startup**	**Shutdown/Status**
Berkeley 1	138	1962	1989
Berkeley 2	138	1962	1988
Bradwell 1	123	1962	2002
Bradwell 2	123	1962	2002
Calder Hall 1	50	1956	2003
Calder Hall 2	50	1957	2003
Calder Hall 3	50	1958	2003
Calder Hall 4	50	1959	2003
Chapelcross 1	49	1959	2004
Chapelcross 2	49	1959	2004
Chapelcross 3	49	1959	2004
Chapelcross 4	49	1960	2004
Dungeness A1	225	1965	2006
Dungeness A2	225	1965	2006
Hinkley Point A1	235	1965	2000
Hinkley Point A2	235	1965	2000
Hunterston A1	160	1964	1990
Hunterston A2	160	1964	1989
Oldbury 1	217	1967	2012
Oldbury 2	217	1968	2011
Sizewell A1	210	1966	2006
Sizewell A2	210	1966	2006
Trawsfynydd 1	196	1965	1993
Trawsfynydd 2	196	1965	1993
Wylfa 1	490	1971	Operating to end 2014
Wylfa 2	490	1971	2012
Total: 26			

3.4.9 Key aspects of this early stage of the UK nuclear programme, including its origins in the atomic weapons programme, the emphasis on developing independent UK designs and the formation of competing consortia, had important impacts on the way the programme developed and its subsequent success, particularly:

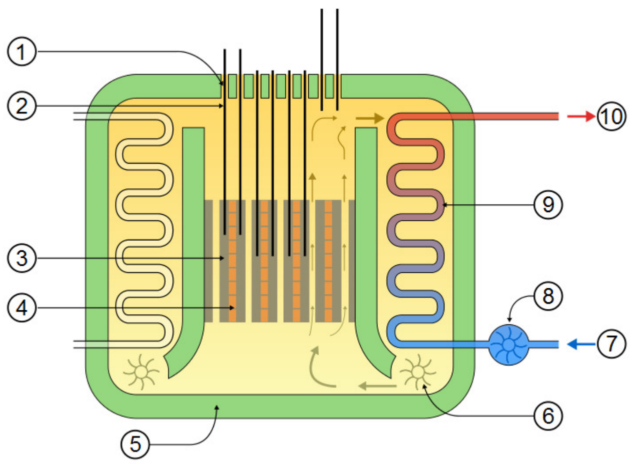
- Relatively high investment in R&D
- Limited opportunities to internationalise
- Limited opportunities to standardise designs and construction methods, and associated high costs

3.4.10 Also, during this period there was little or no attention given to the eventual need to decommission facilities, either in the weapons programme or in electricity generation, and the Magnox stations would prove to be much more costly to decommission than other designs. This left a legacy of costs and negative perceptions that still affect the nuclear industry today.

The AGR Programme – Seeking UK Technology Independence

3.4.11 With the Magnox programme nearing its completion, the Government began consulting on a Second Nuclear Power Programme with a White Paper in 1964. There was some debate about the reactor technology to be adopted, with the CEGB, the Government-owned utility, favouring US-designed water-cooled reactors. But in the event it was the UK Atomic Energy Authority's own gas-cooled design the AGR that was chosen. Again the choice of reactor design was made largely to allow the UK to be internationally independent in energy technology; national pride was certainly a factor for the Government at the time.

Schematic diagram of an Advanced Gas-cooled Reactor type nuclear reactor



1. Charge tubes
2. Control rods
3. Graphite moderator
4. Fuel assemblies
5. Concrete pressure vessel and radiation shielding
6. Gas circulator
7. Water
8. Water circulator
9. Heat exchanger
10. Steam

3.4.12 Twin reactor AGRs were built at seven locations around the UK, coming onto the grid between 1976 and 1989 and providing 7600 MWe of capacity. But there was little opportunity for standardisation; of the 14 reactors that were built, there were effectively 12 different designs. Moreover, there were numerous technological and operational problems with the AGRs and the design was not adopted anywhere outside the UK.

AGR Stations			
Plant name	Capacity (MWe net)	First power	Scheduled date of decommissioning
Dungeness B 1&2	2 x 545	1983 & 1985	2018
Hartlepool 1&2	2 x 595	1983 & 1984	2019
Heysham I-1 & I-2	2 x 580	1983 & 1984	2019
Heysham II-1 & II-2	2 x 615	1988	2023
Hinkley Point B 1&2	2 x 610, but operating at 70% (430 MWe)	1976	2023
Hunterston B 1&2	2 x 610, but operating at 70% (420 MWe)	1976 & 1977	2023
Torness 1&2	2 x 625	1988 & 1989	2023
Total: 14 units	**Approx. 7600**		

3.4.13 The AGR design that was chosen was 20 times larger than the 30MW prototype Windscale Advanced Gas Cooled Reactor on which it was based. This required a revised design of the fuelling system, with a larger fuel bundle than that which had been fully tested in the WAGR prototype, as this was thought at the time to be more economically attractive. In addition, the turbines for the 600MW plants, although based on a current design, were untested on this scale. But perhaps the most fundamental difficulty with all the AGRs was that a great deal of the high technology construction and assembly had to be done on site, and in-situ inside the pre-stressed concrete pressure vessel.

3.4.14 At the beginning of the AGR programme the Government still encouraged industrial consortia to compete for the design and delivery of the projects. Following mergers during the course of the Magnox programme, the five industrial consortia had been narrowed to three which now went on to deliver the AGR programme. But one of these, the APC consortium which was awarded the first AGR contract at Dungeness B, faced financial difficulties and went into administration. The Government then encouraged the remaining two consortia to merge to form the National Nuclear Corporation (NNC) which took on the later phase of AGR development and construction.

3.4.15 The serious design and construction problems with the AGR technology were most clearly demonstrated in the case of the Dungeness B plant. Although this was the first to commence construction, in 1965, it was not fully commissioned until 20 years later. The difficulties included errors in design, mistakes in the fabrication of components and faults in construction on the site. Eventually, in 1969, the consortium involved was effectively declared bankrupt, and subsequently existed on paper only. The CEGB set up a management agency to run the construction project. Even after the plant started to generate electricity, it was still several years before it did so reliably.

3.4.16 Some of these problems with the AGRs were being addressed during the programme and the most successful projects were the later Torness and Heysham projects completed in the late 1980s. But by then there was already extensive debate about moving to other reactor technologies.

Here again, therefore, the second nuclear programme was characterised by:

- High reliance on independent UK reactor technology
- Limited standardisation of design
- No opportunities to internationalise

Towards a Third Nuclear Programme?

3.4.17 With the AGR programme still under way, the Government considered alternative future technologies during the 1970s, including light water and gas-cooled designs. The CEGB argued that future development should be based only on proven designs, and itself favoured the PWR, but this was personally resisted by the then Labour Secretary of State Tony Benn. With a change of Government in 1979, the incoming Conservative administration supported the Westinghouse PWR. Ministers talked of a possible programme of 10 PWRs but the Government outlined plans for only four reactors.

3.4.18 The CEGB decided to take on the leadership of the project itself rather than to transfer responsibility to a consortium. NNC, the last remaining part of the consortia which had built the Magnox and AGR programmes, provided the design, based on the Westinghouse reactor technology, but extensively revised for the UK. Most of its staff working on the project transferred to CEGB. Other suppliers were contracted directly to CEGB.

3.4.19 The planning inquiry for the first of these, at Sizewell B, proved to be very lengthy and consent was only given in 1987. Although this led to delay the inquiry also raised a wide range of issues which were addressed during the planning process, leading to improvements in design. It enabled all aspects of the design to be revisited and led to the highest standards being adopted in all civil structures and mechanical equipment. It is widely acknowledged that Sizewell B compares well with later Generation III designs.

3.4.20 These changes also led to added costs and the projected cost was increased from £1691 million in 1987 to £2030 in 1990.

3.4.21 Although the construction of Sizewell B was successful and the project was delivered within schedule and the (revised) budget, the enthusiasm for further projects had weakened. Nuclear Electric – the public sector company that inherited the CEGB's nuclear fleet following its privatisation – received planning consent for the second PWR, at Hinkley Point C, in 1990, but subsequently decided not to proceed with construction. In the event, therefore, Sizewell B was the only PWR to be built

3.4.22 Despite the attempts during this period to move away from a 'buy-British' mentality and to build support for a series of plants based on a proven design, political compromise forced the industry to delay and then to curtail the initial plans for a series of PWRs. But it was not a simple shortage of political support for nuclear power that was to lead to a new build programme being abandoned. For the explanation we need to look at the complicated circumstances of privatisation.

Privatisation

3.4.23 In 1990, as Sizewell B was still being built, the Government privatised the electricity industry. Nuclear was left out of the first sell-off but both the privatisation of the non-nuclear parts of the industry, and the later sale of the nuclear parts, had huge impacts on the nuclear programme.

3.4.24 Nuclear had been left out of the 1990 electricity industry privatisation because the emerging uncertainties about historic liabilities, long fuel contracts and high operating costs for the AGRs would make it impossible to finance. The capital costs of the PWR programme was also an important factor. Market sentiment, with the combination of high interest rates and low gas prices, made it difficult to finance capital intensive projects with long pay-back periods and the investment programme was therefore seen as a balance sheet liability rather than as a prospective return.

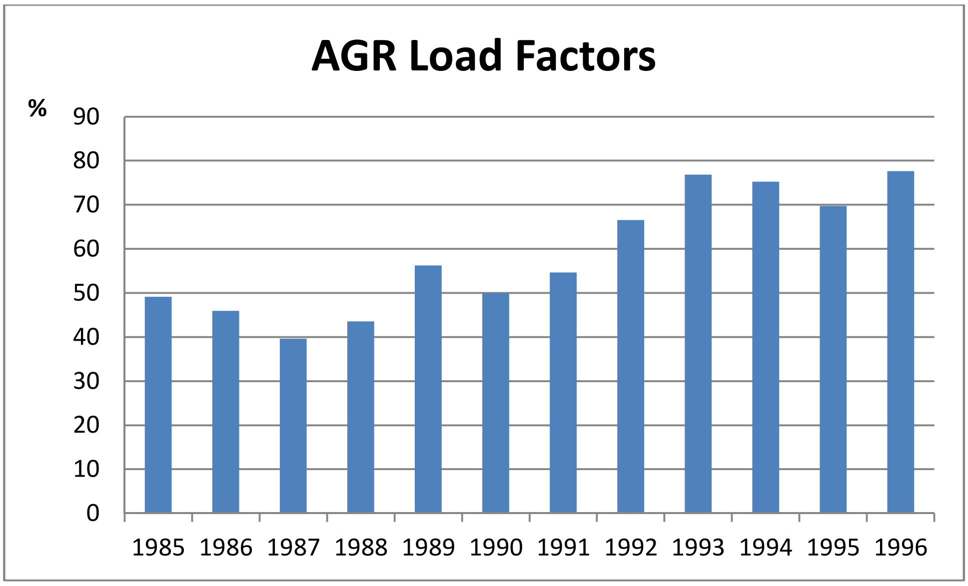
3.4.25 The nuclear generating interests of the major utilities were therefore put into two publicly-owned vehicles, Nuclear Electric and Scottish Nuclear. At the time these included the Magnox plants as well as AGRS, bundled together with various other nuclear and non-nuclear interests.

3.4.26 Because neither company at that time was economically viable in the newly privatised market the Government set up a mechanism to provide some guarantee of revenues. This mechanism – the Non Fossil Fuel Obligation (NFFO) – imposed a requirement on electricity suppliers to purchase a proportion of their electricity from nuclear generators. In principle, the NFFO was supposed to be a way of funding the decommissioning liabilities of the Magnox plants, but it provided important revenue security for the nuclear companies and helped to stabilise their finances.

