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What is nuclear power?
Media briefing

November 2001

Nuclear reactors and reprocessing plants were first designed and created to produce plutonium - for nuclear weapons. Electricity was simply a by-product. The first nuclear power station in Britain was built at Calder Hall in Cumbria, in 1953. And when this was connected to the national grid in 1956, it became the first nuclear power station in the world to provide electricity.

Today there are 15 nuclear power stations operating in the UK, generating a quarter of the nation's electricity. Many still use aged Magnox reactors identical to, and including, the one built at Calder Hall. They were only designed for a maximum of 20 to 25 years' use, and yet the oldest stations are now more than 40 years old.

The UK government is beginning to talk about nuclear power as the energy source of the future. The argument is that nuclear power stations produce less carbon dioxide (the main contributor to global warming) sulphur dioxide and oxides of nitrogen (responsible for acid rain) than fossil-fuelled stations.

Weigh this up against the severe long-term dangers to human health, the environment, and global security - caused by the production, transport, storage and reprocessing of highly radioactive nuclear materials - and the stupidity of the argument becomes clear.

The nuclear reaction

Nuclear power involves the liberation of energy from an atom, by the process of fission - the splitting of its nucleus into two or more parts.

Fission is initiated by bombarding nuclei with neutrons, causing them to fly apart into two large fragments and to simultaneously release several free neutrons of their own. These neutrons then cause other nearby atoms to fission, producing even more neutrons, setting off a chain reaction. The two large fragments of the split nucleus become new chemical elements - mostly highly radioactive - including isotopes[i] such as iodine-131, caesium-137 and strontium-90.

Only a few isotopes of heavy elements lend themselves easily to nuclear fission, notably uranium-235 and plutonium-239.

Nuclear reactors

In nuclear weapons, energy release is uncontrolled. Commercial nuclear power stations control the release of heat energy, raising steam to produce electricity.

A thermal nuclear reactor is a device for sustaining a fission chain reaction. Fission takes place within the reactor core, which is contained within a pressure vessel and biological shield. Within the core is a moderator, usually made of graphite or water. The moderator acts to slow down the neutrons so that an efficient chain reaction occurs.

Fuel rods containing fissile material are placed within this core, and control rods are interspersed between them. These control rods are made of a material that absorbs neutrons, thereby controlling or stopping the reaction. The control rods are withdrawn to start the reaction and reinserted to shut it down. A coolant, such as water or gas, passes through the reactor and conveys heat away from the reactor core. Heat is then converted into electricity via a system of heat exchangers and turbines, in the same way as in a fossil-fuelled station.

There are three different reactor designs used in the UK:

- **Magnox reactors**

  Seven of the nuclear power stations in the UK contain Magnox reactors. These were designed to produce plutonium for nuclear weapons, not for the safest and most economic production of energy for civilian purposes. They were also designed to run for only 20 to 25 years. But all the UK's Magnox reactors are now over 30 years old. The oldest station – at Calder Hall, Sellafield – has been operating for 45 years.

  Magnox reactors use natural uranium metal as fuel, have a graphic moderator and use pressurised CO2 as coolant.

- **Advanced gas-cooled reactors (AGR)**

  These are the successors to the Magnox reactors, also developed in the UK. Seven were built between 1976 and 1988.

  AGRs use enriched uranium clad in stainless steel cans, a graphite moderator and pressurised CO2 as coolant. This allows them to operate at a higher temperature than Magnox reactors.

  Neither Magnox nor AGR reactors have the same level of safety features as more recent stations. They would not be approved by safety regulators today.

- **Pressurised water reactors (PWR)**

  These were developed in the US, and are the most common reactors throughout the world. The only PWR in the UK is at Sizewell in Suffolk – a 1188MW reactor that first supplied electricity to the grid in February 1995.

  The PWR reactor is contained in a steel pressure vessel. Pressurised water, acting as both moderator and coolant, is pumped around the reactor and through the boilers. The pressure vessel, the boilers and connecting pipe-work form a sealed primary pressurised circuit, which is contained within a steel-lined pre-stressed concrete containment building, which also acts as a biological shield. Safety depends on the integrity of the pressure vessel, which can become brittle over time. An accident involving loss of coolant water can have catastrophic consequences.

