8. Nuclear Fuel

8.1 Introduction

8.1.1 This chapter focuses on the supply and demand of nuclear fuel in the UK and globally. Prospects for nuclear power generation in the UK are considered in paragraph 4.6.5.

8.1.2 The analysis in this chapter draws heavily on the most recent reports published by the Organisation for Economic Co-operation and Development's Nuclear Energy Agency and the International Atomic Energy Agency[93] (OECD/IAEA), and the Euratom Supply Agency[94] (ESA).

8.2 Demand for nuclear fuel in the UK

8.2.1 The UK currently has nineteen operating reactors at ten nuclear power stations. The UK's nuclear power stations provided 57.25 TWh of electricity, around 15 per cent of the UK's electricity supply, in 2007[95].

8.2.2 As explained in paragraph 4.4.8 a number of these stations are due to close over the next few years. However, since the last Energy Markets Outlook was published there have been significant developments in Government policy and these are summarised in paragraph 4.6.6 above.

8.3 Uranium supply in the UK

8.3.1 The majority of nuclear fuel is made from enriched uranium. Uranium in the form of uranium ore concentrate (commonly known as yellowcake, U3O8) is readily available on the world market where commercial demand for uranium is principally determined by the requirements of nuclear electricity generation. The UK is not a uranium producer, but uranium ore may be stockpiled. The stockpiling of fuel in the UK is the responsibility of the

93 Uranium 2007: Resources, Production and Demand. OECD Nuclear Energy Agency and the International Atomic Energy Agency. June 2008. http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=9789264047662

94 Euratom Supply Agency: Annual Report 2007. June 2008. http://ec.europa.eu/euratom/ar/last.pdf

95 Digest of United Kingdom Energy Statistics 2008. http://www.berr.gov.uk/whatwedo/energy/statistics/publications/dukes/page45537.html

utilities concerned and the actual fuel stock levels held by commercial companies are confidential. Fuel costs make up only a small proportion (around 10%) of overall plant running costs, with uranium ore accounting for approximately 1.5% of total generation costs[96].

8.3.2 There are fuel fabrication and enrichment facilities located in the UK with the capability to manufacture fuel for all major designs of nuclear reactors. The first step in producing fuel for the UK's Advanced Gas-cooled Reactors (AGRs) and Pressurised Water Reactors (PWR) is to convert uranium into uranium hexafluoride which, for AGR and PWR fuel (Magnox stations use natural (un-enriched) uranium) is then enriched to increase the proportion of Uranium 235[97] (U235) from approximately 0.7% to typically between 2.5 and 5.0%. The enriched material is then converted into either AGR or PWR ceramic (UO2) fuel pellets which are then packed into stainless steel tubes for AGRs to form fuel pins or zirconium alloy tubes for PWRs to form fuel rods. A number of these pins or rods are then assembled into a fuel element. A fuel assembly remains within an AGR for a period of typically four to eight years, and PWR fuel elements remain within the reactor for typically three to five years.

8.3.3 A report[98] published by the Nuclear Decommissioning Authority (NDA) in June 2007, examined the uranium and plutonium stocks held by the Authority. The report provided an economic analysis of potential future disposition options for the significant stock of nuclear materials held by the NDA and concluded that they could be immobilised and disposed of, stored over the long-term, sold and/or converted to fuel to be re-used in nuclear power stations. Table 8.1 presents the inventory of nuclear materials held by the NDA.

96 Meeting the Energy Challenge: A White Paper on Nuclear Power. Department for Business, Enterprise and Regulatory Reform. January 2008. http://www.berr.gov.uk/whatwedo/energy/sources/nuclear/whitepaper/page42765.html

97 The isotope found in uranium that is readily fissionable in a nuclear reactor is U-235, but only 0.7% of natural uranium is U-235, the remainder being U-238. By enriching uranium the U-235 content can be increased to typically around 2.5 – 5%. Enriched fuel is capable of reaching much higher temperatures in a nuclear reactor and is more efficient in generating electricity.

