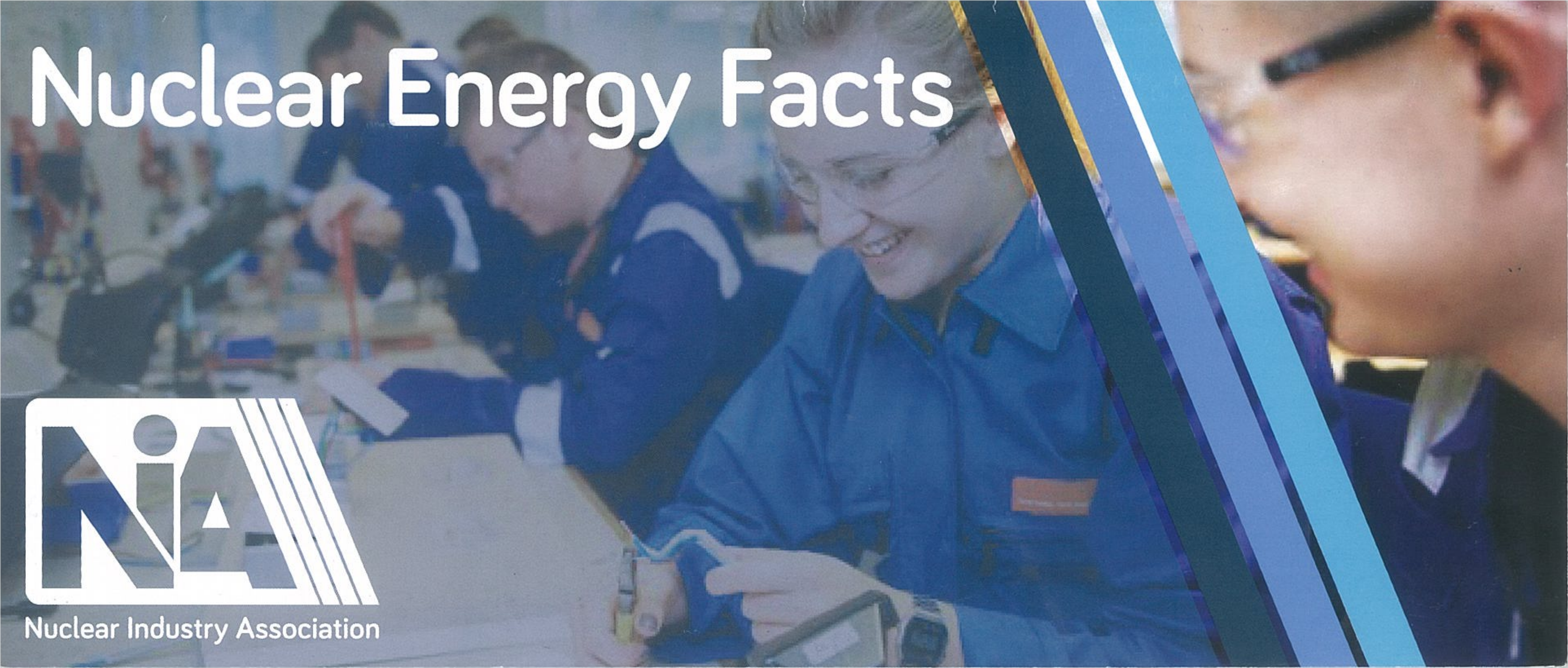
Nuclear Energy Facts



Nuclear Industry Association

CONTENTS...

With the growing threat of climate change, nuclear energy is essential to meet the UK's future clean energy needs. Along with renewables and energy efficiency, nuclear can reduce carbon emissions. As part of a diversified energy mix, nuclear generated electricity can provide safe and reliable sources of power for UK homes, hospitals, schools and industries.

This booklet sets out how nuclear energy works and highlights some of the benefits it can bring.

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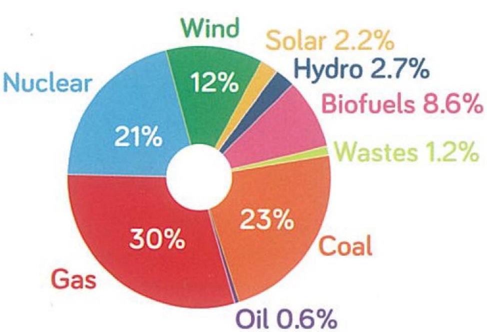
Cover image: Courtesey of EDF Energy — www.edfenergy.com/energy

AT A GLANCE...

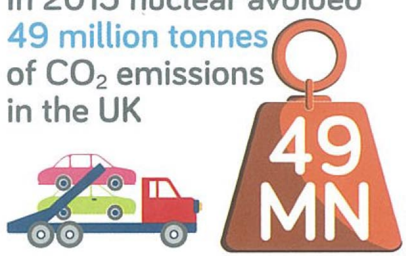
Nuclear is a major part of our energy mix. Today it accounts for 21% of electricity generated in the UK and has been providing secure low carbon electricity for over 60 years.

Low carbon energy, including nuclear power and renewables, account for 40% of the UK's electricity mix

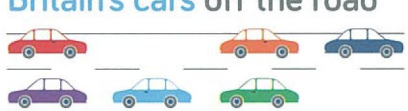


▲Digest of UK Energy Statistics 2016

In 2015 nuclear avoided 49 million tonnes of CO_2 emissions in the UK



That's equivalent to taking around three quarters of Britain's cars off the road



There are 15 reactors operating in the UK

Almost three quarters of the public believe nuclear should be part of the energy mix

65,000+

jobs across the UK civil nuclear industry

14,531
Women working in nuclear

1,940
People on apprenticeships

1,074
People on graduate schemes

Figures for the Jobs Map are generated from participating NIA members

A BRIEF HISTORY OF NUCLEAR...

This simple timeline charts some of the key people, events and legislation that have helped to shape the civil nuclear industry in the UK today.