3.4.27 In response to the higher productivity and (short term) financial performance of the privatised generators, Nuclear Electric and Scottish Nuclear set about progressively reducing their own operating costs.

3.4.28 The first priority, given the high fixed costs in the industry, was to raise output by improving the poor load factors that had been achieved by the AGRs. The biggest single problem with the AGR design had been the fuelling process. AGRs were designed to refuel at full power, which was intended to lead to big cost savings. In practice this proved impossible to fully achieve and the process was complex, with equipment being handled at very high temperatures. However, the output improvements arose not from a single formula but from developing a culture that encouraged incremental improvements and sharing of lessons across teams. Interestingly, one commentator described this as a "Japanese approach imported via the US", with staff working in teams and being motivated by a sense of pride in their work. An important element in the success was breaking down the hierarchical and centralised structures inherited from the CEGB to allow all levels of management to focus relentlessly on improvement.

3.4.29 As a result, load factors improved steadily from below 50% in 1990 to over 75% three years later.



3.4.30 In time, the improved performance allowed some reduction in their dependence on the NFFO.

Productivity in the run up to Privatisation					
	1992	1993	1994	1995	1996
Operating costs, p/KWh	3.3	2.8	2.5	2.4	2.5
Output per employee, GWh	5.0	6.3	7.3	8.0	9.4
Source: British Energy Prospectus 1996					

3.4.31 With these improvements in productivity, and Sizewell B having been delivered on time and within the revised budget, the nuclear utilities believed they could be successfully privatised. They persuaded the Government to form a new company, British Energy, bringing together the AGRs of Nuclear Electric and Scottish Nuclear but without the Magnox plants and other liabilities, ready for privatisation.

Privatisation and the New Build Programme

3.4.32 When the first electricity privatisation was being planned, there had been a view in Government and in the utilities themselves, that privatisation would also offer the best way of ensuring that the next wave of new PWRs could be financed on a commercial basis. In retrospect, this was clearly a misjudgement. But it was certainly the case that, at the time that privatisation was initially being considered, it was hoped that there could be commercial financing of the future PWR programme.

3.4.33 When the Government announced the review of the prospects for nuclear that would lead to privatisation of the nuclear industry, it made clear that the ability to secure private financing for new power stations would be a factor in the review.

3.4.34 As the preparations for privatisation proceeded, however, it became clear that continuing the PWR would make the sale unworkable. Including a planned investment programme in new PWRs in the prospectus would have created huge prospective liabilities, with uncertain returns, making a successful flotation impossible.

3.4.34 The nuclear utilities argued that new plants could only be built with Government guarantees, which the Government was unwilling to give. The Government concluded that there was no case for public investment in new nuclear plants.

3.4.35 This thinking was not helped by the fact that the Government at the time prided itself on not having an energy policy, in the sense of concerning itself with how much power generating capacity was needed and where it would come from. It was thought that these were matters for the market rather than Governments and that future development of new generating capacity would be essentially marginal: guided by changes in relative fuel costs rather than by an imperative for new capacity.

3.4.36 So the Government's policy of standing back, combined with the market's lack of appetite for long term investment, meant that the planned PWR programme was abandoned after Sizewell B. But it was not a deliberate policy by Government of opposing nuclear power, rather its policy of privatisation and commitment to leave the market to decide what investment was required, that brought the planned programme to an end.

3.4.37 British Energy was successfully privatised in 1996 through a stock market flotation and set about maximising value for shareholders. In its first years of privatisation, British Energy profits soared, and its share price massively increased.

3.4.38 Building on this early financial success, there were attempts to diversify the company with mixed results:

- Acquisition of a electricity supply company – Swalec (South Wales Electricity) – which was disposed of only weeks later
- Acquisition of a 2000 MWe coal-fired plant at Eggborough, intended to improve the flexibility of its generation assets. However it was purchased at the peak of the market and its value was written down from £640 million to £300 million in 2002
- Overseas acquisitions in the USA - through a joint venture with the Philadelphia Electric Company to create Amergen - and in Canada to create Bruce Power. These were profitable but the need to make investments meant they did not provide financial flows in the short term.

3.4.39 Despite this diversification the company was still heavily dependent on base load prices and these fell sharply after the introduction of the New Electricity Trading Arrangements (NETA) in 2000, which favoured plants with variable load. This coincided with a period when gas prices were falling which contributed further to the price collapse. Wholesale prices fell below the level of British Energy's production costs, pushing it into huge losses.

Prices collapse under NETA					
British Energy performance	1999/2000	2000/1	2001/2	2002/3	2003/4
Operating profit/loss	£430m	£230m	-£281m	-£3,899m	£340m
Electricity price (pence per kWh)	2.6p	2.3p	2.0p	1.8p	1.7p

3.4.40 There were also other factors which added to British Energy's difficulties:

- The company was locked into expensive reprocessing contracts with BNFL
- It became liable for an additional tax, the climate change levy (at up to 0.15 p/kWh) which was introduced by the Government in 2001, despite the fact that its nuclear plants do not emit carbon dioxide.

3.4.41 By 2002, British Energy was no longer able to meet its liabilities. The Government granted the company a credit facility to allow it to continue operation and the company was forced into a restructuring.

3.4.42 This restructuring was completed in 2005. As part of the agreement, British Energy disposed of its acquisitions in North America, which raised £2.3billion, and the reprocessing contracts with BNFL were also renegotiated.

3.4.43 A key part of the restructuring deal was that the company would contribute 65% of its free cash each year to the Nuclear Liabilities Fund (NLF), which is responsible for the future cost of decommissioning British Energy's existing fleet of nuclear power stations. This cash flow was later converted into shares, giving the NLF, controlled by the Government, 36% of the shares in British Energy.

3.4.44 Although the company's AGRs continued to experience ageing-related issues, the wholesale price of electricity increased after restructuring, and the company was in possession of prime sites for new build. In 2008, when the Government gave support to a new nuclear build programme, British Energy became the object of a bidding war that was eventually won by EDF. The £12.5 billion acquisition was completed in January 2009. Later in 2009, Centrica bought a 20% stake in British Energy for £2.3 billion.

3.4.45 A number of conditions were attached to the acquisition of British Energy by EDF, including the disposal of the Eggborough coal-fired plant and EDF's 790 MWe Sutton Bridge gas-fired station.

Growth and restructuring of BNFL

3.4.46 The other major component of the nuclear industry at this time was British Nuclear Fuels Limited (BNFL). This was born out of the break-up of UKAEA in 1971, with UKAEA retaining the research facilities and BNFL taking on the Calder Hall and Chapelcross Magnox palnts, the nuclear fuel manufacturing facility at Springfields and the Sellafield site (although it was only renamed Sellafield after 1981).

3.4.47 In 1984, BNFL became a public limited company, still fully-owned by the Government. It was to become one of the world's largest nuclear companies, providing services covering almost every part of the nuclear fuel cycle.

3.4.48 One of BNFL’s main activities was reprocessing of spent fuel, including used oxide fuel from the UK’s AGR fleet. A Thermal Oxide Reprocessing Plant (Thorp) was built at Sellafield, coming into operation in 1994. As well as reprocessing fuel from UK reactors, there were also contracts with Germany and Japan. However, following a leak of radioactive waste in 2005, the future of the Thorp plant was reviewed and a decision was taken to close it in 2018 after completing existing contracts.

3.4.49 BNFL itself became a significant generator when the remaining Magnox plants were transferred to its control in 1998. The company then also acquired the Westinghouse Electric Company and established a US decommissioning division.

3.4.50 BNFL also built a plant to manufacture mixed oxide (MOX) fuel from plutonium and uranium; although this was completed in 1997, with construction and operating costs reaching £1.2 billion, approval for its operation was not achieved until 2001. Its potential output was also significantly downgraded. The plant produced its first fuel assembly in 2005 for export but by 2010 its only remaining customers were Japanese utilities. In 2011, in the light of the Fukushima accident, it was announced that the plant would close.

3.4.51 Although decommissioning was a core part of the company's mission, it was not given financial incentives to achieve it. In the light of the Government's decision in 2003 not to support further new nuclear build and the shift of priority to decommissioning, the Government set up a review of BNFL.

3.4.52 This led to the company being broken into four major divisions. In 2005 the UK facilities owned by BNFL, and their associated decommissioning liabilities, were transferred to the Nuclear Decommissioning Authority (NDA) and the company became a contractor, owned by Government. Over the next four years it disposed of its commercial assets, including the sale of Westinghouse to Toshiba Corporation in 2006 and its one third share of the uranium enrichment company Urenco in 2008. By 2009 BNFL had no remaining operating businesses and it was formally wound up.

(5) Transition of U.K. nuclear power policy

3.5.1 As with energy policy in general, Government policy towards nuclear was the subject of cross-party consensus for the first three decades of the programme. There was support for nuclear power, on the grounds of economics and energy security. And there was a common desire to promote indigenous UK design and engineering capability.

Labour Turns Against Nuclear Power

3.5.2 Some differences started to emerge during the 1970s regarding the favoured reactor design, with the then Labour Government continuing to promote UK reactor designs and the Conservatives favouring PWRs. But the significant differences emerged during the 1980s. Just at the same time as the Conservative Government was embracing market solutions and privatisation, the Labour Party began to turn against nuclear power. Initially calling for a reduction in dependence on nuclear and a reversal of the Conservatives PWR programme, the party hardened its position to one of opposing all new build or extending the life of existing stations.

3.5.3 Labour policy on nuclear was shaped by three factors:

- A political shift to the left after 1979
- Adoption of a policy of unilateral nuclear disarmament in the defence area, which became confused with policy on civil nuclear power
- Attempts by the National Union of Mineworkers, especially after the election of the left-wing Arthur Scargill as the union's president in 1982, to close down nuclear generation

3.5.4 Later in the 1980s and 90s, the Labour Party also became heavily influenced by green ideology. This was initially part of the ideological shift to the left after 1979 but it survived after Tony Blair became leader of the party in 1994. Indeed it survives to this day.

3.5.5 The Labour Government under Tony Blair conducted a review of nuclear policy. There were clear differences of view within Government and in the event the anti-nuclear view dominated. In 2003 the Government announced that the "current economics" of nuclear power "make new nuclear build an unattractive option and there are important issues of nuclear waste to be resolved". It therefore said that it would not support further new build. But, critically, it said that it would keep the option open.

BNFL National Social Dialogue

3.5.6 An important part of improving public trust in the nuclear industry was a radical experiment in stakeholder engagement undertaken by BNFL in the 1980s.

3.5.7 The company had strong relations with its workforce and their trade unions and with the communities around its sites. However, it faced hostility from many groups beyond these communities and was widely distrusted.

3.5.8 Environmental concerns about nuclear power were given a strong focus by the Sizewell B planning inquiry in the 1980s, and to some extent continued around operational power plants after that. But BNFL recognised that it was the organisation that was the "problem-holder" for many of the most difficult issues where public concerns were raised, including waste management, reprocessing of fuel and plutonium.

3.5.9 The company was confident that it had strong arguments on these and other issues, but its way of dealing with them was essentially technical: to gather robust evidence with which to rebut its critics. But BNFL recognised that these technical arguments were not enough to allay public concerns or to secure public and political acceptance of its activities: the company's "licence to operate" in the broadest sense.

3.5.10 BNFL therefore decided to try a different approach and to engage directly with its critics as part of a broader process of stakeholder engagement or Social Dialogue. The company worked with an independent and trusted charitable organisation – the Environment Council – which facilitated the dialogue and managed the process. The Environment Council had experience of building dialogue around a number of difficult environmental issues, but it was recognised that nothing as challenging or on such a large scale as the task for BNFL had ever been attempted.