98 Uranium and Plutonium: *Macro-Economic Study*. Final Report. Nuclear Decommissioning Authority. June 2007. http://www.nda.gov.uk/documents/upload/Uranium-and-Plutonium-Macro-Economic-Study-June-2007.pdf

Table 8.1: Inventory of nuclear materials[99] held by the NDA

Source	Quantity (tonnes) of heavy metal
Tails Uranium Hexafluoride[100]	25,000
Magnox Depleted Uranium[101]	30,000
Thorp Product Uranium[102]	5,000
Plutonium Dioxide[103]	100
Total	60,000

8.3.4 The report stated that the inventory held by the NDA could be used to fuel up to three modern 1000MW PWR reactors over a period of 60 years. However, the decision on what option will be followed to manage the NDA's inventory in the future has yet to be made by the UK Government.

8.4 Import requirement

8.4.1 The UK nuclear industry currently sources the majority of its uranium from Australia[104]. The supply of uranium is carried out in accordance with the procedures stipulated by the Euratom Supply Agency[105] (ESA). The ESA's Annual Report 2007[106] presents information on the countries of origin for the supply of uranium to the EU. Chart 8.1 draws on the supplier country information given in the ESA Report.

99 These materials (Uranium and Plutonium, in a variety of physical and chemical forms) have arisen principally from uranium enrichment, nuclear fuel manufacture and used nuclear fuel reprocessing.

100 This is residue from enrichment of natural uranium for fuel manufacture. This material has a lower U-235 content (typically in the range 0.2-0.4%) than natural uranium.

101 Material obtained from Sellafield reprocessing of used fuel from Magnox reactors. The recovered uranium from reprocessing contains around 0.4% U-235.

102 Material obtained from Sellafield reprocessing of used fuel from AGR reactors in Thermal Oxide Reprocessing Plant (Thorp). This material typically contains a higher percentage of U-235 (around 0.9%) than natural uranium.

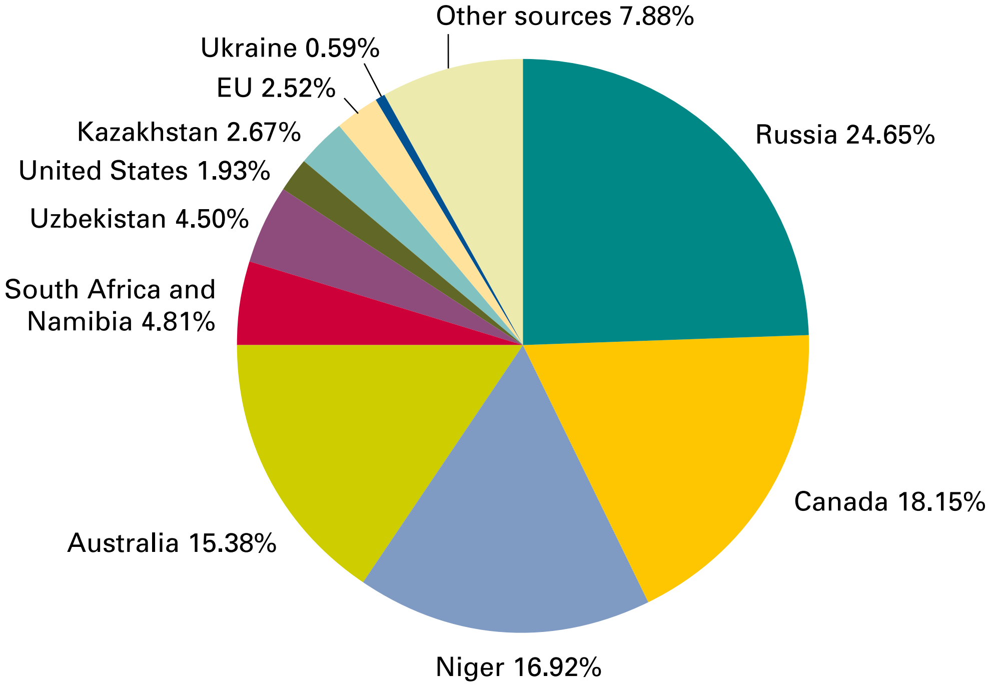
103 This is plutonium recovered from Sellafield reprocessing (Magnox and Thorp) of used fuel.