1895 WILHELM RÖNTGEN ACCIDENTALLY DISCOVERS X-RAY & IONISING RADIATION

1896 HENRI BECQUEREL DISCOVERS RADIOACTIVITY

1898 PIERRE & MARIE CURIE EXPERIMENT USING RADIUM TO CURE CANCER, A PROCESS STILL USED TODAY

Samuel Prescott uses radiation to kill bacteria in food

1902 RUTHERFORD LEARNS TO MANIPULATE ELEMENTS BY BOMBARDING THEM WITH ALPHA PARTICLES

1905 ALBERT EINSTEIN PUTS FORWARD HIS THEORY RELATING MASS TO ENERGY

$E=mc^2$

1903 NIELS BOHR PUBLISHES HIS MODEL OF THE ATOMIC STRUCTURE WHICH IS STILL TAUGHT IN CLASSROOMS TODAY

1932 CHADWICK DISCOVERS NEUTRONS AN IMPORTANT PARTICLE IN NUCLEAR FISSION

1934 ENRICO FERMI ACHIEVES THE FIRST CONTROLLED SELF-SUSTAINING NUCLEAR FISSION REACTION

1939-45 THE US DEVELOPS NUCLEAR WEAPONS DROPPING TWO BOMBS OVER JAPAN WHICH LEADS TO THE END OF WWII

1954 ATOMIC ENERGY ACT: THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY IS CREATED

1962-71 NINE MAGNOX NUCLEAR POWER STATIONS OPEN ACROSS THE UK

1965-88 AFTER GOVERNMENT APRROVAL SEVERAL ADVANCED GAS COOLED REACTORS ARE BUILT

1971 BRITISH NUCLEAR FUELS LIMITED IS CREATED TO TAKE CONTROL OF THE UK'S FUEL CYCLE OPERATIONS

1986 CHERNOBYL ACCIDENT

1988-95 SIZEWELL B, THE UK'S FIRST PRESSURISED WATER REACTOR IS BUILT AND STARTS GENERATING ELECTRICITY IN 1995

27% OF ELECTRICITY IN THE UK IS SUPPLIED BY NUCLEAR POWER

1997 Two nuclear waste stores are to be built at Sellafield, for intermediate level waste for the next 50 years with another 10 planned

2005 NDA

THE NUCLEAR DECOMMISSIONING AUTHORITY IS CREATED TO TAKE STRATEGIC RESPONSIBILITY FOR THE UK'S NUCLEAR LEGACY

2006 In a speech to business leaders Prime Minister Blair calls for a new generation of nuclear power stations

2008 WHITE PAPER AGREES NEW NUCLEAR SHOULD PLAY A ROLE IN THE FUTURE UK ENERGY MIX

ENERGY ACT 2008

2009 £12.5BN EDF TAKEOVER BRITISH ENERGY

UK NEW BUILD PLANS:

- EDF ENERGY at Hinkley & Sizewell
- HORIZON NUCLEAR POWER at Wylfa & Oldbury
- NUGENERATION LTD at Moorside

2011 FUKUSHIMA ACCIDENT: CHIEF NUCLEAR INSPECTOR SAYS UK PLANTS HAVE NO FUNDAMENTAL SAFETY WEAKNESSES

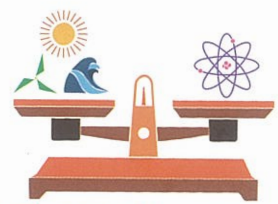
2015 GOVERNMENT INVESTS IN NUCLEAR RESEARCH AND DEVELOPMENT FOR FUTURE TECHNOLOGY

2016 EDF ANNOUNCE FINAL INVESTMENT DECISION FOR HINKLEY POINT C, THE UK'S FIRST NEW NUCLEAR PLANT IN OVER 20 YEARS

BENEFITS OF NUCLEAR ENERGY...

Nuclear energy has a number of benefits that makes it essential as part of a secure low carbon balanced energy mix.

A kilogram of coal would power a 60 watt bulb for **four days**, a kilogram of uranium would power the same bulb for **685 years**



Baseload capacity is increasingly important to **balance** intermittent renewable generation

Investing in low carbon technologies will **create jobs** and **boost the UK skills base**, new nuclear alone will create up to **60,000 new jobs**

Compared to other low carbon technologies nuclear energy is **cost competitive**

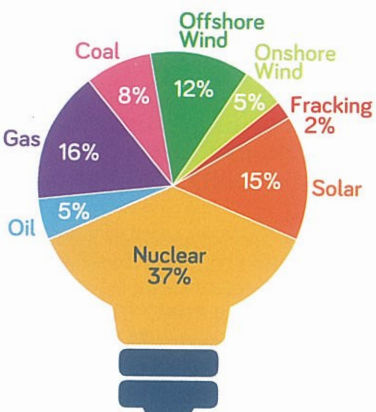
Nuclear power **boosts security of supply** in a diverse and balanced energy mix

Nuclear is a **'homegrown'** source of power reducing our dependence on imported fuels

Nuclear energy is essentially **carbon free**, no carbon dioxide is produced in its operation

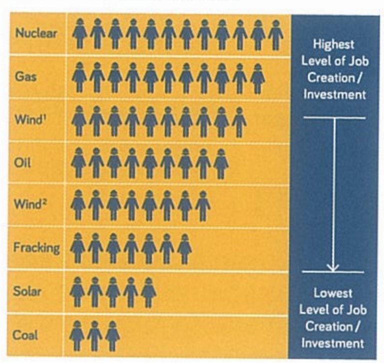
WHAT THE PUBLIC THINK...

Public support for nuclear energy, alongside other low carbon sources, has been strong for several years and nuclear comes first in the energy sources the public believe are needed to keep the lights on.

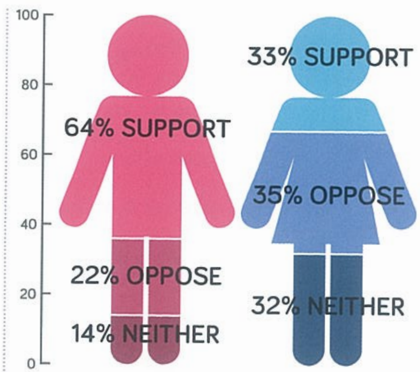


Nuclear energy is seen as **most secure** for **keeping the lights on**

Nuclear energy is **ranked highest** for jobs creation and investment

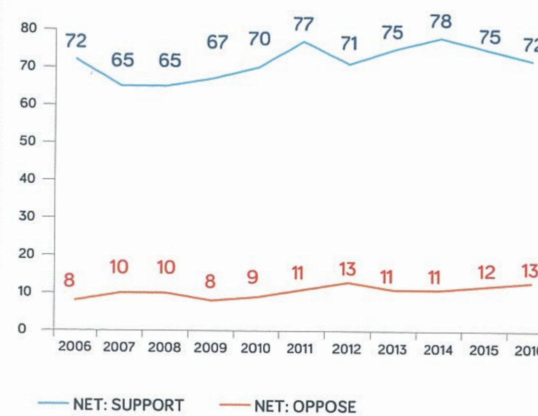


¹ OFFSHORE ² ONSHORE



Men are **more in favour** of new build **than women**

More people **support** nuclear as part of the low carbon energy mix



▲All results are from a survey of 2,051 people, conducted on behalf of the Nuclear Industry Association by YouGov, 31 October to 6 November 2016.

