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Electricity Association

Environmental Briefing

Nuclear Power

Energy for a More Sustainable Future?

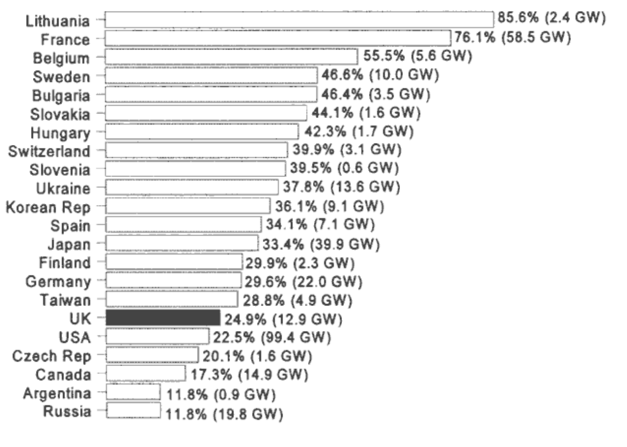
The Source of Nuclear Energy

Nuclear and fossil-fuelled power stations both use heat to produce steam which drives a turbine coupled to a generator. The main technical difference between nuclear and fossil-fuelled plant is the source of the heat. In fossil-fired stations, heat is produced when coal, oil or gas is burnt. In nuclear reactors the heat comes from energy released when nuclei of uranium or plutonium atoms are split (undergo "fission"). The energy recoverable from each tonne of nuclear fuel depends on the type of reactor and fuel cycle, but is at least 10,000 times that released when a tonne of coal is burnt in a power station.

Nuclear Electricity Production in Britain

Nuclear power stations have been operating continuously in Britain for 40 years and now generate about 25% of all electricity in the United Kingdom and around 50% in Scotland. This compares with 17% of total electricity supply worldwide and over 75% in France and Lithuania (see Figure 1).

Figure 1: Nuclear Share of Electricity Generation

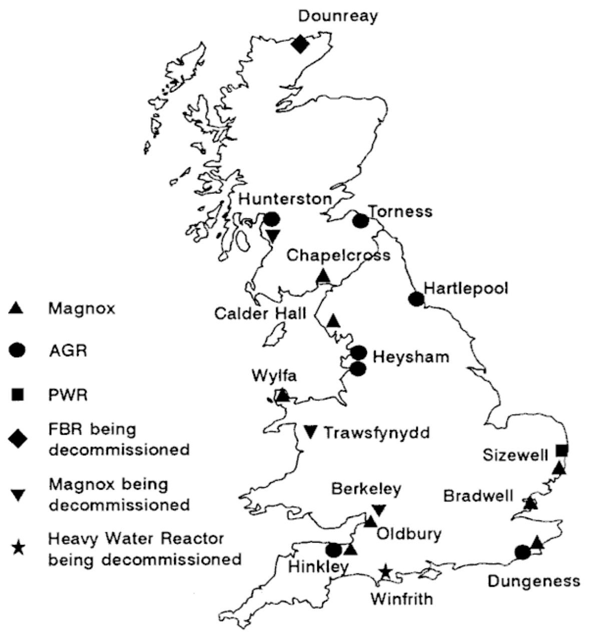


Nuclear capacity shown in brackets; 1995 data *Source: IAEA, 1996*

Several types of nuclear reactor have been built in Britain (see Figure 2). Commercial reactors commissioned between 1956 and 1973 were of the gas-cooled Magnox design. Between 1976 and 1988, seven advanced gas-cooled reactors (AGRs) were built. The latest power station constructed, at Sizewell in Suffolk, is a Pressurised Water Reactor (PWR), which is the type of reactor most commonly used throughout the world. This 1188 MW reactor first supplied electricity to the grid in February 1995. A heavy water reactor at Winfrith and a fast breeder (FBR) at Dounreay (both closed) were experimental reactors operated by the Atomic Energy Authority.