The nuclear fuel cycle

- Uranium ore is first mined, crushed and ground. It is then leached to dissolve the uranium, which is separated out and precipitated as a concentrate containing 90 per cent, or more, oxides of uranium. This ‘yellowcake’ is then refined to pure uranium oxide, which can be used in Magnox reactors. For use in AGR and PWR reactors, however, the uranium must be enriched in order to increase the proportion of uranium-235 it contains.
- The uranium is then converted into ceramic fuel pellets. These are packed into stainless steel tubes for AGRs, to form fuel pins, or zirconium alloy tubes for PWRs, to form fuel rods. The pins or rods are assembled into fuel elements, then stacked to form a fuel assembly, which is loaded into a reactor. AGRs typically contain 300 to 330 fuel assemblies in one reactor. A fuel assembly will remain in an AGR reactor for between four to eight years, or in a PWR reactor for three to five years.
- Spent fuel from a nuclear reactor is highly radioactive. It contains approximately 96 per cent uranium and one per cent plutonium, the rest consisting of highly radioactive isotopes. Once removed from the reactor, it is stored – to cool and to allow some of the short-lived radioactive isotopes to decay. The choice is then between long-term storage or, after a minimum of three years for AGR fuel and five years for PWR fuel, reprocessing.
- Reprocessing involves the separation of uranium, plutonium and other high-level waste (HLW), by dissolving the fuel in nitric acid. The resulting materials are then stored and the reprocessed uranium can be recycled into new AGR and PWR elements. Commercial reprocessing facilities exist at La Hague, in France, and at BNFL’s Sellafield site. The process began as a way of producing plutonium for nuclear weapons and for ‘fast-breeder’ reactors. These fast-breeder reactors were never successfully developed and reprocessing has been responsible for some of the world’s worst radioactive pollution problems.
- Plutonium can then be combined with fresh uranium, to form mixed oxide reactor fuel (MOX) – an expensive and dangerous process.

The UK nuclear power industry[ii]

There are 11 Magnox stations in the UK, seven of which are still operating. All remain in the public sector and are run by British Nuclear Fuels Ltd (BNFL) - a government owned company, whose main activity is reprocessing spent nuclear fuel from UK and abroad, at Sellafield in Cumbria.

There are a further eight nuclear power stations in the UK - seven AGRs and one PWR. These are run by British Energy (BE), which was privatised in 1996. An unattractive, uneconomic option, they were sold for £1.5 billion – less than the cost of building the PWR at Sizewell that was completed just 12 months earlier.

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[i] The nucleus of every atom contains protons (positively charged) and neutrons (with no electrical charge) surrounded by a cloud of negatively charged electrons. All atoms of the same chemical element have the same number of protons. This is the atomic number of the element. Atoms of the same element can however have different numbers of neutrons, and these are called isotopes of the element. The number of an isotope (also called the mass number) refers to the total number of protons and neutrons in the nucleus. Uranium, for example, has two common isotopes: uranium-235 (92 protons and 143 neutrons) and uranium-238 (92 protons and 146 neutrons).

ii

Station	**commissioning date**	**no. of reactors**	**capacity (MW)**	**operator**
Magnox				
Calder Hall (Cumbria)	1956	4	192	BNFL
Chapelcross (Dumfries & Galloway)	1959	4	196	BNFL
Berkeley* (Gloucestershire)	1962	2	276	BNFL
Bradwell** (Essex)	1961	2	240	BNFL
Hunterston A* (Ayrshire)	1964	2	320	BNFL
Trawsfynydd* (N. Wales)	1965	2	390	BNFL
Sizewell A (Suffolk)	1965	2	430	BNFL
Dungeness A (Kent)	1965	2	445	BNFL
Hinkley Point A* (Somerset)	1964	2	475	BNFL
Oldbury on Severn (Gloucestershire)	1967	2	430	BNFL
Wylfa (Anglesey)	1971	2	1050	BNFL

*Undergoing decommissioning

**To close in 2002

AGRs				
Hinkley Point B (Somerset)	1976	2	1300	BE
Hunterston B	1976	2	1150	BE

(Ayrshire)				
Dungeness B	1985	2	1104	BE
(Kent)				
Hartlepool	1983	2	1237	BE
(Cleveland)				
Heysham I	1984	2	1148	BE
(Lancashire)				
Heysham II	1988	2	1320	BE
(Lancashire)				
Torness	1988	2	1250	BE
(East Lothian)				
PWRs				
Sizewell B	1995	1	1220	BE
(Suffolk)				