HOW NUCLEAR CREATES ENERGY...

Nuclear power stations generate electricity by releasing energy held within atoms. Atoms are the smallest building blocks of matter and in the middle there is a nucleus. In a process called fission the nucleus of an atom is split apart releasing lots of energy. The best material to do this is uranium.

URANIUM WAS IDENTIFIED IN 1789 AND NAMED AFTER THE RECENTLY DISCOVERED PLANET URANUS

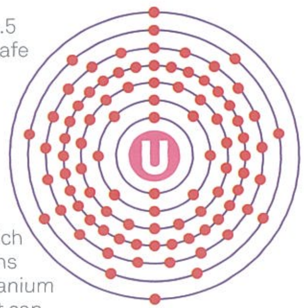
Uranium

Uranium is a heavy metal and occurs naturally in rocks. It has been used for over 2,000 years, originally to colour glass, but the uranium atom was only discovered in 1789.

Uranium has a half-life of about 4.5 billion years. It is radioactive but safe to be around because it takes so long to decompose.

Half-life is the time taken for the radioactivity of an isotope to fall to half its original value.

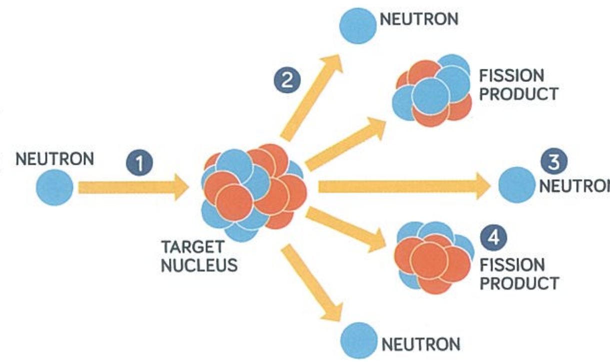
Uranium has several isotopes which have different numbers of neutrons inside their atoms. The isotope uranium -235 is used as a nuclear fuel as it can undergo nuclear fission.



Fission

Fission simply means splitting an atom using a neutron. It was discovered in 1938 and its potential was quickly realised. The neutron population inside a reactor is important. It is managed using control rods which absorb neutrons. They move up and down to increase or decrease the nuclear reaction.

1. The absorption of a neutron causes uranium to become unstable and split apart.
2. Potential energy inside the atom is released as heat which can be used to make electricity.
3. On average 2.5 neutrons are released. By design and control these neutrons are managed so there is just the right amount inside the reactor. Too few and the reaction will stop, too many and it will go too fast.
4. Fission products are created which subsequently go on to split as well. This continues until a stable element is reached. About 7% of a reactor's power comes from fission products splitting.

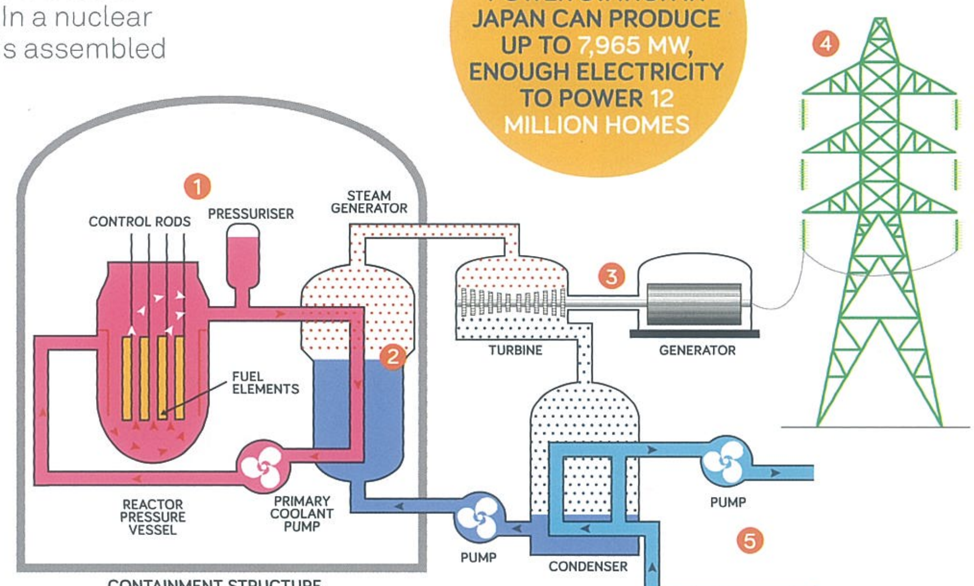


HOW A REACTOR WORKS...

There are many types of nuclear reactor which essentially work the same way, creating steam that turns a generator to make electricity. In a nuclear reactor, heat is produced by splitting U-235. The uranium fuel is assembled in such a way that a controlled chain reaction is achieved.

THE WORLD'S LARGEST NUCLEAR POWER STATION IN JAPAN CAN PRODUCE UP TO 7,965 MW, ENOUGH ELECTRICITY TO POWER 12 MILLION HOMES