Before April 1996 nuclear power in the UK was in the public sector. Since then a private sector holding company, British Energy plc has controlled the AGR and PWR stations through two operating subsidiaries: Nuclear Electric Ltd in England and Wales and Scottish Nuclear Ltd in Scotland. The Magnox stations (26% of the UK's nuclear capacity) remain in the public sector, most of them being operated by Magnox Electric plc, although the two oldest stations, Calder Hall and Chapelcross, continue to be operated by British Nuclear Fuels Ltd.

Figure 2: UK Nuclear Power Stations



Environmental Considerations in the Design and Planning of a Nuclear Station

Like all large industrial sites and any power plant, nuclear power stations have an impact on the environment. This is assessed in detail at each stage of a station's development, from design and planning, through its construction and operation, to the end of its operating lifetime and decommissioning. Great care is taken to protect the environment and to limit its disturbance at each stage. Before a power station can be constructed in Britain, consent must be obtained from the President of the Board of Trade in England and Wales or the Secretary of State for Scotland. Section 38 of the Electricity Act 1989 requires that licensed electricity generators "shall have regard to" preserving the quality of the environment in formulating any new proposals. Section 36 of the Act sets out the statutory requirements for consent application and consultation with the relevant planning authorities (defined under the Town and Country Planning Act 1971 or the Local Government (Scotland) Act 1973) and with other interested bodies such as environmental agencies. The Environmental Assessment Regulations 1988 require that an environmental impact statement is submitted with the planning application for all major developments. If the consultations lead to objections, the Secretary of State may set up a public inquiry. The consultation process can take several years, particularly when it includes an extensive public inquiry. For example the inquiry alone into the PWR at Sizewell lasted over 2 years and was the longest ever held in Britain.

Safety Aspects of Nuclear Power

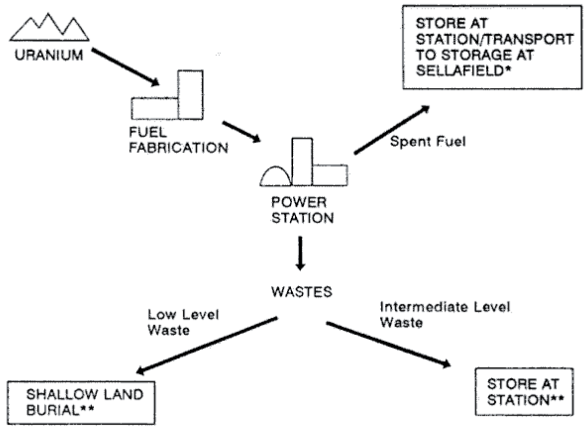
For a nuclear power station, there is also a statutory requirement, under the Nuclear Installations Act 1965, to obtain an operating licence from the Health and Safety Executive. A safety case must be produced which satisfies both the operators and the Nuclear Installations Inspectorate on the safety of the proposed station. Nuclear reactors are designed to stringent guidelines to operate within radiation safety standards which ensure that radiation exposures are as low as reasonably practicable, both for workers and the public. The safety case must show that the probability of a nuclear accident is acceptably low and that, in the event of an accident, the effect would be limited. Many safety features are included in their design, such as the multiple layers of physical barrier provided between the nuclear fuel and the environment.

The worst ever accident at a commercial nuclear reactor occurred in 1986 at Chernobyl in the USSR, with a catastrophic impact in the local region. It released radioactivity which dispersed across Europe. The concentration of radioactivity reaching the UK was generally low, but some hillsides received sufficient contamination to lead to the impounding of local sheep. This type of accident could not happen in the UK, since neither the Chernobyl type of reactor design nor the way it was operated would allow it to be licensed in the UK. At another serious accident in 1979 at Three Mile Island in the US, a major release of radioactivity to the atmosphere was prevented by the high standard of protective containment built into the plant.