104 Uranium Asset Management Ltd.

105 http://ec.europa.eu/euratom/index_en.html

106 Euratom Supply Agency: Annual Report 2007. June 2008. http://ec.europa.eu/euratom/ar/last.pdf

Chart 8.1: Major suppliers of uranium to the EU



Source: ESA

8.4.2 The only European states that supplied uranium to the EU were the Czech Republic and Romania, but they supplied only a very minor part of the total EU needs.

8.4.3 The ESA Annual Report also notes that *for the second time since 2006, uranium deliveries to EU utilities were higher than the amount of uranium loaded into reactors. Thus inventories are being rebuilt in response to security of supply concerns and rising prices.*

8.5 Global uranium demand

8.5.1 Over the next 20 to 30 years (assuming an operating lifetime for older type nuclear reactors to be between 40 to 50 years) around 285GW (electricity), which equates to almost 77% of current global nuclear capacity, is expected to retire. There is great interest throughout the world in new nuclear capacity, as a means of securing electricity supplies and tackling carbon emissions. There are currently 34 reactors under construction. Table 8.2 gives the countries and number of reactors being constructed[107] as of June 2008.

107 Power Reactor Information System. International Atomic Energy Agency. http://www.iaea.org/programmes/a2/

Table 8.2: Reactors under construction globally

Country	Number of reactors	Total capacity MW (electricity)
China	6	5220
India	6	2910
Russian Federation	6	3639
Rep. of Korea	3	2880
Bulgaria	2	1906
Taiwan	2	2600
Ukraine	2	1900
Argentina	1	692
Finland	1	1600
France	1	1600
Islamic Rep. of Iran	1	915
Japan	1	866
Pakistan	1	300
United States	1	1165
Total	34	28193

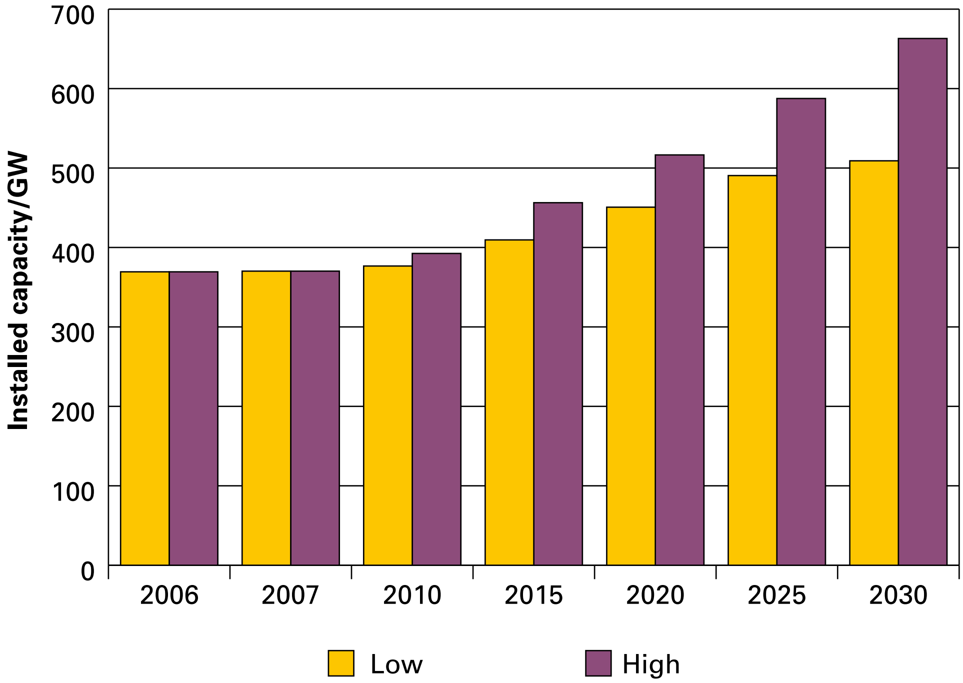
Source: IAEA

8.5.2 The OECD/IAEA has produced projections[108] covering low and high case scenarios for global installed nuclear capacity and future global uranium requirements. The OECD/IAEA forecast significant growth in nuclear capacity and in turn higher demand for nuclear fuel.