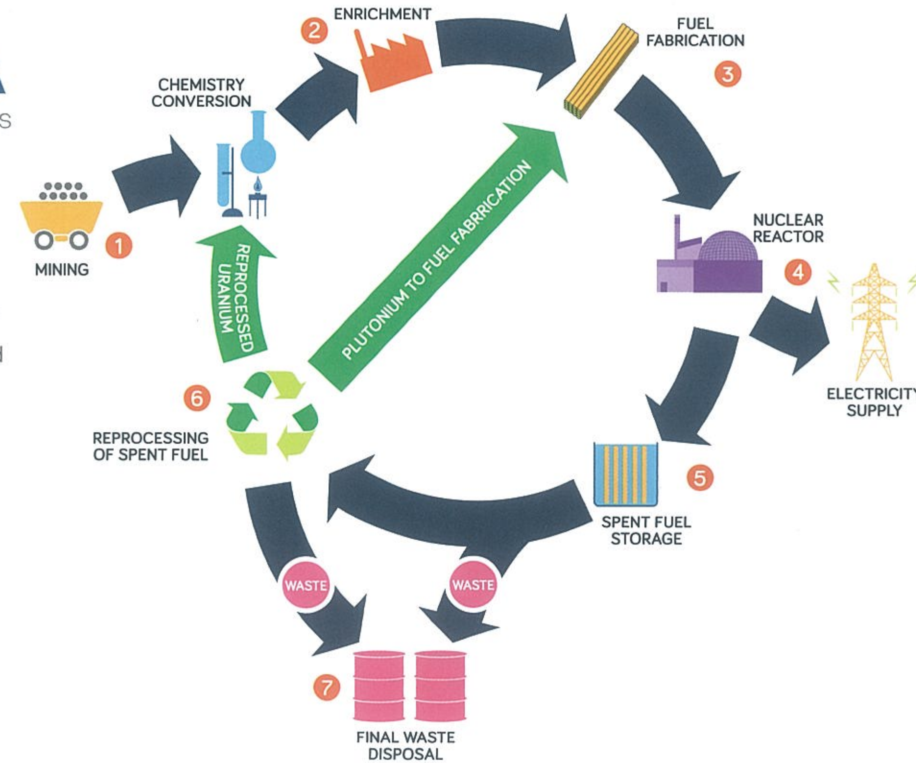
1. In a pressurised water reactor heat from a nuclear reaction is transferred into surrounding water
2. The heat boils the water and turns it into steam
3. Steam turns a turbine and drives a generator to make electricity
4. Electricity is transported to your home using the national grid
5. Sea or river water is used to absorb excess heat



THE NUCLEAR FUEL CYCLE...

From mining to final disposal, uranium goes through different stages in the fuel cycle.

1. Uranium is mined in places like Australia, Canada and Kazakhstan. It is usually refined at the mine and converted into uranium hexafluoride on site.
2. The proportion of uranium-235 in the fuel is increased through a process called enrichment, making fuel last longer and making it easier to achieve a chain reaction.
3. Uranium is converted into uranium dioxide (UO_2) powder. This powder is then pressed to form small fuel pellets, which are heated to make a hard ceramic material. The pellets are inserted into thin tubes to form fuel rods which are grouped together to form fuel assemblies.
4. Fuel is loaded into a reactor to generate electricity. Over time the fuel builds up radioactive fission products.
5. Fuel is left in storage to allow its radioactivity to reduce before it is reprocessed or disposed of.
6. Used fuel can be reprocessed to extract unused uranium-235 and plutonium to make more fuel.
7. In the long term, the Government is looking to store waste in deep underground impermeable rock.



MANAGING WASTE...

What is nuclear waste?

Producing electricity with nuclear energy creates nuclear waste, which is radioactive. However, most of our waste comes from the previous generation of power stations and early nuclear facilities.

For example a fleet of new plants to replace the current ones, would only add around 10% to the volume of existing waste over their 60-year lifespan.

HIGH LEVEL WASTE (HLW)
Made up of spent fuel, requires cooling, accounts for 95% of radioactivity produced from generating electricity but only 3% of waste by volume.

INTERMEDIATE LEVEL WASTE (ILW)
Made up of resins, chemical sludges and metal fuel cladding, requires shielding.

LOW LEVEL WASTE (LLW)
Produced by hospitals, industry and nuclear energy. It comprises of paper, rags, tools and clothing. 90% of the volume but only 1% of the radioactivity.

How is waste managed?

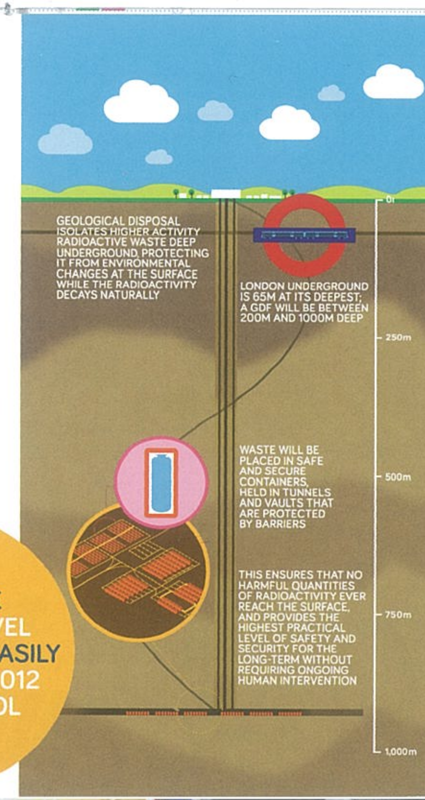
To ensure waste does not escape into the environment it is 'vitrified', turned into glass, so it is impermeable to water and chemically stable. It is then placed in a special above ground storage facility.

To develop a permanent solution for this high level radioactive waste, the Government plans to build a geological waste repository.

It will isolate waste deep underground to ensure no harmful quantities of radioactivity ever reach the surface environment.

In Finland, plans to build a geological disposal facility near Olkiluoto nuclear power plant, were approved in 2015.

ALL OF THE UK'S HIGH LEVEL WASTE COULD EASILY FIT INTO THE 2012 OLYMPIC POOL



RADIATION EXPLAINED...

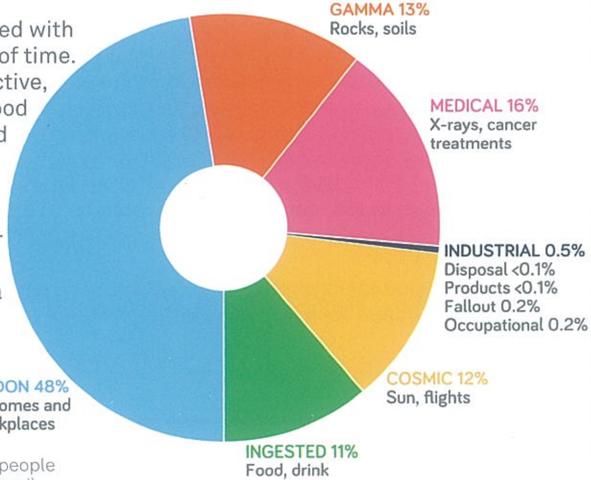
The radioactivity of a substance, or the rate at which decay is taking place, is measured in bequerels (Bq), and the unit which estimates the effect a dose of background radiation has on living matter is the millisievert (mSv).