3.5.11 At first the contacts were at arms length, through the Environment Council, but then a meeting of stakeholder organisations was held at an independent location in 1998. The conversations were at first difficult, not only between BNFL and the environmental groups, but also between the environmental groups and the other stakeholders who were present. But gradually trust was built up and serious dialogue took place around the priority issues that were identified, mainly though working groups looking at agreed topics:

- Waste
- Discharges
- Spent fuel management options
- UK plutonium disposition
- BNFL business futures
- Security

3.5.12 An important factor in success was that BNFL was fully committed to the process from the most senior level, which was essential in giving participants confidence that the dialogue would be genuine and comprehensive.

3.5.13 In order to get away from the problems of contested facts – one set of experts being pitted against another – an approach of joint fact finding was adopted. Having identified a problem to be addressed, the participants would agree on what evidence would be gathered and who would do it. So both sides would be committed to the results of any work that was done.

3.5.14 There were also some important issues of process that were addressed in order to encourage the right behaviours and collaborative working. These ranged from the locations of meetings, to the way meeting rooms were laid out and the language that was used.

3.5.15 It was not however, a soft process of simply finding areas of agreement and consensus. Although the early stages of the dialogue did identify some issues where it was possible to reach agreement, the dialogue also deliberately set out to identify areas of differences and to address them directly. This entailed all sides recognising the legitimacy of each other's concerns and interests, and acceptance that the parties applied different values to different factors.

3.5.16 The Social Dialogue lasted for six years. The individuals within BNFL who were directly engaged in it felt it had had a major impact on the way they and the company operated. The effect can be seen in part through a comparison of the company's vision statements at the beginning and after the dialogue:

1998 to "*become the leading global nuclear company*." This included maximising the value of the used fuel and the recently acquired Magnox generation businesses

2004 "*to be an economically viable, environmentally responsible and socially beneficial company that is fully accountable for its performance*" where the "*main focus will be the decommissioning and clean-up of Britain's nuclear facilities and the safe, expert handling of the resultant waste*"

3.5.17 The Social Dialogue process came to an end when BNFL itself had its core responsibilities transferred to the NDA. Some of the approaches that formed part of the Social Dialogue are evident in the stakeholder engagement processes of the NDA, the later consultation by Government around new build, and more notably in the development of policy on radioactive waste management. But it has not been followed through with the level of commitment of time and corporate engagement that was evident in the BNFL Social Dialogue process.

Policy on Nuclear Waste

3.5.18 Environmental concerns about nuclear power have focused increasingly on the question of how to manage waste and spent fuel.

3.5.18 A highly significant report was published in 1976 by the Royal Commission on Environmental Pollution, generally known as the Flowers Report (named after its Chairman Lord Flowers).

3.5.19 The key recommendation in the Flowers Report was that the UK should not embark on an expansion of nuclear power unless the question of waste disposal had been resolved. This was – and remains today – a question of public acceptability of solutions, and therefore a political rather than a technical issue.

3.5.20 The UK's legacy of nuclear waste is highly complex. It has been driven by diverse considerations ranging from a desire to keep up with the US on nuclear weapons to a desire to innovate in almost every possible new nuclear technology, and every new nuclear construction. But successive attempts to find technical solutions to the problems of managing higher level waste collapsed because of a failure to secure political and stakeholder support. This led to political indecision and delay, including three failed attempts to identify sites for a radioactive waste repository. Meanwhile the waste has remained above ground, mostly on the Sellafield site in Cumbria.

3.5.21 In 2003 the Government set up the Committee on Radioactive Waste Management (CORWM) to consider how to manage the UK's higher activity radioactive waste in the long term. The Committee deliberately set out to build stakeholder support around options, rather than simply to explore technical issues, most of which were already well-understood. The Committee issued its report in 2006, recommending that:

- Geological disposal is the best available long term solution
- Safe and secure interim storage is needed in the meantime
- Further research and development is needed

3.5.22 Government accepted CORWM's recommendations and began a process of consultation to give communities the option to volunteer to explore the possibility of accepting a geological facility in their area.

Recent Development of Nuclear Policy

3.5.23 It was not long after the Government's announcement in 2003 appeared to close the door on future new build that the process of shifting policy began. In 2005 the Government began a review of policy and a critical point was reached when the Prime Minister Tony Blair made a speech to a business audience at the Confederation of British Industry which stated his support for a new build programme.

3.5.24 This was followed by a further Government White Paper in 2007 which said that the Government's preliminary view was that the private sector should have the option of developing new nuclear plants. It also began the process of consultation that would lead to it affirming its support for new build.

3.5.25 The Government's view, continuing the policy of the previous Conservative governments, was that investment in new power plants would be for the private sector, but it did undertake to make a series of facilitative actions to make such investments possible. These included changes to the planning system and the process of Generic Design Assessment.

Justification	A requirement under European law that the Government must establish that the benefits of any new nuclear activity outweigh the health risks.
National Policy Statements	Statements of strategic need for development which will form the basis for the decision-making processes of the independent Planning Inspectorate. Once adopted, the statements mean that questions about the strategic need for a certain type of development do not need to be further considered in the planning process. In the case of nuclear, the statement included a strategic siting assessment which set out the strategic locations that would be suitable for development of the first phase of new nuclear power stations.
Generic Design Assessment (GDA)	A process conducted jointly by the Office for Nuclear Regulation, part of the Health and Safety Executive, and the Environment Agency. The GDA allows the generic safety, security and environmental aspects of new nuclear reactor designs to be assessed

before applications are made for licences and permits to build a particular design of reactor on a particular site.

Funded Decommissioning Programme (FDP)

The Energy Act 2008 requires operators of new nuclear power stations to have secure financing arrangements in place to meet the full costs of decommissioning and their full share of waste management and disposal costs.

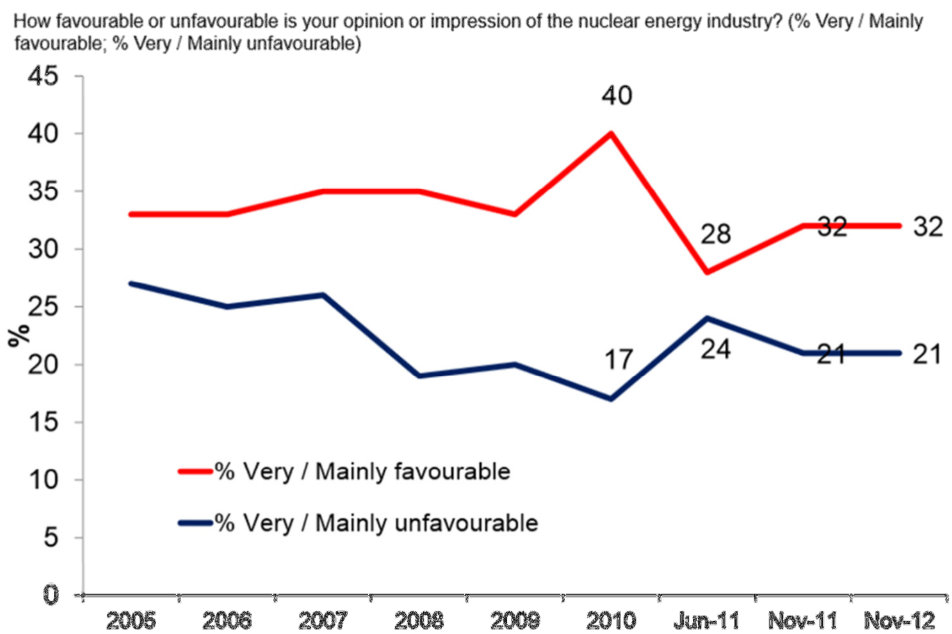
Electricity Market Reform

Reforms to the UK's electricity market are intended to give greater certainty to investors to develop low carbon sources of generation.

The principal elements of the reform are:

- A carbon floor price, to provide greater certainty about the future price of carbon in the EU Emissions Trading Scheme
- Implementation of feed-in tariffs with contracts for differences
- Introduction of a capacity mechanism.
- Emission performance standards

3.5.26 Support for the nuclear programme continued after the change of Government in 2010 and benefits from cross-party support. An important element in maintaining this support has been the favourable climate of public opinion. Following a dip in support after the Fukushima accident, support for nuclear recovered and is now at the same level as in 2011:



Current Status of Nuclear Policy

3.5.27 The facilitative actions described above have now been implemented and the process of Electricity Market Reform is included in the Energy Bill which is currently passing through Parliament.

3.5.28 The Government does not have a target for the share of nuclear power but will support, through the facilitative actions, investment by private consortia. Plans for 16GWe of new nuclear capacity have been put forward by three development consortia at five sites:

EDF Energy	EDF Energy 2 x 1600 MW EPRs for Hinkley Point 2 x 1600 MW EPRs for Sizewell
Horizon Nuclear Power	Up to 7,800 MW Plans for ABWRs at Wylfa and Oldbury to be confirmed following completion of the acquisition by Hitachi
NuGen	Iberdrola/GDF Suez Joint Venture Up to 3600MW operating by 2025 Technology to be decided

3.5.29 These projects will be privately financed but the revenues for each project will be underwritten by Contracts for Differences introduced under the Energy Bill currently being considered by Parliament.

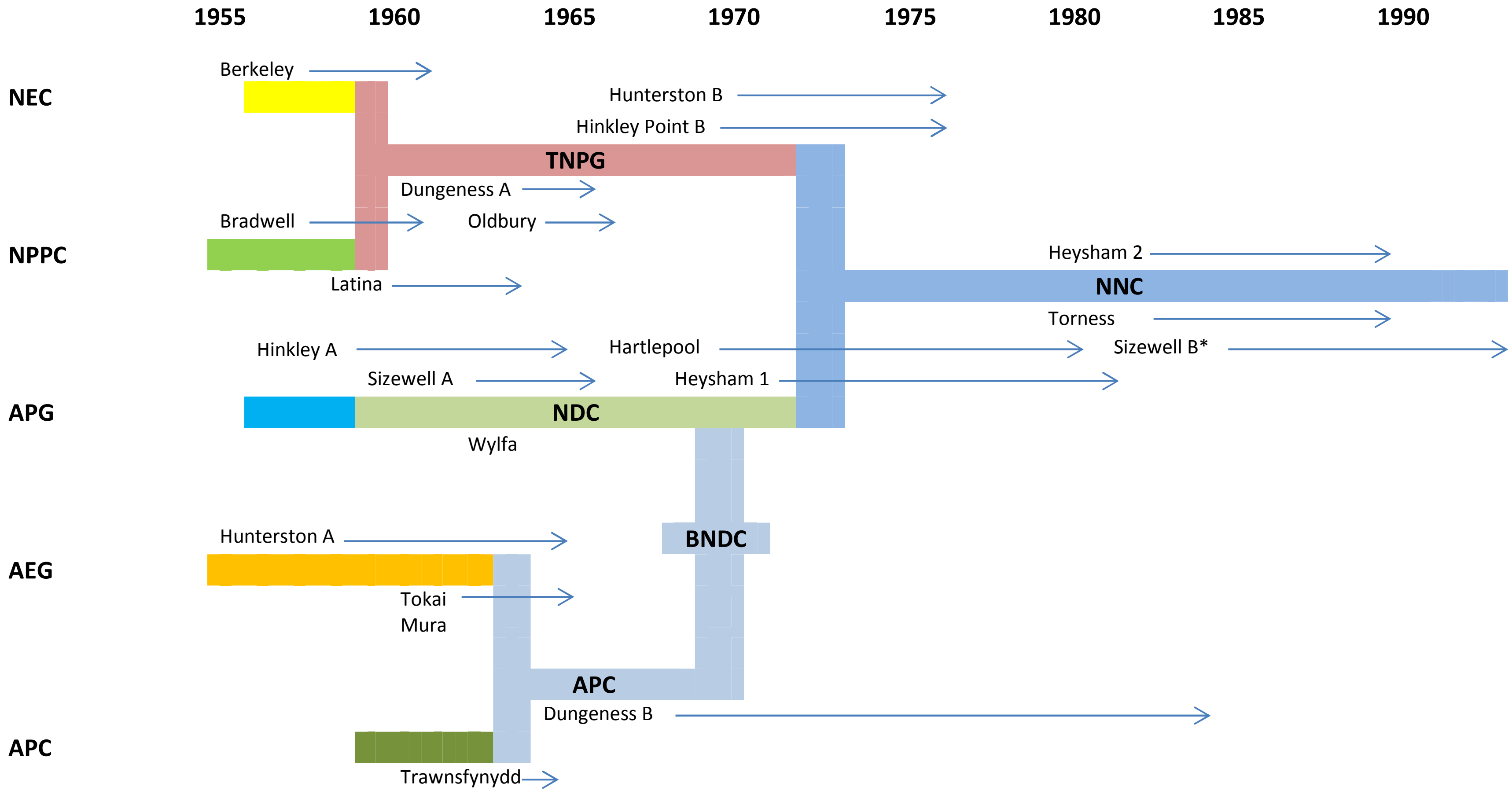
3.5.30 Planning consent for EDF Energy's plant at Hinkley Point was granted on March 19th 2013.