8.5.3 The OECD/IAEA have stated that *installed nuclear capacity is projected to grow from about 370 GWe net at the beginning of 2007 to about 509 GWe net (low case) or 663 GWe net (high case) by the year 2030. The low case represents growth of 38% from current capacity, while the high case represents a net increase of about 80%.* Chart 8.2 provides graphical representation of the OECD/IAEA projected low and high case scenarios for installed capacity.

108 Uranium 2007: Resources, Production and Demand. OECD Nuclear Energy Agency and the International Atomic Energy Agency. June 2008. http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=9789264047662

Chart 8.2: Projected world installed nuclear generating capacity to 2030



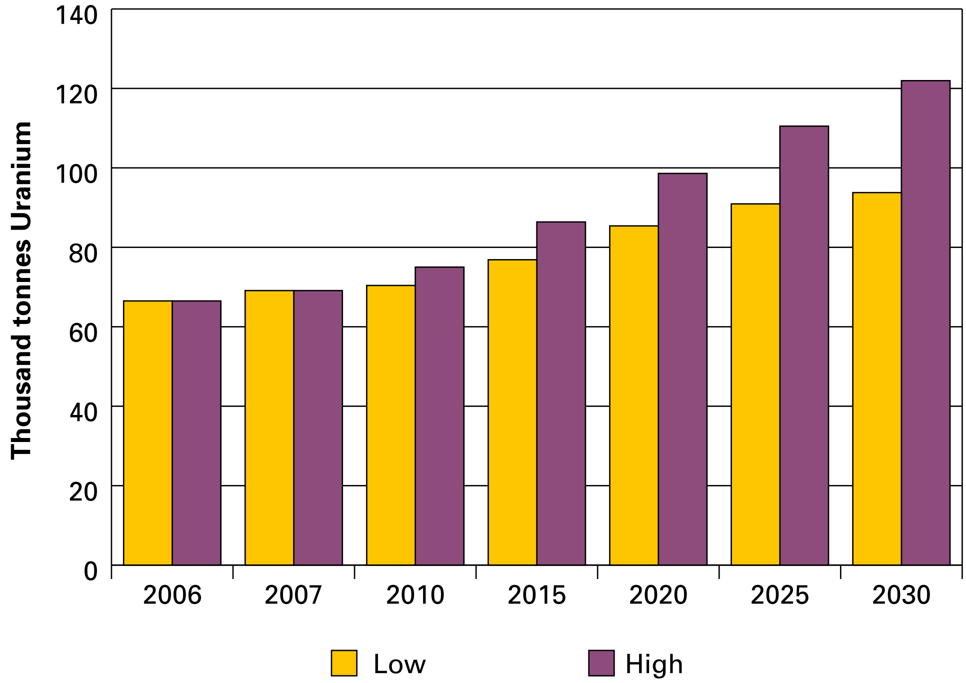
Source: OECD/IAEA[109]

8.5.4 The OECD/IAEA have stated that *world reactor-related uranium requirements by the year 2030 (assuming a tails assay*[110] *of 0.3%) are projected to increase to between 93 775 tU/year in the low case and 121 955 tU/year in the high case, representing about 41% and 83% increases respectively, compared to 2006.* Chart 8.3 provides a graphical representation of the OECD/IAEA projected demand for uranium out to 2030.

109 Forty Years of Uranium Resources, Production and Demand in Perspective, Sept 2006. Uranium 2007 Resources, Production and Demand, June 2008.

110 Tails assay – This is the quantity of fissile uranium (U-235) that is contained in the waste material following the uranium enrichment process.