Environmental Impact of Nuclear Power

Many of the operational environmental effects, such as noise, are qualitatively similar for all power stations. Like a fossil-fuelled power station, operation of a nuclear power station involves transport of fuel to the station, "burning" the fuel to produce electricity and disposal of the wastes arising. However, because of the high energy intensity of uranium and plutonium, the quantity of materials involved in these processes is far smaller for nuclear power. Figure 3 shows a simplified schematic diagram of the fuel cycle associated with a nuclear station. The relatively small quantity of radioactive waste produced is carefully handled in different ways according to its radioactivity (see Environmental Briefing no 8: *Radioactive Waste Management*). In its *Review of Radioactive Waste Management Policy*, 1995 (Cm 2919), the Government stated that future policy would emphasise the respective roles of Government, regulators and producers of the waste and would apply the concept of sustainable development.

Figure 3: Nuclear Fuel and Solid Waste Flow Diagram



* Final Disposal either - Reprocessing and Vitrification
or - Deep Store
** Deep Disposal Under Development

Irradiated fuel is highly radioactive and is kept carefully segregated. The radioactivity decays with time and initially the rate of decay is very rapid. Ultimately the spent fuel can be either placed in a long-term store, possibly for several decades, or transferred to a reprocessing plant at Sellafield, where reusable uranium and plutonium is separated out from high level waste.

A vitrification plant at Sellafield enables reprocessed high level waste to be solidified in glass blocks, sealed in stainless steel cans and placed in a carefully controlled storage facility. In its 1995 Policy Review the Government concluded that underground disposal was the favoured option for the long-term management of vitrified high level waste and reported that it was putting in hand development of a research strategy, with the aim of producing a statement of future intent in this area. It also concluded that a repository for the disposal of low and intermediate level radioactive waste should be constructed as soon as reasonably practicable. In the meantime disposal of low level waste by shallow burial at the Drigg site in Cumbria would continue.

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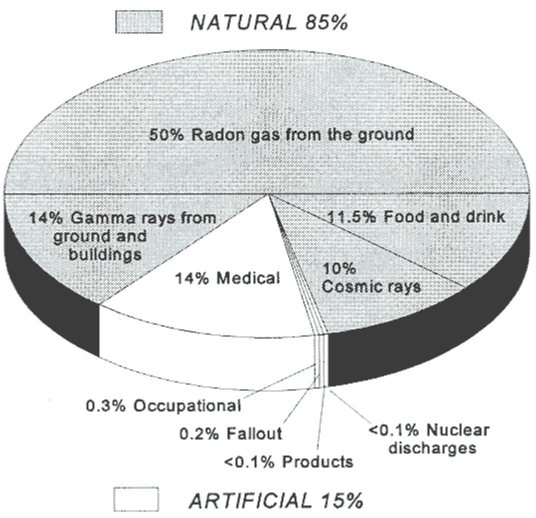
Very low levels of radioactivity are released from nuclear plant in gaseous emissions via stacks or in liquid effluent discharged to the sea. These releases are kept below authorised limits set by the Environment Agencies, using a variety of techniques, such as filtration and ion-exchange treatments. These limits ensure that the levels of radioactivity released to the environment are negligible compared with natural background levels. The discharges are monitored by both the nuclear industry and the Ministry of Agriculture, Fisheries and Food and the results of the monitoring are published regularly. As a result of these controls, population radiation exposure due to discharges from a nuclear power station is about the same as that due to the emissions from a coal-fired station, arising from the traces of natural radioactivity in the coal.

Everyone is exposed to background radiation from the sun and outer space and from the natural radioactivity in rocks, soil, buildings and diet. These sources account for 85% of the average person's annual radiation dose and most of the rest comes from medical sources such as X-rays (see Figure 4). The contribution from nuclear industry discharges amounts to less than 0.1% of the total. Over a year this amounts to less than the radiation dose received from eating one brazil nut. (These nuts naturally accumulate radioactive elements from the soil during growth.)