3.5.31 Whilst the decommissioning and the costs of waste management associated with any new nuclear plants lie with the developers of new plants, the Government supports the decommissioning of the Magnox plants and other older facilities through the Nuclear Decommissioning Authority. This is funded mainly by the Government (although it earns some commercial revenues) and spending is in excess of £2 billion per annum. Most of this is spent on contracts awarded through site licence companies which manage the facilities.

3.5.32 Having consulted on the programme for the Managing Radioactive Waste Safely through CORWM as described above, the Government invited voluntary expressions of interest from local communities to explore further the potential for a geological repository in their areas. Three communities began this voluntary process, all of them in the area of Cumbria around the existing Sellafield site, but in January 2013 one of the three withdrew from the process. The Government is currently considering how to take forward its policy but is maintaining its support for the policy of deep geological disposal, as recommended by CORWM, and for a voluntarist approach to community participation. It is expected that a deep geological repository would not be built until 2040.

3.5.33 In response to a report by the House of Lords Science and Technology Committee, which was highly critical of Government policy on nuclear R&D, the Government has set out a long term R&D strategy to be led by a new Nuclear Industry Research Advisory Board.

Nuclear Power Consortia and Projects



*Note: The role of NNC had changed by the time of Sizewell B. It provided detailed design and formed a joint venture – PWR Power Projects - with Westinghouse to deliver aspects of the project.

4. Results of Trend Survey of UK Nuclear Industry

(1) Trends of overall UK Nuclear Industry

4.1.1 As noted earlier, the Government encouraged the formation of industrial consortia to deliver the Magnox and, later, the AGR programme. These were initially built around turbine-alternator manufacturers and industrial boiler (heat exchanger) makers but they developed in slightly different ways. Some brought in civil engineering contractors as part of the consortium, others as nominated civil engineering partners. In some cases, the consortium was formalised as a separate, jointly-owned, vehicle whilst in others it was simply a contracting partnership.

4.1.2 A chart setting out the development and consolidation of the consortia from 1955 onwards and the projects which they were contracted to deliver is opposite.

4.1.3 The following table shows the companies that made up the early delivery consortia, colour coded to show their status today. Those marked in red have gone out of business altogether, those in orange are part of international groups that retain the relevant capability but do not currently provide it from the UK, those in yellow have capability in the UK but no longer in the relevant area of expertise, whilst those in green still have relevant UK capability.

4.1.4 When the last of the AGRs were built at Torness and Heysham, these were still recognisably UK projects. NNC, which was the remaining part of the consortia which the Government had encouraged to deliver the Magnox programme, had designed the stations and built the reactors whilst the turbines were supplied by GEC and NEI respectively, both of which had brought together, through mergers, companies involved in the early consortia.

4.1.5 By the time of Sizewell B seven years later, NNC provided the UK design but on the basis of the Westinghouse SNUPPS (Standard Nuclear Unit Power Plant System) reactor design already built in the USA. Of the principal equipment suppliers involved in the early consortia only GEC-Alsthom (by then a French-British merger and now part of Alstom) and Babcock Energy (now Doosan Power Systems) remained on the Sizewell B project. GEC-Alsthom supplied the turbines from the former GEC factory in Rugby, whist Babcock Energy supplied the steam generators.

Nuclear Power Plant Delivery Consortia 1955-57

	POWER PLANT/ TURBINE	BOILERS/ HEAT EXCHANGERS	REACTOR MECHANICAL PLANT	REACTOR PRESSURE VESSELS	CIVIL ENGINEERING CONSTRUCTION
AEI - JOHN THOMPSON	Associated Electrical Industries	John Thompson	John Thompson Ordnance	John Thompson	Balfour Beatty and John Laing employed but were not consortium members
EE/B&W/TWC	English Electric	Babcock & Wilcox	English Electric	Babcock & Wilcox	Taylor Woodrow Construction
GEC / SIMON CARVES	GEC	Simon Carves	GEC	Motherwell Bridge employed but was not a consortium member	John Mowlem (Scotland) employed but was not a consortium member
NUCLEAR POWER PLANT CO (NPPC)	C A Parsons	Clark Chapman	Strachan & Henshaw	Whessoe	Sir Robert McAlpine and Alexander Findlay
	A Reyrolle	Head Wrightson			
ATOMIC POWER CONSTRUCTIONS (APC)	Richardsons Westgarth	International Combustion	Fairey Engineering	Babcock & Wilcox employed but not a consortium member	Trollope & Colls and Holland, Hannen & Cubitts
	Crompton Parkinson				

Source: UK Experience Of Consortia Engineering For Nuclear Power Stations, S H Wearne and R H Bird, 2009, plus NIA research

Key:
- Capability exists in UK
- Part of a company with global capability but not currently in UK
- Part of company but no current capability in this specialty in the UK
- Company ceased to exist

4.1.6 The PWR programme was therefore already becoming internationalised in terms of its major structural components, and this would have remained the case if the programme had been extended to a series of four or more reactors.

4.1.7 Nevertheless, the major part of the work for Sizewell B – over 90% of the value of hardware contracts - went to British companies. A list of the principal contractors and consultants, showing those that still have current UK capability in the work packages concerned, is in the following table and includes the following British companies:

John Laing	Main civil works
GEC Alsthom	Turbine Generators
Babcock Energy	Steam Generator supply, weld inspection
BPA	Pipework and Mechanical Plant
Kier	Cooling Water Works
Taymech	HVAC equipment
Davy Energy	Radwaste plant
NG Bailey	Cabling and cable steelwork
PWR Projects	Primary Circuit Auxillary System
BNFL	Fuel Design & Supply
Weir Pumps	Main feedwater pumps
NEI	Process plant control & instrumentation

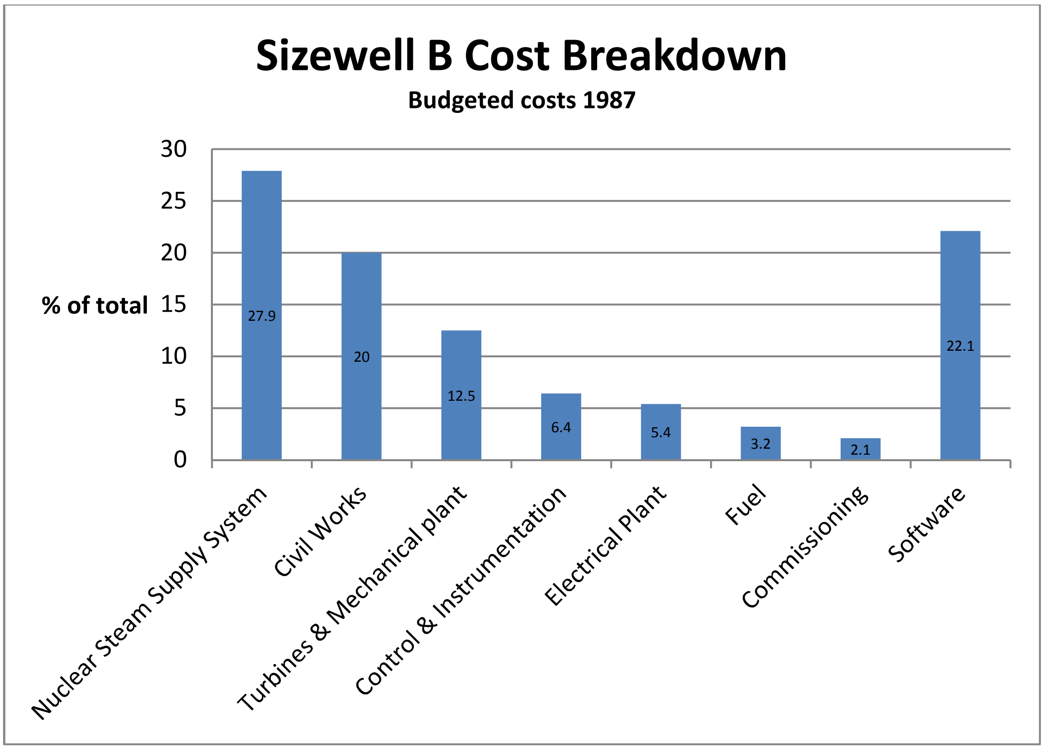
Sizewell B Contractors		Company has current UK Capability	
Principal Contractors			
Main Civil Works	**John Laing Construction**	✓	
Reactor Pressure Vessel	**Framatome**		
Primary Circuit System	**Westinghouse**		
Turbine Generator	**GEC Alsthom**		Now Alstom
Steam Generator	**Babcock Energy**		Now Doosan Power
Pipework & Mechanical Plant	**BPA Joint Venture**	✓	Joint venture led by Babcock
Cooling Water Works	**Kier Construction**	✓	
Electric cabling	**NG Bailey**	✓	
Cable supply	**Pirelli General**		Joint venture between Pirelli and GEC
Primary Circuit Auxiliary System	**PWR Power Projects**		Joint venture between NNC and Westinghouse
Heating, Ventilation, Air Conditioning System	**Taymech**		Specialist arm of Taylor Woodrow now focused on maintenance
Radwaste Plant	**Davy Energy**	✓	
Fuel Supply	**BNFL**		Contract transferred to AREVA
Radwaste Mechanical	**Laing Industrial**	✓	
Main Feedwater Pumps	**Weir Pumps**	✓	
Control Room Equipment	**Cegelec**		
Diesel Generators	**Mirrlees Blackstone**		Now part of MAN Group
Small electricals	**Balfour Kilpatrick**	✓	
Diaphragm Wall	**Stent-Soletanche**		
Reactor Building Lining Plate	**Cleveland Structural Engineering**	✓	
Fire Protection	**Wormald Ansul UK**	✓	
Transformers	**GEC Alsthom**		Now Alstom
General Mechanical Services	**Press Construction**	✓	
Aggregate Supplies	**ARC Eastern**	✓	Acquired by Hanson Quarry Products
Reserve Ultimate Heat Sink	**NEI Power Projects**	✓	Acquired by Rolls Royce

Low Voltage Switch Gear	**Laurence Scott**	✓	
Automated Weld Inspection	**Babcock Power**	✓	Now Doosan Power
Fuel Building and Polar Crane	**Butterley Engineering**	✓	
Refuelling Cavity & Pond Liner	**Darchem Engineering**	✓	
Engineering Computer System	**EDS**		Acquired by HP
Generator Main Connection	**Balfour Beatty**	✓	
Process Plant Control & Instrumentation	**NEI Control Systems**	✓	Acquired by Rolls Royce
Consultants			
Licensing & Engineering Support	**NNC**	✓	Acquired by AMEC
Materials & Weld validation	**AEA Technology**		
Civil Engineering Design Assistance	**Nuclear Design Associates**	✓	Joint venture now wholly owned by Sir Robert McAlpine
Quantity Surveyor	**Davis Langdon**	✓	
Architects	**YRM**	✓	Acquired by RMJM
Independent Third Party Inspection	**Lloyds Register**	✓	

4.1.8 Nuclear Electric carried out an assessment of the benefits to the UK of the construction of Sizewell B. Some of the summary findings of the Nuclear Electric report were:

- Over 3,000 UK-based companies participated in the construction of Sizewell B
- At a time of sharply declining orders, the project helped UK manufacturers retain both the design capability and the skilled manpower necessary to compete in global markets.
- Investment in capability to supply to Sizewell B provided the opportunity for some UK-based companies to compete in the global nuclear power market.
- More than 90% of the value of the hardware contracts was placed directly or indirectly with UK- based companies.
- Over the seven year construction period, it was estimated that 70,000 man years of work were expended directly on the project, and at the peak construction period (end of 1991), the on-site workforce stood at 4,385.

