Nuclear Energy Facts.

Nuclear Industry Association

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

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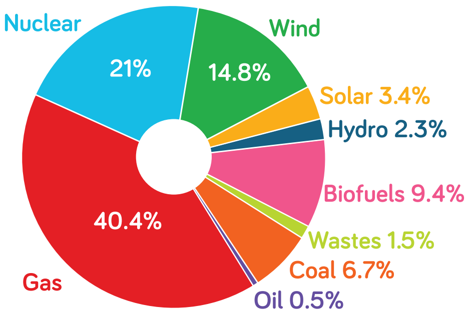
AT A GLANCE...

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 almost 51% of the UK's generation electricity mix



▲BEIS,Digest of UK Energy Statistics 2018

63,816

jobs in the UK civil nuclear sector

12,159

Women in civil nuclear

1,981

People on apprenticeships

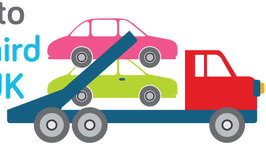
914

People on graduate schemes

▲Jobs Map figures generated from participating NIA members

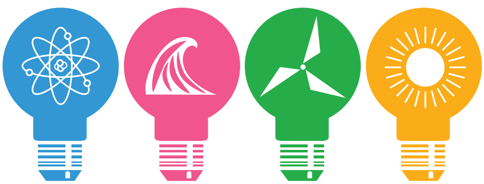
There are 15 nuclear power reactors operating across eight sites in the UK

In 2016 nuclear energy avoided 22.7 million metric tonnes of CO_2 emissions in the UK



That's equivalent to taking around a third of all cars in the UK off the road

Civil nuclear contributes over £6 billion to the UK economy as much as aerospace manufacturing



Three quarters of the public believe nuclear should be part of the clean energy mix

A BRIEF HISTORY OF NUCLEAR ENERGY...

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

1897 J. J. THOMSON DISCOVERS THE ELECTRON, YEARS LATER RECEIVING A NOBEL PRIZE IN PHYSICS FOR THIS DISCOVERY

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

$E=mc^2$

1913 NIELS BOHR PUBLISHES HIS MODEL OF THE ATOMIC STRUCTURE WHICH IS STILL TAUGHT IN CLASSROOMS TODAY

1927 HERMAN BLUMGART USES RADIOACTIVE TRACERS TO DIAGNOSE HEART DISEASE

1932 CHADWICK DISCOVERS NEUTRONS AN IMPORTANT PARTICLE IN NUCLEAR FISSION

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

1954 ATOMIC ENERGY ACT: THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY (UKAEA) IS CREATED

1956 WORLD'S FIRST CIVIL NUCLEAR REACTOR OPENED BY QUEEN ELIZABETH II

1957 IAEA FORMED to promote safe, secure and peaceful nuclear technologies

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

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

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

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

UK NEW BUILD PLANS:

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

2009 £12.5BN EDF TAKEOVER BRITISH ENERGY

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

WYLFA the world's last operating Magnox reactor shuts down

CLOSED

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

2017 FIRST CONCRETE POURED AT HINKLEY POINT C

APPROVED

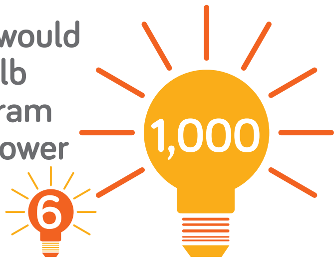
ABWR AND AP1000 PLANT DESIGNS APPROVED FOR DEVELOPMENT IN THE UK

2018 NUCLEAR SECTOR DEAL ENSURING NUCLEAR'S KEY ROLE IN PROVIDING LOW CARBON ENERGY SUPPLY FOR THE UK

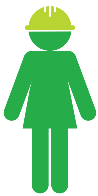
BENEFITS OF NUCLEAR ENERGY...