Figure 4: UK Average Annual Radiation Exposure per Person



Source: NRPB, 1993

Despite the rigorous control of radioactive discharges from power stations, it has been suggested that these increase the risk of childhood leukaemia, and links have been claimed at some nuclear sites. This suggested association has been the subject of intensive research over the past decade. The latest authoritative study in England and Wales by Oxford University researchers, published in the British Medical Journal in 1994, used a very sensitive, new technique for detecting raised incidence of disease near a suspected source of risk. Whilst an excess of childhood leukaemia and related diseases near Sellafield was clearly apparent, the authors concluded that there was no evidence of a general increase of these diseases around nuclear installations. A similar conclusion was reached in a recent study in Scotland. Other possible explanations have been put forward to explain the excess near Sellafield, notably the Kinlen hypothesis that leukaemia is a rare response to a common infection whose spread is facilitated by population mixing, as in new towns, for example. Research is continuing worldwide into the causative mechanisms for human leukaemia.

Environmental Benefits of Nuclear Power

In its environmental white paper, *This Common Inheritance*, 1990 (Cm 1200), and in its strategies on Climate Change (Cm 2427) and Sustainable Development (Cm 2426) in 1994, the Government recognised that nuclear power made a major contribution to curbing acid rain and combating global warming. Nuclear stations emit negligible quantities of the acid rain gases, sulphur dioxide (SO_2) and nitrogen oxides (NO_X), and the greenhouse gas carbon dioxide (CO_2), a major contributor to global warming. Small amounts of these gases are emitted as a result of uranium mining, fuel processing and transport, but this is negligible compared to the amount produced from fossil fuels. Table 1 compares the full fuel cycle emissions for the major fuels used in generating electricity.

Table 1: Emissions in Grammes per kWh Delivered to Final Customer

Fuel	CO_2	CH_4	SO_2	NO_X
Coal*	955	2.92	11.82	4.34
Oil*	818	0.17	14.16	3.98
Gas (CCGT)	445	0.27	0.00	0.49
Nuclear	4	0.01	0.05	0.02

Source: Energy Technology Support Unit
** No flue gas desulphurisation or NO_X reduction*

If all the electricity produced by nuclear stations in 1995 had been generated by coal stations, the UK's total CO_2 emissions would have been 13%, or almost 20 million tonnes of carbon (MtC), greater. Emissions of SO_2 and NO_X would also have been much higher. From 1990 to 1994, the output from nuclear stations increased by 36%, thereby making CO_2 emission savings against generation from coal equivalent to over 5 MtC per annum. This is over half the 10 MtC reduction in annual national CO_2 emissions between 1990 and 2000, to which the UK is committed under the UN Climate Change Convention. In France the large nuclear programme of the late 70s and 80s led to an 80% reduction in the annual CO_2 emissions from power stations within 7 years.

Decommissioning and Disposal

When a nuclear power station comes to the end of its useful life, decommissioning of the station commences with the aim of eventually returning the site to alternative uses with no nuclear legacy. Dismantling of the station takes place in stages, taking full account of public safety in containing the radioactivity at all times. The nuclear companies' "safestore" decommissioning strategy provides for reactor defuelling immediately after shutdown, taking 2-3 years and removing 99.9% of the residual radioactivity. Demolition of non-radioactive plant and buildings and dismantling of some radioactive plant is then undertaken. This is followed by the safe and secure maintenance of remaining structures for up to 135 years before final dismantling and site clearance. This ensures that radiation has fallen to a safe working level; it also reduces the amount of radioactive waste.

In its Radioactive Waste Management Policy Review, the Government acknowledged the suitability of the safestore strategy. It required operators to submit their decommissioning proposals every five years for review by the Health and Safety Executive, in consultation with the Environment Agencies. Whilst recognising that the nuclear companies were in the process of making full provision for decommissioning in their accounts, the Review nevertheless required the establishment of segregated decommissioning funds for the privatised parts of the industry.

The first commercial UK reactor to be closed for decommissioning was the Magnox station at Berkeley. Decommissioning work started in 1989 and is progressing to the care and maintenance stage. The Magnox stations at Trawsfynydd in Snowdonia and at Hunterston in Scotland are also being decommissioned; both have been defuelled and work is continuing in line with the safestore strategy. Minimising any adverse impacts on the environment is a key objective throughout this work.