4.1.9 The total budgeted costs for the Sizewell B project were apportioned as shown in the chart below:



4.1.10 After Sizewell B, GEC Alsthom ceased production of turbines at its Rugby works and the successor company Alstom now has no UK manufacturing capability in turbines. Babcock Energy, which had built a large manufacturing facility in Renfrewshire in anticipation of a programme of PWRs, no longer manufactures steam generators in the UK. The company is now Doosan Power which focuses on installation and maintenance contracts but also has manufacturing capability.

4.1.11 These changes illustrate a more general development in the profile of British industry that was evident before Sizewell B and has been continued since then: leading contactors on major projects organising themselves around the softer services associated with the design and delivery of projects rather than the manufacture of major components. In some cases this has entailed companies moving out of equipment manufacture and focusing their business model on installation, maintenance or facilities management.

4.1.12 By the time of the construction of Sizewell B, NNC, which had had its roots in the industrial consortia formed around the manufacturers of the major components of a nuclear power plant, was no longer directly responsible for equipment manufacture. Rather it was an engineering and design company, acting as Architect Engineer and overseeing procurement of contractors.

4.1.13 This is not to suggest that such services are of secondary value. Whether they are at the higher end – design and engineering - or at the lower end – installation, maintenance and testing of equipment – they constitute a large proportion of the value of a power plant.

4.1.14 For example:

- Programme Management and related engineering services are typically worth 10% of the value of a new nuclear plant
- Over the 40 year lifetime of a plant, operations and maintenance costs are higher than construction costs
- Inspections carried out to confirm the quality of fabrication and integrity for major pieces of equipment can often cost as much as purchase price of the equipment itself.

4.1.15 Companies pursued a number of other commercial strategies to deal with the drop in domestic nuclear orders, including:

- Diversification into other sectors where technologies and quality standards might be transferred; there were some successes, notably in the oil and gas sectors, but also some problems
- Internationalisation, in many cases by acquiring companies in other countries

4.1.16 The experience of companies in the nuclear industry is also part of the broader story of UK industrial policy as much as it is about the specifics of the nuclear industry. And just as in other sectors, the companies that have survived and thrived in the nuclear sector have done so as part of larger international groups which has both advantages and disadvantages. Even if the companies shown in orange in the table above no longer have the relevant capability within the UK, they do have access to overseas markets for the sectors where they do have capability. And where a global company wins a contract to supply the UK on the basis of its capabilities overseas, it is more likely to support that capability from the UK than one that has no UK presence at all.

Electricity Utilities

4.1.17 As noted in the section on the History of UK Energy Policy, the separation of the electricity industry at the time of privatisation broke down over time and it became dominated by vertically integrated players. Some downstream energy supply companies bought generating businesses and the major generators themselves became suppliers.

4.1.18 Paradoxically, although the industry is now more open to competition than ever, it is also highly concentrated, with the market dominated by six major utilities, supplying gas as well as electricity, all of them vertically integrated businesses.

Major Energy Suppliers			
	Number of customers (gas & electricity) million	**% of UK electricity generating capacity**	**Parent Company**
British Gas	20	5.6	Centrica
EDF Energy	5.7	16.6	EdF
E.ON UK	5.3	12.4	E.ON
npower	6.5	15.2	RWE
Scottish Power	5.2	8.8	Iberdrola
SSE	9.6	8.3	SSE Group
Total		**67**	

4.1.19 Power generation is therefore divided between vertically integrated businesses which both generate electricity and also supply it to customers, and independent merchant generators, which sell power into the wholesale market. The independent generators are mostly smaller companies; they include the many wind power companies that are now entering the market but also Drax, the largest coal-fired power station.

4.1.20 Broadly speaking, the big six energy companies are able to provide enough power from their own generating capacity to cover the requirements of their customers. They have little need to trade in the open market and do so mainly to balance or hedge their market positions. The relatively small amount of power output that is traded has led to concerns about the lack of competition in the wholesale market.

4.1.21 Although EDF is one of the big six, its nuclear capacity is baseload and is dependent on prices set by variable capacity. In current market conditions the variable load price setter in the UK wholesale market is coal fired capacity but at other times it is CCGTs. Nuclear is therefore a price-taker and does not dominate price setting in the market. EDF also has 4.8 GWe of coal, CCGT and wind capacity.

Decommissioning

4.1.22 It had been recognised by successive Governments that there would be substantial liabilities for decommissioning the UK's civil nuclear facilities, including the Magnox plants but also the older facilities owned by UKAEA and BNFL. However, these were owned and managed by different parts of the Government, making it more difficult to assimilate them into a single programme.

4.1.23 The first Magnox plants had started to reach the end of their lives from 1989 but the sites were held on a care and maintenance basis.

4.1.24 The creation of Magnox Electric, which took on the Magnox plants after privatisation of British Energy in 1996, helped to ring-fence these liabilities. The Government then began a process of bringing together the public sector's civil nuclear liabilities into one place, setting up a Liabilities Management Fund in 2001.

4.1.25 The process only took on real momentum with the setting up of the Nuclear Decommissioning Authority (NDA) in 2005. This created a single Government body charged with decommissioning and waste management, with a dedicated budget of in excess of £2billion per annum.

4.1.26 The NDA took on the liability for decommissioning:

- The 11 Magnox sites
- The UKAEA sites at Dounreay, Harwell and Winfrith
- BNFL's fuel sites at Sellafield, Capenhurst and Springfields and the low-level radioactive waste repository (LLW Repository) at Drigg close to Sellafield.

4.1.27 The vast majority of decommissioning work on these sites is carried out through contracts managed by site licence companies. Among the first major SLCs, Sellafield Ltd (formerly British Nuclear Group Sellafield) which manages the reprocessing and waste storage facilities at Sellafield, the closed Calder Hall and Windscale reactors, the Capenhurst site and an engineering and design centre at Risley. The management contract was awarded to Nuclear Management Partners (NMP), a US-UK-French consortium of URS, Amec and AREVA.

4.1.28 The other SLCs operating within the NDA estate are:

- Magnox Ltd – responsible for the 10 Magnox reactors in England, Scotland and Wales. The reactors are all in various stages of defueling with the exception of one at Wylfa, Anglesey, which was scheduled to close in December 2010 but, following a review with the site regulators was granted an agreement for extended generation up to 2014, and is still contributing electricity to the National Grid. The total annual budget for Magnox is £510m.
- Dounreay Ltd – responsible for the Dounreay Site in Caithness, Scotland. The Site has an annual budget of £150m.
- Reactor Sites Restoration Ltd – responsible for the Winfrith and Harwell sites with an annual budget of £60m.
- Springfields - predominately an operational site, manufacturing fuel for commercial customers, however there is an ongoing decommissioning programme with an annual budget of £42m.
- LLWR Ltd – responsible for the facility near Drigg in West Cumbria. The Site has an annual budget of some £30m.

4.1.29 The decommissioning programme has sustained nuclear expertise in UK industry and has enabled many companies to retain capabilities and, critically, nuclear-relevant experience. Many of the companies that have secured contracts with the NDA or SLCs are currently tendering or preparing to tender for new build contracts.

4.1.30 It is internationally accepted that the NDA has made real progress in assessing the scale and challenges posed by the UK's nuclear legacy, and in developing and implementing a national strategy for dealing with it. Decommissioning and clean-up of 7 Magnox reactors is well underway, as well as a range of other facilities.

(2) Research Institutes

4.2.1 From its beginnings in the military programme, the nuclear programme in the UK has had a strong research element.

4.2.2 This has developed as a result of a combination of factors:

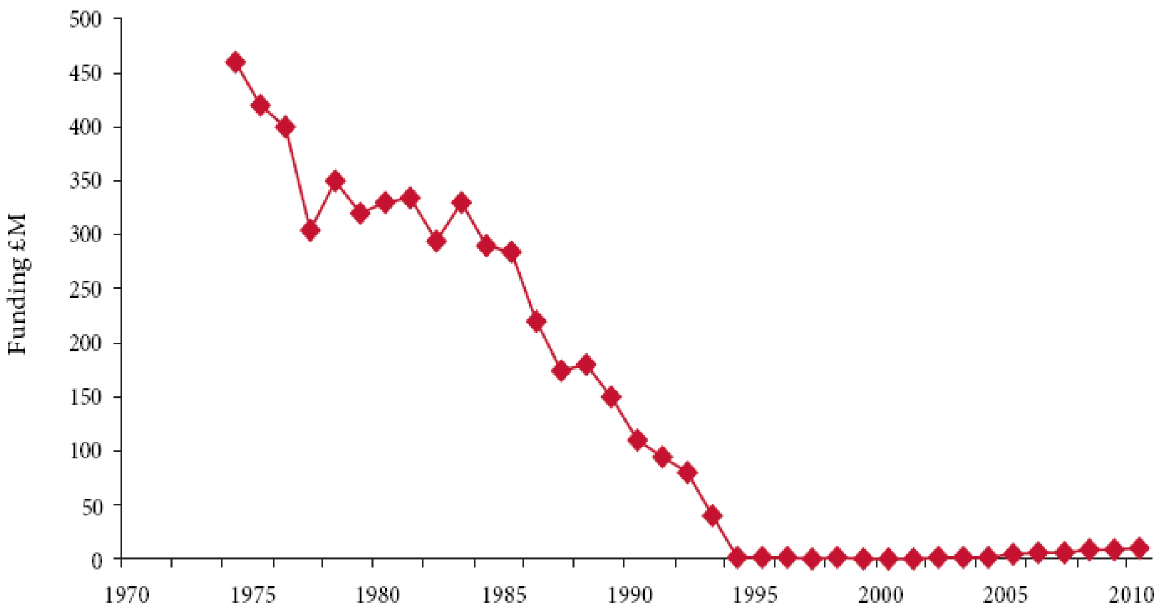
- The need to secure independent UK capability in military expertise, following the 1946 McMahon Act which ended US-international collaboration in nuclear technology
- a desire to develop an independent (specifically, independent of the USA) UK reactor design
- creation of multiple designs for plants using the same generic reactor technology.