Chart 8.3: Projected world uranium requirements to 2030



Source: OECD/IAEA[111]

8.5.5 The OECD/IAEA[112] have stated that there could be an even greater increase in the growth of nuclear energy due to increasing concerns about longer-term security of supply of fossil fuels and the extent to which nuclear energy is seen to be beneficial in meeting greenhouse gas reduction targets.

8.6 Uranium supply: resources

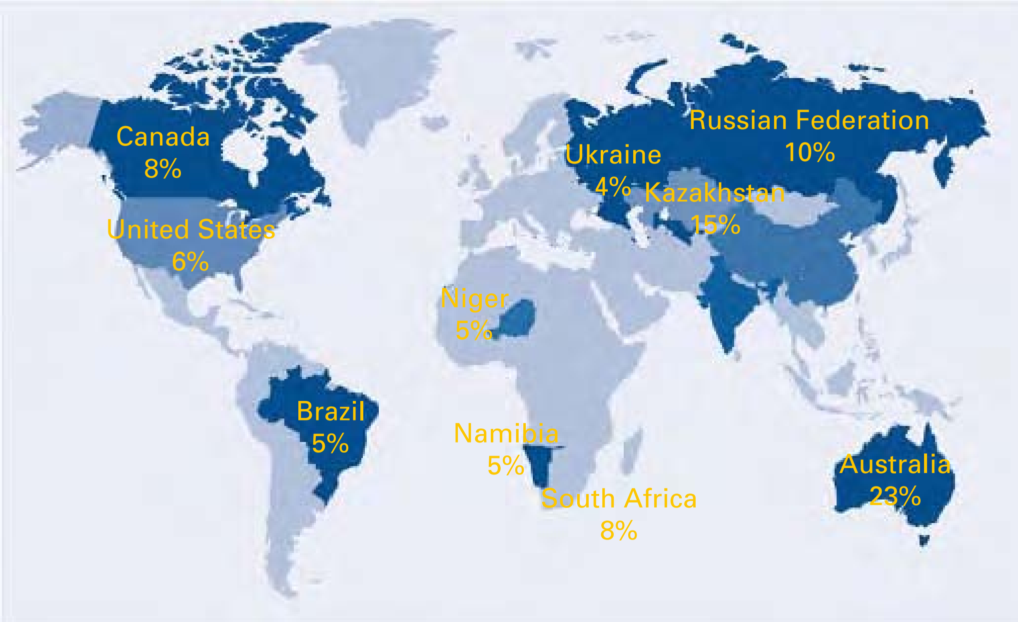
8.6.1 Nuclear energy benefits from having a diverse supply of fuel in insuring against potential interruptions. In this sense uranium is less vulnerable than other fuels. Deposits of uranium are widely dispersed across a number of countries. The potential sources include countries that we do not currently rely on for fossil fuels. There are also considerable resources available in OECD countries.

8.6.2 The identified global uranium resource base is spread throughout 43 countries and is listed in the OECD/IAEA *Red Book*. The ten countries with the largest resources are given in chart 8.4.

111 Forty Years of Uranium Resources, Production and Demand in Perspective, Sept 2006. Uranium 2007 Resources, Production and Demand, June 2008.

112 Uranium 2007: Resources, Production and Demand (*Red Book*). OECD Nuclear Energy Agency and the International Atomic Energy Agency. June 2008. http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=9789264047662

Chart 8.4: The ten countries with the highest identified uranium resources



Source: OECD/IAEA

8.6.3 The OECD/IAEA and the ESA have both stated that sufficient global uranium resources exist to accommodate future nuclear power expansion. The latest figures available from the OECD/IAEA state that at 2006 estimated rates of uranium consumption in nuclear power reactors, identified uranium resources would be sufficient for about 100 years of reactor supply. They also state that *given the limited maturity and geographical coverage of uranium exploration worldwide, there is considerable potential for discovery of new resources of economic interest.*