RADIATION IS OFTEN DEPICTED AS GLOWING GREEN, IN REALITY IT GLOWS BLUE WHEN CHARGED PARTICLES PASS THROUGH WATER

Where does radiation come from?

We and our ancestors have lived with radiation since the beginning of time. Our planet is naturally radioactive, so is the air we breathe, the food we eat, the water we drink and even our own bodies.

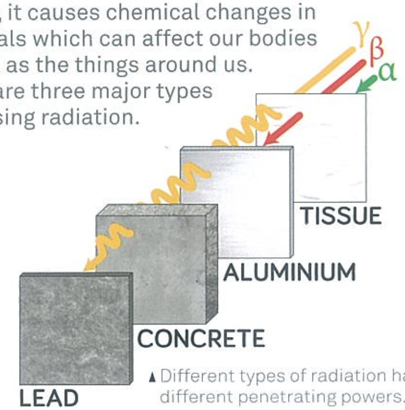
Radiation generated from nuclear energy is very small. A return flight to New York, for example, would expose you to almost as much radiation as a nuclear worker's dosage over an entire year.



► Average annual radiation doses to people living in the UK (Public Health England).

How does radiation work?

Radiation occurs naturally all around us and comes from atoms breaking down. When ionising radiation bumps into other matter, it causes chemical changes in materials which can affect our bodies as well as the things around us. There are three major types of ionising radiation.



▲ Different types of radiation have different penetrating powers.

α ALPHA

These are large, heavy particles with a lot of energy. Because they are so big they interact with atoms in their path and quickly lose their energy. They can only penetrate about 20cm of air and are blocked by a sheet of paper.

β BETA

Beta particles are electrons, they are much lighter than alpha particles and do not interact as much with atoms in their path so can travel slightly further. They can be stopped by a thin sheet of aluminium.

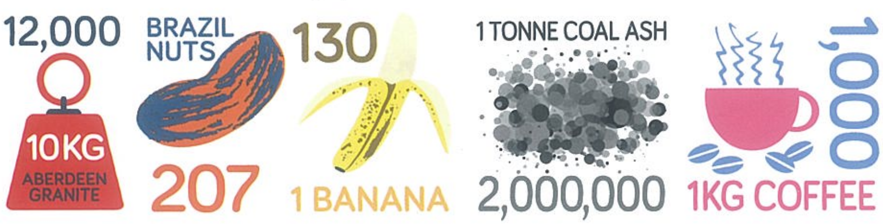
γ GAMMA

Gamma is an electromagnetic wave, like light or a radio signal, but it has a very small wave length. It interacts the least and lead or lots of concrete is needed to absorb it.

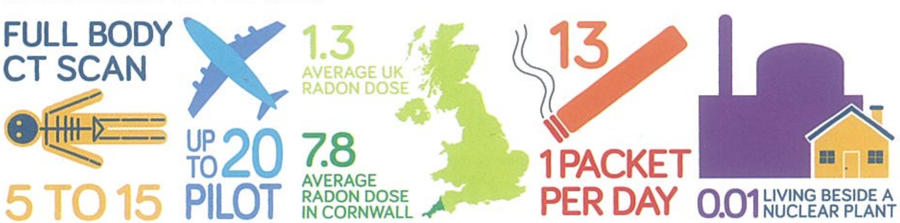
Our average annual radiation dose in the UK is 2.7 mSv. Typically, we get about 85% of it from natural sources such as rocks, the sun and radon in the air.

Sources of radiation?

EXAMPLES OF RADIOACTIVITY (Bq)



AVERAGE ANNUAL DOSES (mSv)



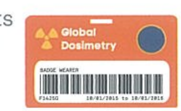
Uses of radiation?

RADIATION PLAYS A VITAL ROLE IN ESSENTIAL TECHNOLOGIES OF THE 21ST CENTURY:

Medicine: X-Ray examinations are the most common cause of exposure to manmade radiation. Radiation is also used in very small doses to diagnose injury and disease, and in large doses to kill cancer cells.

Food preservation: Food irradiation is an alternative to using chemicals to kill bacteria and stop foodborne diseases. It also preserves food for longer.

Fire alarms: Small amounts of radioactive material are used in some fire alarms to detect the presence of smoke or heat.



Safety: Dosimeters detect, measure and record levels of ionising radiation within an object or individuals immediate environment.