4.2.3 Since 1954 this activity has been led by the UK Atomic Energy Authority. The UKAEA built and operated prototype reactors for new designs, some of which were subsequently developed as operational technologies. Others were not developed for operation, including a high temperature gas cooled reactor and a steam generating heavy water reactor (SGHWR) which was favoured by the Labour Government in the 1970s before the PWR programme was preferred. The UKAEA also acted as adviser to both the clients (the utilities) and the contractors (the delivery consortia) for the Magnox and AGR plants.

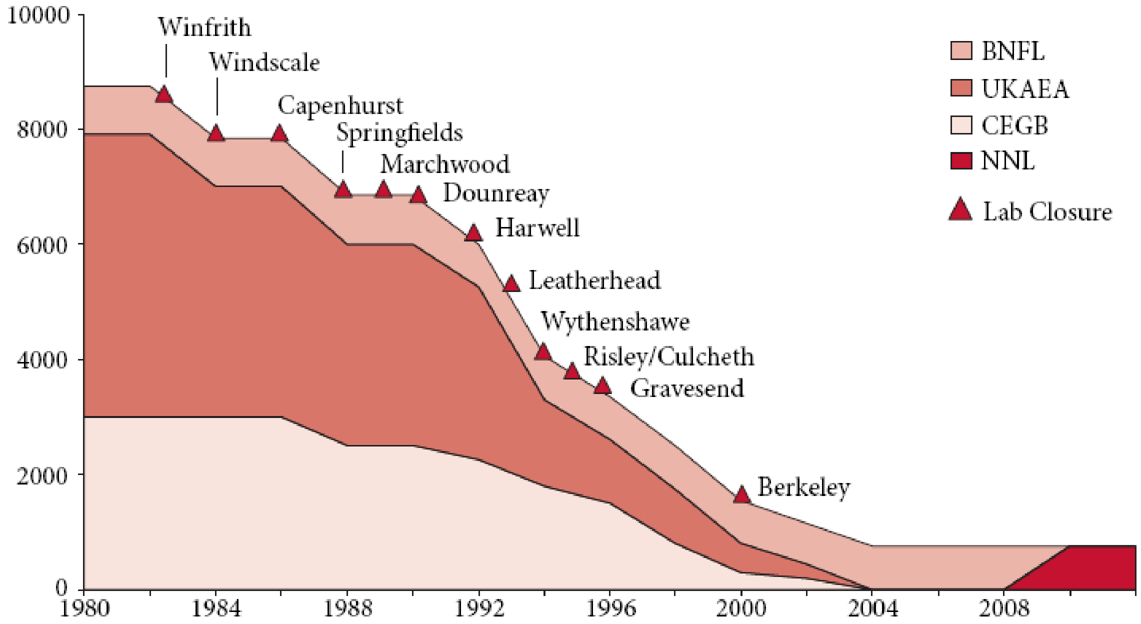
4.2.4 UKAEA also conducted research on a fast breeder programme at Dounreay in Scotland, including operating a prototype fast reactor which supplied electricity to the grid until 1994, when the Government decided to withdraw further support to the programme.

4.2.5 The UKAEA also carries out fusion research in Culham in Oxfordshire where it is a participant in the JET (Joint European Torus) project.

4.2.6 However, since 1980, the UK has not participated in research on new reactor designs and, although R&D funding was already falling by 1980, it has contracted sharply since then, particularly since privatisation of the electricity industry.



4.2.7 The nuclear R&D workforce, employed in the UKAEA's facilities, at BNFL and in the CEGB, was around 8,000 in 1980. The following diagram shows the decline of the nuclear R&D workforce since then and the closure of Government nuclear laboratories.



4.2.8 Government funding for civil nuclear R&D is approximately £66m (2010/11), half of which goes into fusion research. Funding of fission research is slightly less, at £29m, of which £10.9m goes to the NDA to support the decommissioning programme.

UK Government Expenditure on Nuclear R&D 2010/11		
Total fission (£29m)	Total BIS (£18.1m)	EPSRC (£11.7m)
		STFC (£2.6m)
		NERC (£1.8m)
		TSB (£2.0m)
	Total DECC (£10.9m)	NDA (£10.9m)
Total fusion (£33m)	Total BIS (£33.0m)	EPSRC (£33.0)
Total other (£4m)	Total DH (£3.7m)	HPA (£1m)
		FSA (2.7m)
	Total Defra (£0.3m)	EA (£0.3m)

Key	
BIS	Department for Business, Innovation and Skills
DECC	Department for Energy & Climate Change
EPSRC	Engineering and Physical Sciences Research Council
DH	Department of Health
DEFRA	Department of Environment, Food & Rural Affairs
STFC	Science & Technology Facilities Council
NERC	Natural Environment Research Council
TSB	Technology Strategy Board
NDA	Nuclear Decommissioning Authority
HPA	Health Protection Agency
FSA	Food Standards Agency
EA	Environment Agency

4.2.9 A report by the Government's Technology Strategy Board identified UK strengths and weaknesses in nuclear R&D as perceived by domestic and international stakeholders:

Perceptions of UK Nuclear R&D Strengths and Weaknesses		
International Stakeholders		**Domestic Stakeholders**
• Sodium-cooled reactor experience • Post-irradiation examination of fuel & reactor components • Fuel performance modelling • Storage of irradiated fuel • Management of irradiated fuel including reprocessing • Irradiation behaviour of graphite • Facilities for experimental work on radioactive materials • Physical protection of nuclear infra-structure	**R&D Capabilities perceived as strong**	• Reactor physics • Gas-cooled reactor experience • Computational fluid dynamics/thermal hydraulics • Accident simulation, e.g. Loss of coolant accident • Reactor core modelling • Radiation damage (physical examination & modelling) • Graphite technology • Fuel design and manufacture • Fuel cycle assessment • Enrichment • Reprocessing • Waste treatment
• Systems for remote handling • High temperature materials • High temperature chemical processes • Digital instrumentation and control • Probabilistic risk assessment • Human factors engineering	**Spin-in/Spin-out Technologies where UK perceived as strong**	• Decontamination and Decommissioning • Non Destructive Evaluation • Structural Integrity Assessment • Materials Degradation Mechanisms including welds, and non- metallic materials including concrete. (Mechanisms include corrosion, fatigue, creep, thermal cycling.) • Digital command and control systems • Thermal Hydraulics/Computational Fluid Dynamics • Structural Integrity • Corrosion
• Limited R&D programmes in advanced reactors and fuel cycles • Limited academic base experienced in nuclear • Limited R&D infrastructure	**R&D Capabilities perceived as weak**	• Operational Experience of Gen III reactor systems • Optimisation of modern Generation III reactor systems • Specific aspects of advanced reactor systems including Fast Reactor (FR), High Temperature Reactor (HTR) and • Very High Temperature Reactor (VHTR) including • Pebble Bed Modular Reactor (PBMR), • Thorium

(3) Educational Institutes

4.3.1 Because of the gap in building new nuclear plants and the lack of recruitment, the UK nuclear workforce has an older average age than the average age of the total UK workforce, with a higher percentage expected to retire over the next 15 years. To meet these demands, the UK universities with nuclear expertise have developed programmes for both undergraduates and postgraduates – both taught courses and opportunities for research.

4.3.2 A report commissioned by the Health and Safety Executive in 2002 was highly critical of the state of nuclear education and suggested that immediate action was needed if nuclear education was not to disappear entirely. It recommended that the focus of nuclear education should be on postgraduate courses.

4.3.3 A small number of postgraduate nuclear courses, such as those at the Universities of Birmingham, Surrey and Liverpool, had survived the downturn in student numbers

4.3.4 To address this challenge as the arguments for nuclear new build began to gain pace, a grouping called the Nuclear Technology Education Consortium (NTEC) was formed in 2004. It originally consisted of 11 Higher Education organisations – the Universities of Birmingham, Highlands & Islands Millennium Institute, Leeds, Lancaster, Liverpool, Manchester and Sheffield, City University and Imperial College, London plus Westlakes Research Institute in Cumbria and the Defence Academy College of Management and Technology (based in Bedfordshire and Oxfordshire). The University of Central Lancashire joined in 2009.

4.3.5 NTEC demonstrated that students were once again becoming extremely interested in doing nuclear science and engineering courses. As a result, a range of new undergraduate and graduate programmes based in individual universities have been established. Lancaster University was the first in 2006 with an undergraduate programme in Nuclear Engineering. Imperial College London and the Universities of Manchester and Leeds developed joint undergraduate courses which allow mechanical and chemical engineers and material scientists to benefit from 25% nuclear content in their courses.

4.3.6 The Engineering and Physical Sciences Research Council (EPSRC) has been increasing its support for nuclear research and in particular for PhD students. By 2010 two PhD programmes led by the University of Manchester were training over 20 students every year. The Nuclear Industrial Doctoral Centre (led by the University in Manchester in partnership with Imperial College London) has taken a different approach whereby 'research engineers' carry out their research primarily in industry with a project of direct relevance to the sponsoring company.

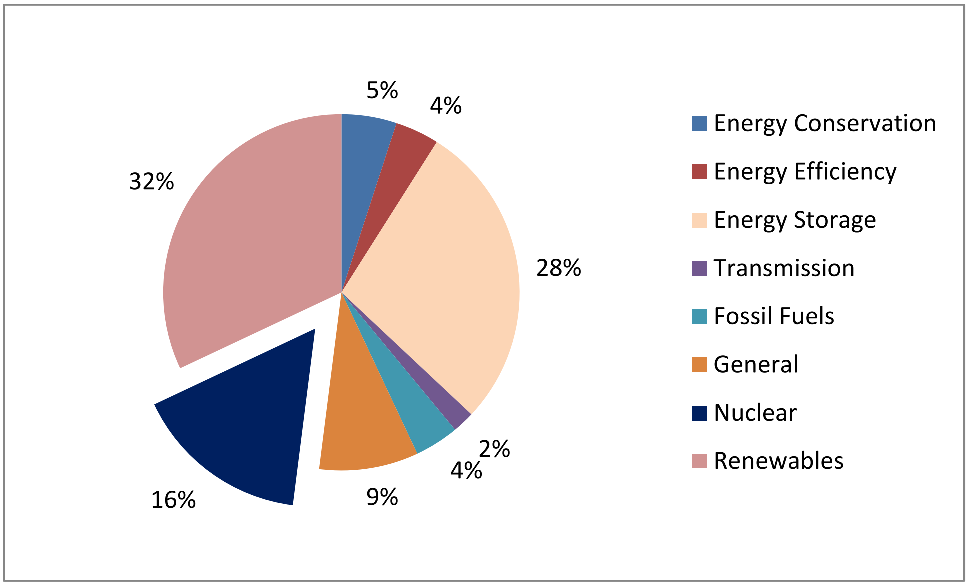
4.3.7 There are now 36 nuclear related degree courses at Bachelor or Master degree level at 17 Universities around the UK.

4.3.8 The success of such courses will also depend on improving interest in schools in science and engineering disciplines and a number of initiatives have been taken to ensure that young people at school and their teachers understand the opportunities and what is involved.