8.7 Uranium supply: exploration and production

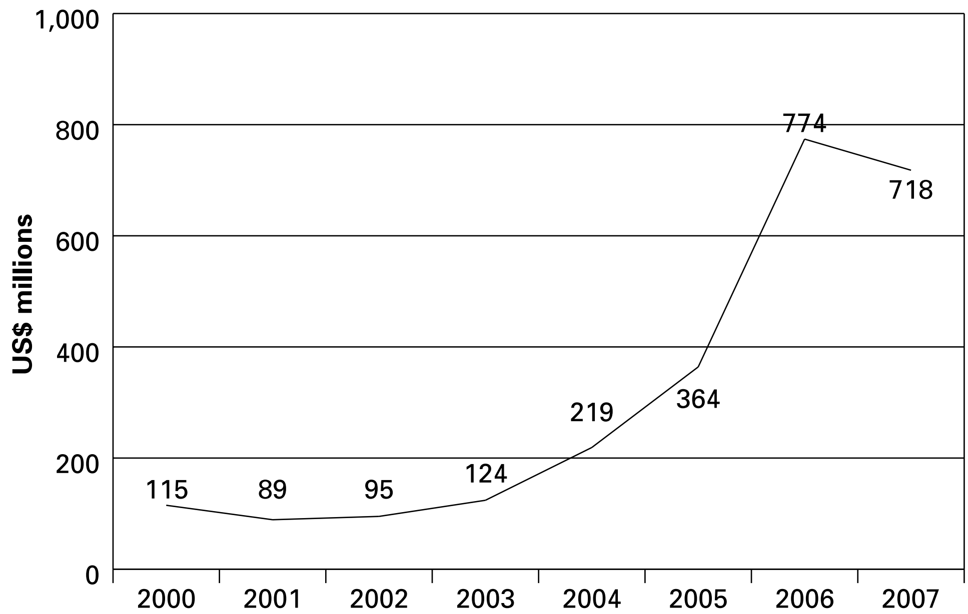
8.7.1 The development of mines and the increase of uranium production are necessary to ensure that the uranium resources continue to be available to the market. The *Red Book* acknowledges that *a continued strong market and sustained high prices will be necessary for resources to be developed within the timeframe required to meet future uranium demand*.

8.7.2 The recent renewed interest in nuclear power generation and the rises in uranium prices have delivered substantially increased expenditure on exploration for new uranium resources, including in several EU Member States. The

OECD/IAEA[113] has reported that exploration activities are being conducted in *countries which explored and developed uranium deposits in the past and also in many countries where exploration for uranium had not been conducted for many decades*.

8.7.3 Chart 8.5 below shows how exploration expenditure has increased over the years.

Chart 8.5 Uranium exploration expenditure



Source. OECD/IAEA.
Note: for 2007 this is an estimated figure.

8.7.4 Exploration expenditure has increased more than seven fold since the early part of this decade.

113 Uranium 2007: Resources, Production and Demand. OECD Nuclear Energy Agency and the International Atomic Energy Agency. June 2008. http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=9789264047662

8.8 Conclusion

8.8.1 The UK Government has concluded that nuclear should have a role to play in the generation of electricity, alongside other low carbon technologies. The Government is taking the steps set out in the Nuclear White Paper[114] to facilitate the development of new nuclear power stations in the UK.

8.8.2 Following analysis and wide consultation the UK Government reached the conclusion, with respect to uranium fuel, in the 2008 White Paper that …*there should be sufficient reserves to fuel any new nuclear power stations constructed in the UK.*

8.8.3 There is a growing interest globally in constructing new nuclear generating capacity in response to security of supply and climate change concerns. The OECD/IAEA predicts an increase in nuclear power to take place over the coming years. The OECD/IAEA and the ESA nevertheless estimate that there are sufficient uranium resources to meet future demand.

114 Meeting the Energy Challenge: A White Paper on Nuclear Power. Department for Business, Enterprise and Regulatory Reform. January 2008. http://www.berr.gov.uk/whatwedo/energy/sources/nuclear/whitepaper/page42765.html