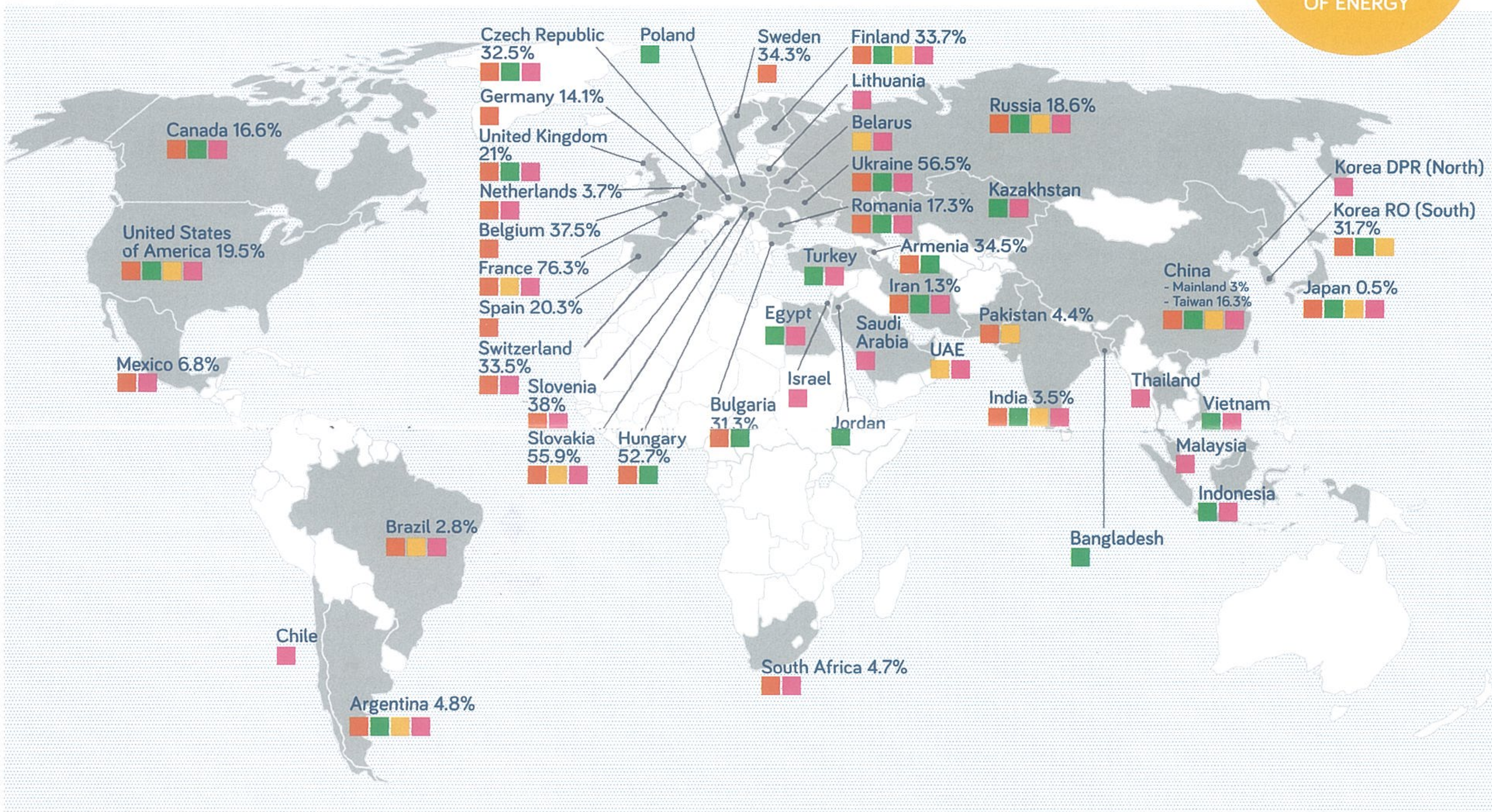
Industry: As some kinds of radiation can pass through some types of matter, they can be used to measure the thickness and structure of materials and find defects.

Agriculture: Radiation is used in pest control. To protect food crops, it is possible to irradiate male insects so they become sterile and cannot reproduce.

NUCLEAR AROUND THE WORLD...

Since commercialisation in the 1950s nuclear now provides over 11% of the world's electricity. There are currently 447 commercial nuclear power reactors operating in 30 countries, with over 390,000 MWe of total capacity, enough electricity to power more than two billion lightbulbs. About 60 more reactors are under construction.

A COAL PLANT EMITS 100 TIMES MORE RADIATION THAN A NUCLEAR POWER PLANT PRODUCING THE SAME AMOUNT OF ENERGY



447 — OPERATING REACTORS

164 — PLANNED REACTORS

60 — UNDER CONSTRUCTION

347 — PROPOSED REACTORS

This map shows which countries around the world use nuclear energy as part of their energy mix as well as the percentage of that contribution where applicable. It also displays the countries planning to introduce nuclear energy.

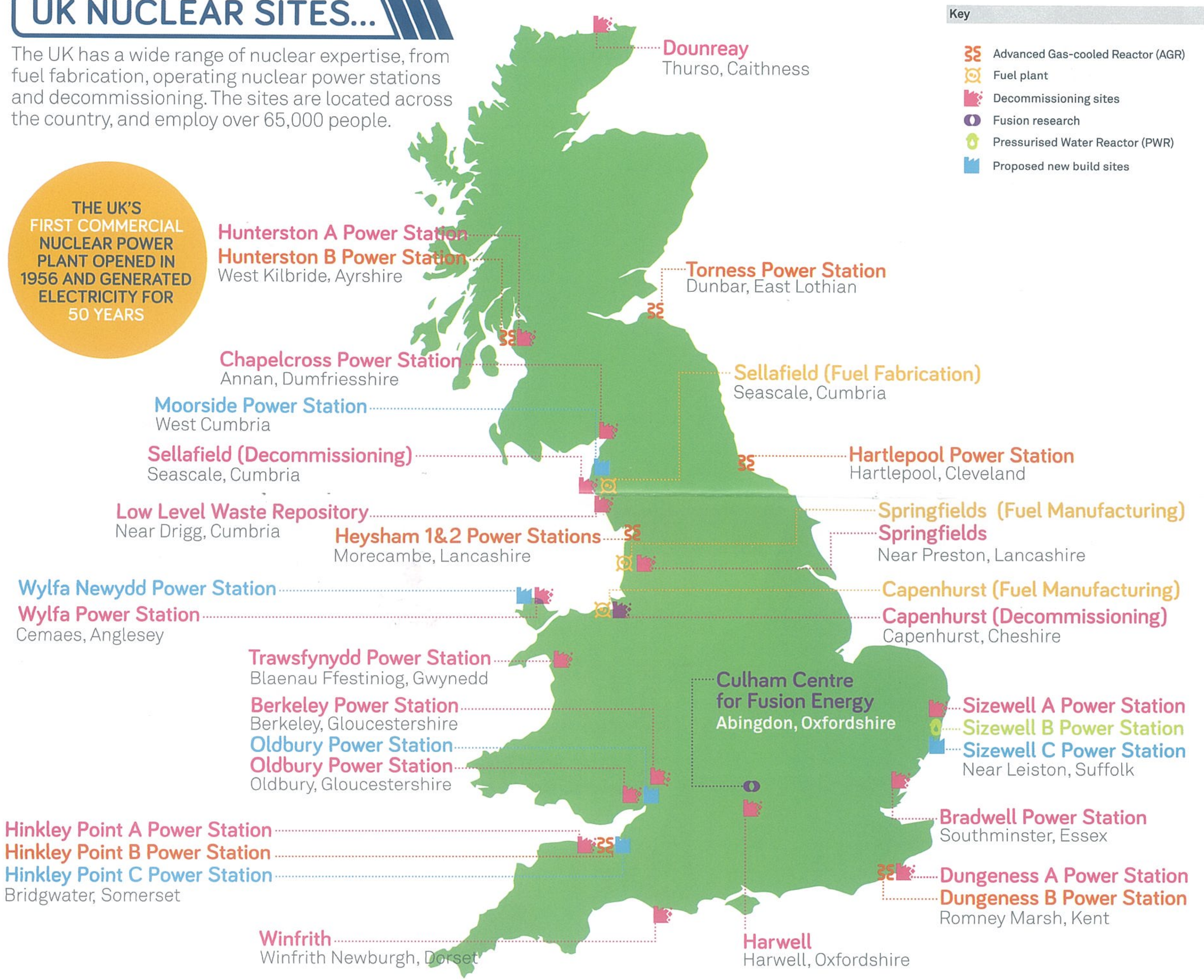
(Operating = Connected to the grid; Planned = Approvals, funding or major commitment in place; Under Construction = First Concrete for reactor poured or major refurbishment under way; Proposed = Specific programme or site proposals)

Source: World Nuclear Association www.world-nuclear.org – As of 9 January 2017. Percentages of energy mix from IAEA figures for 2015.