University Research

4.3.9 Funding for University research on nuclear related matters is provided by the Engineering and Physical Sciences Research Council (EPSRC). The chart below shows the changes in funding for power generation related projects, between 2002/03 and 2006/07:

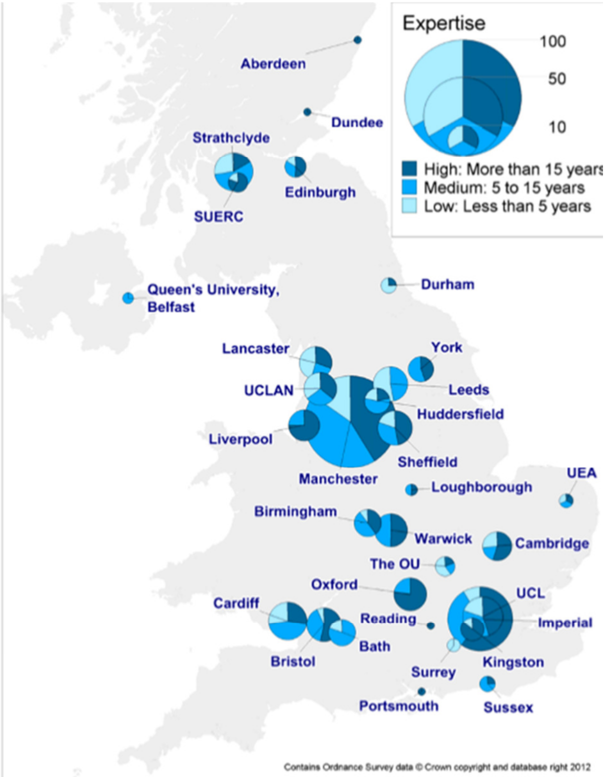
EPSRC funding 2002/3 – 2006/7



4.3.10 Over this period, the key changes have been:

- A large reduction in the funding of projects related to power generation via fossil fuel- fired technologies (to zero in 2006/07).
- Doubling of the funding of projects related to renewable energy sources.
- Near doubling of funding of projects related to nuclear energy.

4.3.11 The map below summarises the University research centres working on nuclear related matters.



Collaborative Research Programmes

4.3.12 The following collaborative research programmes are currently operating in nuclear research:

DIAMOND

The DIAMOND (Decommissioning, Immobilisation and Management of Nuclear waste for Disposal) University research consortium was formed in response to a call for proposals issued in August 2007 by the Engineering and Physical Sciences Research Council on the topic of Nuclear Waste Management and Decommissioning. Led by the University of Leeds, the consortium members include Imperial College London, Loughborough University, University of Manchester, University of Sheffield and University College London.

Doctoral Training Centre for Nuclear Fission Research, Science and Technology (Nuclear FiRST)

Nuclear FiRST aims to underpin UK Energy and Defence strategy by addressing a growing doctoral skills gap in nuclear fission science and engineering. It offers an interdisciplinary approach to postgraduate research training, combining a Masters level foundation year with a three year

Doctoral level thesis project. This is supplemented by training in professional skills and project placements in industry or research institutes in the UK and overseas.

KNOO

KNOO (Keeping the Nuclear Option Open) is a four-year initiative set-up to address the challenges related to increasing the safety, reliability and sustainability of nuclear power. Through collaboration between the key industrial and governmental stakeholders and international partners, KNOO has been established to maintain and develop skills relevant to nuclear power generation. Funded through the "Towards a Sustainable Energy Economy Programme" of Research Councils UK, it represents the single largest commitment to fission reactor research in the United Kingdom for more than thirty years.

Nuclear Engineering Doctorate Programme

The primary objective of the Nuclear EngD is to provide outstanding young nuclear Research Engineers with intensive, broadly based training in collaboration with industrial companies so that they are equipped to take up senior roles within the nuclear industry. In addition to obtaining a high quality qualification the Research Engineers will gain experience of working in an industrial research and development environment. This four year programme involves the Research Engineer being based within an industrial company in the UK.

SPRing

Sustainability Assessment of Nuclear Power: An Integrated Approach (SPRIng) is a consortium project funded by EPSRC and ESRC.

The overall aim of the project is to develop an integrated decision-support framework for assessing the sustainability of nuclear power relative to other energy options (fossil fuels and renewables), considering both energy supply and demand.

The main deliverables of the project are:

- A multi-criteria decision-support framework for sustainability assessment of energy options;
- Sustainability assessments of the nuclear option within an integrated energy system; and
- Engagement with and communication of the results of research to relevant stakeholders.

4.3.13 A full list of the currently active university nuclear research centres and their areas of expertise is attached in Appendix A.

(4) Administrative Agencies/ Regulatory Agencies

4.4.1 One of the outcomes of the fire at Windscale in 1957 was the establishment of an independent Nuclear Installations Inspectorate. This was formed as part of the Health and Safety Executive and continued as the principal regulator for the nuclear industry since then.

4.4.2 In 2008, the Government commissioned a major review into the UK's nuclear regulatory regime, conducted by Dr Tim Stone, senior adviser on nuclear new build to the Secretary of State for Energy and Climate Change and to the Chief Secretary of the Treasury.

4.4.3 Dr Stone made a number of recommendations including the creation of a new, sector-specific regulator for the nuclear industry – the Office for Nuclear Regulation (ONR).

4.4.4 The Office for Nuclear Regulation (ONR) was formed on 1 April 2011 as an Agency of the Health and Safety Executive (HSE) pending relevant legislation to create ONR as a statutory corporation. The Energy Bill which is currently being considered by Parliament includes the provisions needed to establish the ONR as an independent statutory corporation.

4.4.5 ONR brings together the safety and security functions of HSE's former Nuclear Directorate, including Civil Nuclear Security and the UK Safeguards Office, which transferred in 2007 from Department for Trade and Industry, and the Radioactive Materials Transport team, previously within Department for Transport.

4.4.6 The ONR does not set out prescriptive codes and standards that must be followed for a new plant. Rather it is a permission based system: licensees set out their standards and safety cases and the regulator assesses the safety case and monitors compliance through inspections to ensure that licence conditions are being met.

Legal framework and regulations

Health and Safety at Work Act 1974 – Employers are responsible for ensuring the safety of their workers and the public.

Nuclear Installations Act 1965 (NIA) – A site cannot have a nuclear plant unless the user has been granted a site licence by ONR. Only a corporate body can hold such a licence.

Ionising Radiations Regulations 1999 – Provides for protection of workers in all industries from ionising radiations and by the general health and safety regulation which ONR also enforces at nuclear sites.

Nuclear Industries Security Regulations 2003 – ONR Civil Nuclear Security (CNS) conducts its regulatory activities, approving security arrangements within the industry and enforcing compliance under the authority of these regulations.

4.4.7 The other principal regulatory authority for the nuclear industry is the Environment Agency. The Agency is an Executive Non-departmental Public Body responsible to the Secretary of State for Environment, Food and Rural Affairs and a Welsh Government Sponsored Body responsible to the

Minister for Environment and Sustainable Development.

4.4.8 The principal aims are to protect and improve the environment, and to promote sustainable development. The Environment Agency plays a central role in delivering the environmental priorities of central government and the Welsh Government through its functions and roles.

4.4.9 The ONR and Environmental Agency have been jointly responsible for the Generic Design Assessment of reactor technologies and sites put forward by the new build developers.

5. Analysis

(1) Current Status of UK Nuclear Industry

Current Industrial Capability
5.1.1 The NIA's 2012 report *Capability Of The UK Nuclear New Build Supply Chain* provides a detailed examination of the capability of UK industry to supply a domestic new build programme.

Plant & Equipment Manufacturing
5.1.2 The NIA report concluded that there is a small number of items for a nuclear project which can be manufactured by only a few companies in the world and for which there is no current UK capability. These are the reactor pressure vessel, main turbo-generator, steam generator, reactor coolant pump, associated ultra-large forgings and large diesel engines. There are only a very few companies in the UK which could possibly develop this capability; the cost and timescales are very demanding and the business cases for investment are currently not attractive. For the UK new build programme, these key items will therefore be supplied from the few companies in the world that have this capability.

5.1.3 However, the UK does have the capability to supply most of the remainder of the manufactured components for a new nuclear plant including pumps and valves, pipework, vessels, tanks, heat exchangers, HVAC (Heating, Ventilation and Air Conditioning) systems, radwaste plant, control, instrumentation and electrical equipment and forgings. UK Industry could also supply some of the components for the reactor, steam generators and turbines

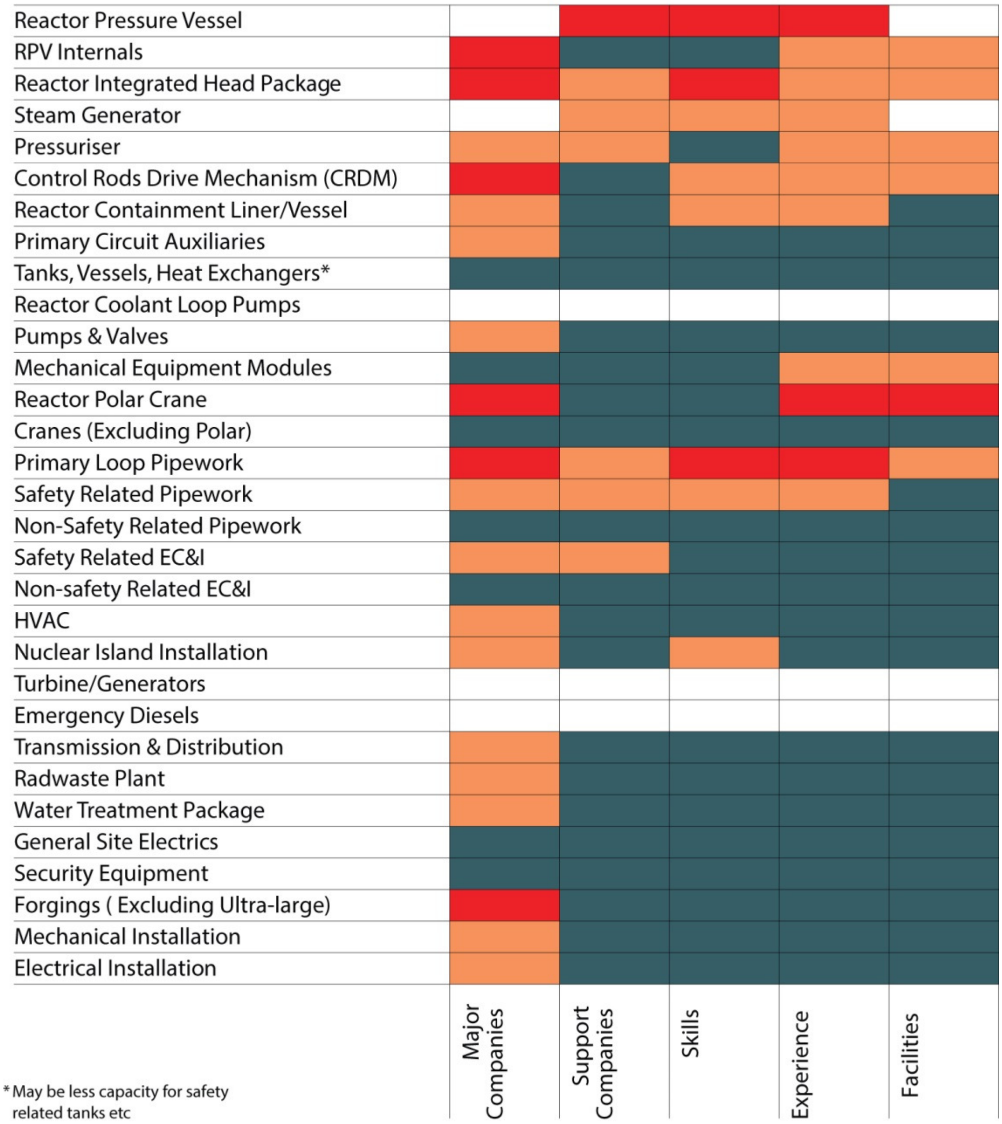
5.1.4 Many of the UK companies that are capable of manufacturing these items are already supplying similar equipment to the global new build market, as well as to the existing nuclear industry in the UK and to other regulated sectors such as the oil and gas, chemical and other process industries.