Future Technical Developments

Only 0.7% of natural uranium consists of the fissile isotope U^{235}. Existing reactors use enriched uranium as fuel, in which the U^{235} fraction has been increased to 2-3½%. During operation of these reactors some of the non-fissile uranium is converted into plutonium. An advanced type of reactor, the Fast Breeder, is fuelled by plutonium extracted from the spent fuel of existing reactors. As well as producing electricity, a fast breeder can also convert depleted uranium, which cannot be used in conventional reactors, into further plutonium. It can thus produce more plutonium than it consumes, providing additional fuel. In this way, a fast breeder can potentially extract about 60 times as much energy from each tonne of uranium as present reactors. If all the depleted uranium in storage in the UK were to be used in fast breeder reactors, it could potentially provide as much electricity as burning 20 billion tonnes of oil (about 7 times the UK's coal, oil and gas reserves). A prototype fast breeder at Dounreay in Scotland was closed in 1994, but experimental fast breeders continue operating in France, Japan and Russia. However, fast breeder reactors are unlikely to be economic for several decades.

Another long term energy source, which is the subject of research in the USA, Europe and Russia, is fusion power. In this process, heavy hydrogen nuclei are fused together to produce helium nuclei, with the release of large amounts of energy. This is the main source of the sun's energy output. Commercial fusion reactors are unlikely to be available until the latter half of the next century.

The Nuclear Review – Plans for the Future

The Government set out its proposals for the nuclear electricity generators in a white paper *The Prospects for Nuclear Power in the UK* (Cm 2860), published in May 1995. Detailed results of the review are given in an EA Special Briefing: *The Nuclear Review*, published in September 1995.

In its Review paper, the Government recognised that nuclear power would continue to contribute to the wide diversity of fuel resources used by the UK electricity industry, provided it was competitive and maintained its high standards of safety and environmental protection. The Government's latest CO_2 emission projections provided the background for assessing the possible role of new nuclear power stations in reducing carbon dioxide emissions. The Review recognised the significant contribution that the existing nuclear stations were making towards meeting the UK's current emission limitation commitments. It also noted that, unless these stations were replaced by other non CO_2 emitting generators when they were decommissioned, there might be a problem for the abatement strategy beyond 2010. In the longer term, if further substantial reductions in emissions were to be required, there could be a role for new nuclear capacity beyond 2010. However, the Government concluded in its Review that the construction of new nuclear plant was not the most cost effective CO_2 abatement strategy for the early years of the 21st century and they were not persuaded of a need to finance further nuclear power stations from public funds.

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Summary

- Nuclear power stations have been generating on base load for many years and now supply about 25% of UK electricity.
- The design and operation of nuclear reactors is strictly regulated. On average in the UK, they contribute less than 0.1% of the total population radiation exposure from all sources, natural and man-made.
- The volumes of radioactive waste produced are relatively small and, as with other hazardous industrial wastes, they are carefully controlled so that environmental protection and safety standards are met.
- Nuclear power stations emit negligible amounts of SO_2, NO_X and CO_2. This was recognised as a significant environmental benefit in the Government's environmental strategy documents published in 1990 and 1994 and in its 1995 review of the nuclear industry's future.
- Although the prospective decommissioning of existing nuclear plants poses a major challenge to the country's CO_2 abatement strategy beyond 2010, the Government concluded in its 1995 review that it was inappropriate to commit public funds to the construction of further nuclear stations.

Addendum (April 2000)

- In January 1998 Magnox Electric became a wholly-owned subsidiary of British Nuclear Fuels (BNFL), known as BNFL Magnox Generation.
- In June 1998 British Energy merged its two operating subsidiaries, Nuclear Electric and Scottish Nuclear, both now operating as British Energy.
- In March 1997 work being undertaken by Nirex on an underground repository for radioactive waste was halted pending further Government policy decisions. A House of Lords Select Committee inquiry into the radioactive waste management concluded in March 1999 that work should start without delay on development of an underground waste repository.
- Between 1990 and 1998 nuclear output in the UK increased by 55%, whilst its share of total electricity generation rose from 19% to 26%.

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