UK NUCLEAR SITES...

The UK has a wide range of nuclear expertise, from fuel fabrication, operating nuclear power stations and decommissioning. The sites are located across the country, and employ over 65,000 people.

THE UK'S FIRST COMMERCIAL NUCLEAR POWER PLANT OPENED IN 1956 AND GENERATED ELECTRICITY FOR 50 YEARS



NUCLEAR NEW BUILD...

There is an urgent need to invest in low-carbon energy infrastructure in the UK. In the coming years the UK will need to build 60GW of new electricity generating capacity as power plants close down.

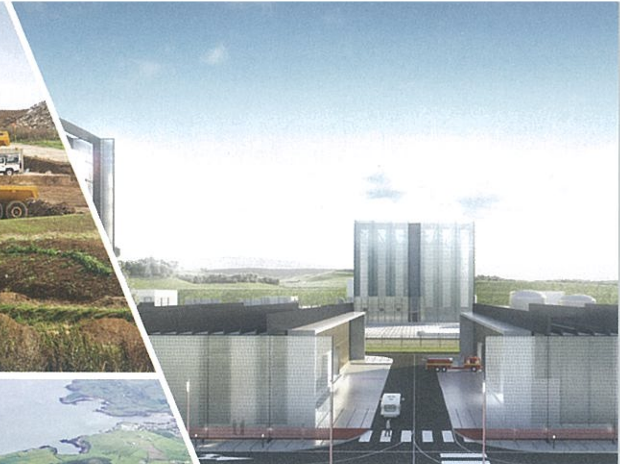
The UK's nuclear fleet currently generates 21% of the country's electricity but all of them are due to retire between 2023 and 2035. These stations are being replaced with 18GW of new nuclear capacity planned to come online in the 2020s.

Construction has begun at Hinkley Point C, the site for the first new nuclear station in a generation. The reactors at Hinkley will generate 3.2GW of power, create 25,000 new jobs, including 1,000 apprenticeships. The company also has plans to build at Sizewell C in Suffolk.

Horizon Nuclear Power, a company based in Gloucester has plans to build two Advanced Boiling Water Reactors generating 2.7GW at Wylfa Newydd on Anglesely in Wales. It will build two more reactors at Oldbury in Gloucestershire.

NuGeneration plans to build three AP1000 reactors at Moorside in Cumbria with a generation capacity of 3.6GW. Moorside will be the biggest ever new nuclear project in Europe.

China General Nuclear, working with EDF Energy also has plans to build Hualong One (HPR1000) reactors at Bradwell in Essex.

Images courtesy of:
EDF Energy — www.edfenergy.com/energy; Horizon Nuclear Power — www.horizonnuclearpower.com; NuGeneration Ltd— www.nugeneration.com; China General Nuclear Power Corporation — www.cgnpc.com.cn

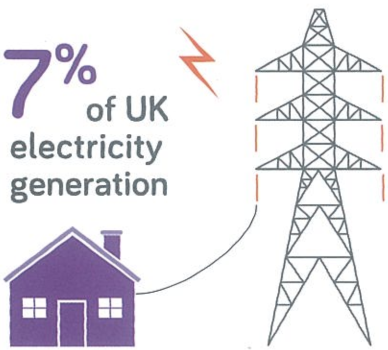
HINKLEY POINT C IN NUMBERS...

Hinkley Point C will be the UK's first new nuclear power station for a generation and is paving the way for a comprehensive 18GW new build programme of low carbon, secure and reliable electricity from nuclear for the future.

9MN tonnes of CO_2 avoided annually

Equivalent to around two and a quarter million return flights from London to Sydney*

7% of UK electricity generation

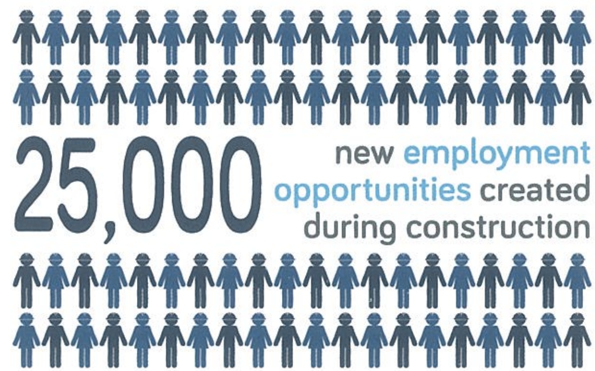


Enough low carbon energy to power more than five million homes

1,000 new apprenticeships during construction

£200 MN per year to local economy

64% project construction value predicted to go to UK companies



25,000 new employment opportunities created during construction

*Return flight London to Sydney ~4 tonnes CO_2 — Defra NI 185 tool

LOOKING TO THE FUTURE...

Further into the future the UK aims to develop small modular reactors that can be built in a factory and be deployed quickly around the country to supply heat and power.

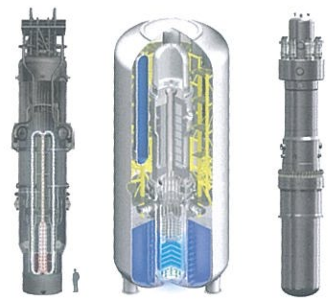
Small modular reactors could be cheaper than conventional reactors and could be exported around the world. Manufactured in a factory, complete components are transported to the site for final assembly. Their compact size allows for greater siting flexibility in comparison to traditional reactors, and because each part is modular it will be easier to upgrade.

The UK also has a stockpile of plutonium, which comes from reprocessing spent fuel. Plutonium can also be used in conventional reactors as a mixed oxide fuel with uranium to make electricity. New reactors could be built to 'burn' plutonium, creating another low-carbon power source.