5.1.5 The UK has capability to provide much of the on-site installation of mechanical and electrical components, in some situations supplemented by specialist engineering skills from the equipment suppliers.

5.1.6 The report also examined UK capability to provide engineering and design support to owners and the civil engineering and construction for a new build project. Currently no single UK company would be seen to be capable of managing the delivery of a programme of nuclear power stations. However, capability has been demonstrated to deliver large, complex projects through special project delivery vehicles with integrated management teams bringing together several organisations with strong international experience.

5.1.7 There are several large UK civil engineering companies, operating internationally on major projects, with the capability to carry out much of the design work and most of the construction work for new nuclear power stations in the UK. The report anticipated that much of this work will be delivered through joint ventures involving both UK and international companies, as is common practice internationally in major infrastructure projects.

Industry Capabilities
Plant and Equipment Manufacture and Installation



* May be less capacity for safety related tanks etc

KEY			
Major Companies	≥ 5 Companies	3 ≤ 5 Companies	≤ 2 Companies
Support Companies	≥ 5 Companies	3 ≤ 5 Companies	≤ 2 Companies
Skills	Sufficient available skills capacity	Capacity available with some investment	Skills shortages, need special attention
Experience	Current experience of nuclear markets	Some experience of nuclear or related markets	Lack of experience, needs special attention
Facilities	Sufficient current capacity	Capacity available with some investment	Shortage of capacity without significant new investment

Actions to Improve Capability

5.1.8 The Government and industry have cooperated on a number of actions to improve the capability, capacity and competitiveness of UK industry to participate in delivering a new nuclear programme.

5.1.9 The Government published a *Nuclear Industry Supply Chain Action Plan* in December 2012 which contained 30 actions to be led jointly by the Government and industry.

5.1.10 The NIA has a Programme Management Board (PMB) which brings together the new build developers, technology vendors, Government and stakeholders to identify common issues affecting the new build programme. As part of its work the PMB is developing, with the support of industry, a UK readiness programme to identify the challenges in preparing the UK supply chain to deliver the programme and where necessary to improve capabilities. The PMB is also leading a Construction Best Practice Forum to ensure that the best practices of major construction and infrastructure projects are brought to bear in the nuclear new build programme.

5.1.11 The NIA has a programme of activity - *sc@nuclear*- to improve awareness in the supply chain of the opportunities arising from new build and to enable companies to improve their capability.

5.1.12 The Government has invested in, with industry support, a Nuclear Advanced Manufacturing Centre (NAMRC) in Rotherham to provide research and technological support for the introduction of advanced manufacturing processes and technologies into the nuclear industry. The NAMRC also has a programme to assist companies to improve their quality and other standards to enable them to compete in the nuclear industry.

(2) Challenges of Japanese Nuclear Industry from the point of view of UK Nuclear Industry

5.2.1 The UK's experience in nuclear power generation has many lessons both for the UK itself and for other countries. We do not suggest that we are able to interpret these lessons for the circumstances of Japanese industry and society; this is best done by Japanese organisations themselves.

5.2.2 Japan must find its own way of sustaining its industrial capability at a time when domestic demand for new nuclear may fall. We hope however that the following general observations from the UK's experience will help to inform that thinking.

- Design of new reactors and other technologies must take full account of the construction and operational feasibility of the design, preferably by proving it in operation, in order to give confidence that it will be attractive to operators/utilities and be subject to repeat orders.
- Faced with a decline of domestic demand, companies may wish to explore options for diversification but they should think carefully before pursuing business in other sectors which may have different commercial and technological drivers. Companies experience of diversification is mixed, with some good outcomes but also numerous difficulties.
- Internationalisation was an important part of the response of UK companies to falling domestic orders, but the failure to internationalise UK reactor designs meant that export opportunities in nuclear technology were limited. Japan is in a different position.
- The abandonment of the UK PWR programme was not a result of a political decision against nuclear power, but the consequence of market structures and market conditions that were not conducive to long term investments at that time.
- The UK did not lose all its industrial capability in nuclear power plants, but where capability was lost it was also part of the general pattern of de-industrialisation and market conditions at that time.
- It is important to maintain cross-party and stakeholder support for nuclear power through openness and transparency.
- The UK has good experience of building stakeholder confidence through genuine engagement and dialogue, rather than relying purely on technical arguments to address concerns. The use of third party advocates, particularly leading academics, has been very helpful.
- The UK has built up a successful decommissioning programme and an experienced supply chain to deliver it.
- In the UK domestic new build market which is now seeing a renaissance, UK companies are open to partnership opportunities with Japanese companies, which can have benefits for both sides.

Appendix A

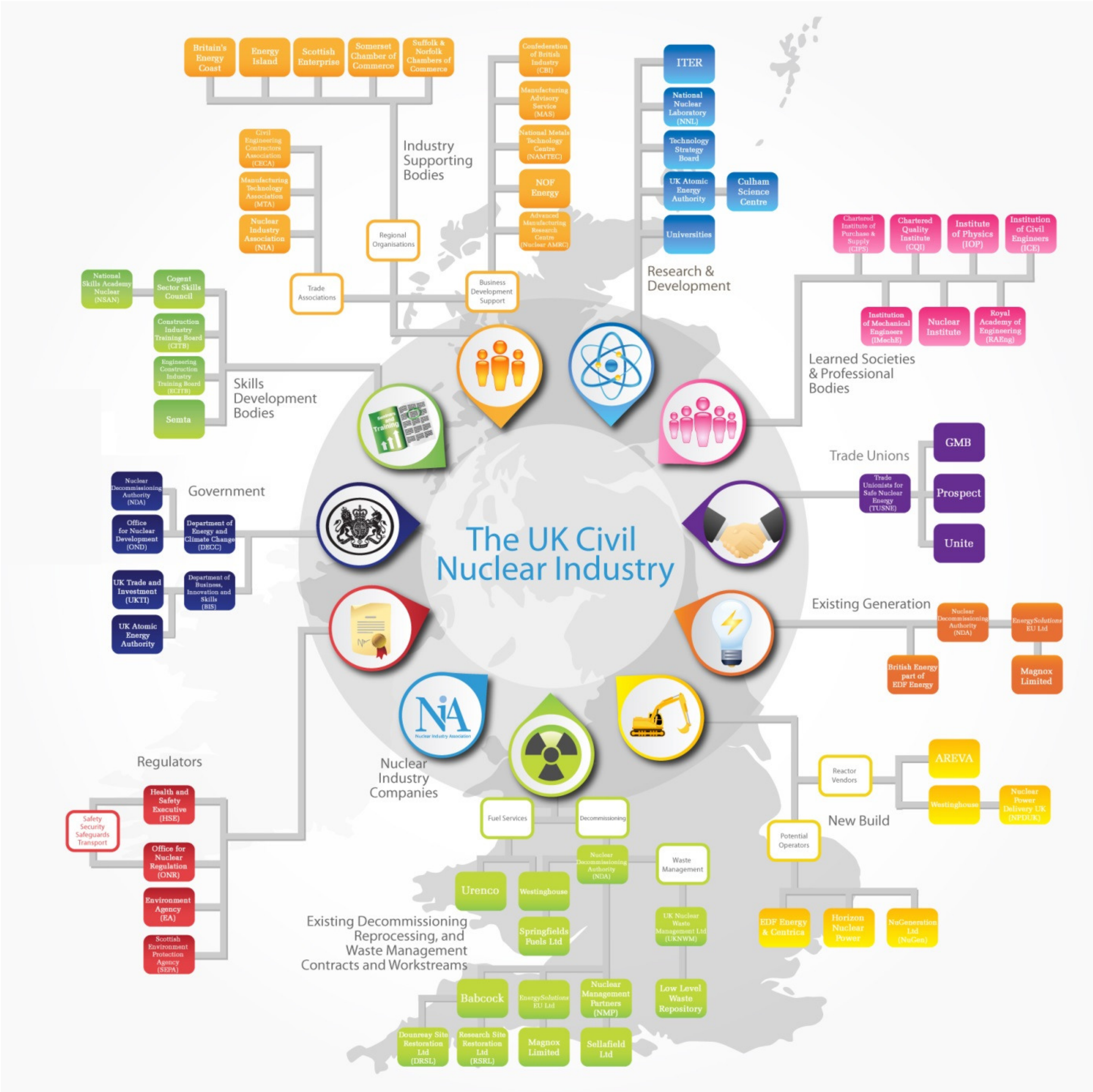
University Research Centres

University of Aberdeen **Construction and Remediation Research Group, Chemistry, School of Natural and Physical Sciences**	Current activities include fundamental studies of cement hydration and durability, and applications to waste management, including nuclear decommissioning.
University of Bath **Nuclear Energy Group**	Core competencies are in nuclear materials, especially graphite, and expertise in decommissioning, mechanical design and energy systems analysis.
University of Birmingham **The Birmingham Centre for Nuclear Education and Research**	Nuclear Engineering, Waste Management and Decommissioning.
University of Bristol **Systems Performance Centre** **Safety Systems Research Centre**	A research alliance between the University of Bristol and British Energy to provide underpinning skills and expertise to deliver systems-based solutions. Research into the challenges of safe and reliable design, operation and maintenance of computer-based systems.
University of Oxford **Materials for Fusion & Fission Power**	A collaborative programme aiming to gain a thorough understanding, at the microstructural level, of key structural integrity issues which underpin development and application of alloys for high-flux, high-temperature neutron environments.
The **Universities of Bristol and Oxford** have a joint nuclear research centre to provide research to support the safe operation of current and future generation nuclear systems. The centre builds on strategic alliances with EDF-Energy, Rolls-Royce and AWE	
University of Cambridge **Cambridge Nuclear Energy Centre**	An area of active current interest is the design of thorium-fueled accelerator-driven subcritical reactors (ADSRs) for power generation

Cardiff University **Geoenvironmental Research Centre, School of Engineering**	The group undertakes fundamental and applied research in the area of deep geological disposal of nuclear waste.
Hull University **Department of Engineering**	Nuclear research is centred within the Materials and Process Performance Group. At present, the main thrust is the effectiveness of UK gas-cooled nuclear reactor core designs, particularly materials performance.
Imperial College London **Centre for Nuclear Engineering**	Brings together a number of disciplines including mechanical, chemical and materials engineering, modelling and radio ecology.
Kingston University, London **Complex Flow Systems Research Group, Faculty of Engineering**	Conducts multi-disciplinary researches on a range of topics including aerodynamics, thermo-fluids, energy systems and granular flow.
Lancaster University **Control and Instrumentation Research Group, Department of Engineering**	A multidisciplinary team working on the combination of instrumentation and generic control in the context of a broad spectrum of autonomous platforms.
Loughborough University **Environmental Radiochemistry Research Group, Department of Chemistry**	Interdisciplinary research work is largely centred on the Geochemistry of nuclear waste disposal.
University of Manchester **Dalton Nuclear Institute**	Interdisciplinary research includes reactor technology, Decommissioning and Radioactive Waste Management Nuclear Medicine
The Open University **Materials Engineering**	Nuclear-related research including residual stresses in power plant welds, performance of high-temperature materials for nuclear plant.
University of Sheffield **Immobilisation Science Laboratory**	The study of glass, ceramic and cement wasteforms for the immobilisation of both radioactive and toxic wastes.

Appendix B

Organisational Map of the UK Civil Nuclear Industry



An interactive version of this map can be found on the NIA website http://www.niauk.org/nia-industry-maps