Research is ongoing on the new technologies which can be developed to secure the UK's energy needs into the future and the Government has allocated funding of £250 million to help this research and development.

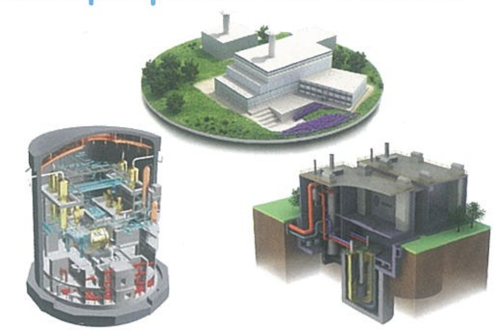
Small Modular Reactors (SMRs) are manufactured in a factory and complete components are transported to the site for final assembly

Example SMRs



▲ *l to r:* NuScale Power, Westinghouse, Generation mPower

Example plutonium reactors



▲ *l to r:* Candu Energy CANMOX, AREVA MOX, GE Hitachi Nuclear Energy PRISM

DECOMMISSIONING...

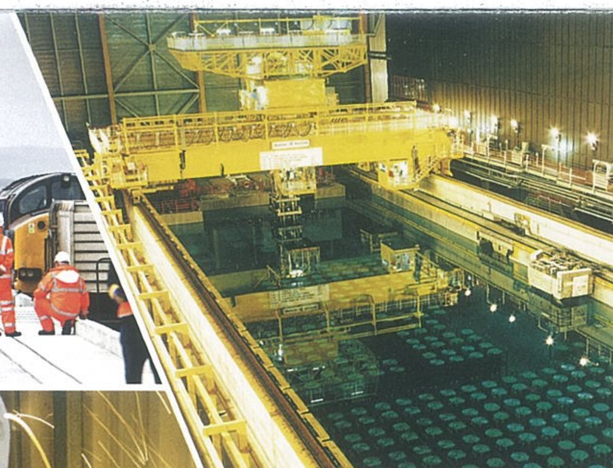
The first generation of nuclear power stations and early research facilities left a legacy that requires management. As a nuclear pioneer the UK has a particularly challenging portfolio to decommission.

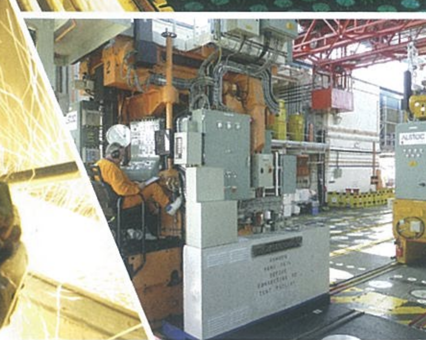
The UK has one of the world's most advanced and challenging nuclear decommissioning programmes. In 2005, the Nuclear Decommissioning Authority (NDA) was set up to manage the UK's legacy nuclear decommissioning challenges.

These challenges include managing what is left from early nuclear research, the first fleet of commercial reactors and from efforts to develop a nuclear deterrent at the start of the cold war. Unfortunately waste storage and treatment was not well planned for. In places there are no accurate blueprints for buildings or inventories, increasing the complexity of the work.

Many of the challenges faced in decommissioning require innovative, unique, high-tech engineering solutions combined with expert people. The UK has become a world leader in decommissioning and is able to export expertise around the world.

For future projects the cost of decommissioning nuclear reactors and sites will be funded by the operator, the taxpayer will not have to pay a penny.





Images courtesy of:
Direct Rail Services — www.directrailservices.com; Sellafield Ltd — www.sellafieldsites.com; Magnox Ltd — www.magnoxsites.co.uk

CAREERS IN NUCLEAR...

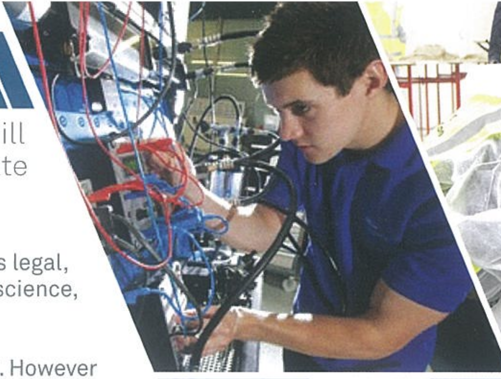
Nuclear new build, existing operations and decommissioning will drive an unprecedented demand for nuclear expertise and create thousands of jobs.

These roles, while in a science-related industry, will cover many varied jobs such as legal, HR and communications. The sector will also need people who have an interest in science, technology, engineering and maths.

Many people who work in nuclear will have a degree, either in science or engineering. However you can get into the industry without a degree through an apprenticeship scheme and work your way up. Many apprentices then go on to study for their degree while they work. To get on to an apprenticeship programme you will need to have at least five GCSEs including maths and a science subject, at grade A-C.

Skills and knowledge

To work in the nuclear sector you will need to have an interest in science and technology, analytical and problem solving skills, excellent maths and computer skills, the ability to manage projects as well as good spoken and written communications.



Images courtesy of:
EDF Energy — www.edfenergy.com/energy; Horizon Nuclear Power — www.horizonnuclearpower.com

FURTHER INFORMATION...

For news, facts and general information on nulcear:

- www.niauk.org
- www.world-nuclear.org
- www.foratom.org
- www.nei.org
- www.nuclearinst.com

For career advice:

- www.cogentskills.com/nssg
- www.nsan.co.uk
- www.ecitb.org.uk/Apprenticeships-Careers

To learn about operations, new build and decommissioning:

- www.edfenergy.com/energy
- www.horizonnuclearpower.com
- www.nugeneration.com
- www.sellafieldsites.com
- www.gov.uk/government/organisations/nuclear-decommissioning-authority
- www.magnoxsites.com
- www.urenco.com/about-us
- www.westinghousenuclear.com/springfields
- www.areva.com
- www.hitachi-hgne.co.jp/en
- www.westinghousenuclear.com/New-Plants/AP1000-PWR

To learn about how Industry is governed:

- www.onr.org.uk
- www.gov.uk/government/organisations/nuclear-decommissioning-authority
- www.iaea.org

For research & development:

- www.nnl.co.uk
- www.amecfw.com/sectors/nuclear/reactor-technology-laboratories-randd
- www.namrc.co.uk
- www.ccfe.ac.uk
- www.nirab.org.uk