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

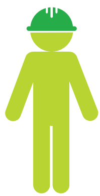
A kilogram of coal would power a 40 watt bulb for six days, a kilogram of uranium would power the same bulb for over 1,000 years



Compared to other low carbon technologies nuclear energy is cost competitive

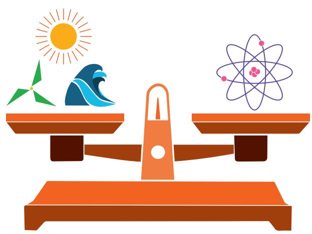


Investing in low carbon technologies will create jobs and boost the UK skills base



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

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



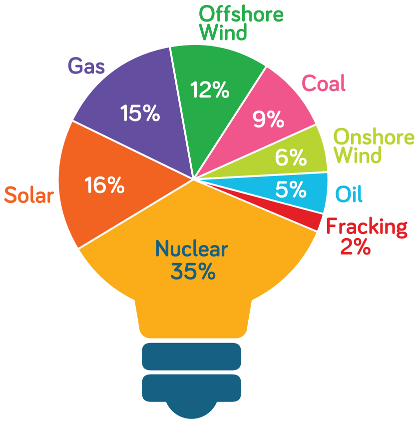
Baseload capacity is increasingly important to balance intermittent renewable generation

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

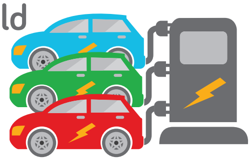
WHAT THE PUBLIC THINK...

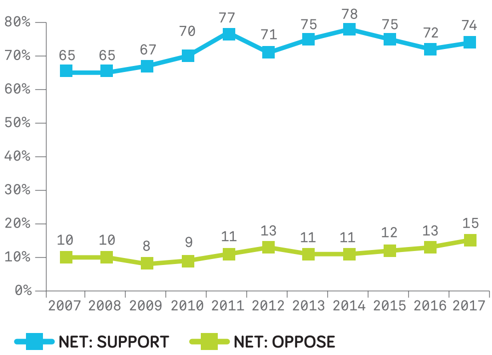
Public support for nuclear energy, alongside other low carbon sources, has been strong for several years and **nuclear comes first** in the energy sources the public believe are needed to **keep the lights on**.

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



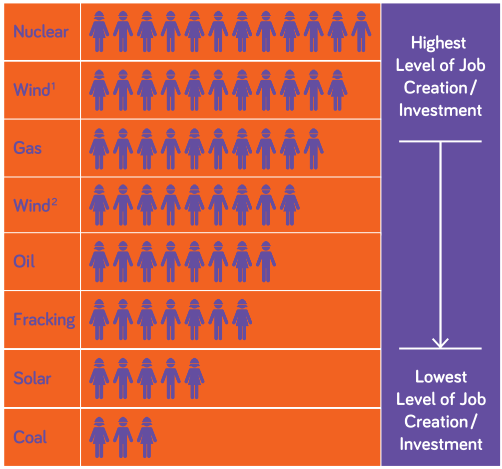
44% of people say nuclear could meet increased demand from electric cars





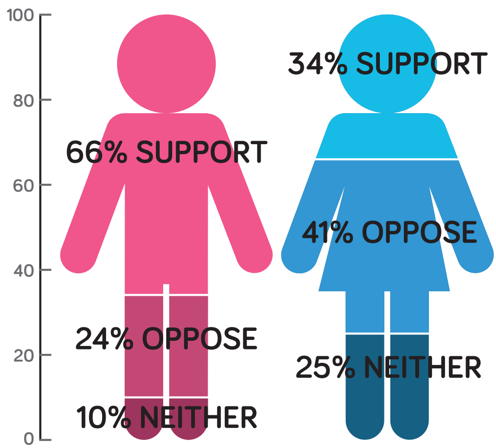
More people support nuclear as part of a low carbon energy mix

Nuclear energy is ranked highest for jobs creation and investment



[1] OFFSHORE [2] ONSHORE

Men are more in favour of nuclear new build than women



▲All results are from a survey of 2,016 people, conducted on behalf of the Nuclear Industry Association by YouGov, 7 to 16 August 2017 .

HOW NUCLEAR CREATES ENERGY...

Nuclear power stations generate **electricity** by releasing energy held within **atoms**. Atoms are 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 most common material used for this is **uranium**.

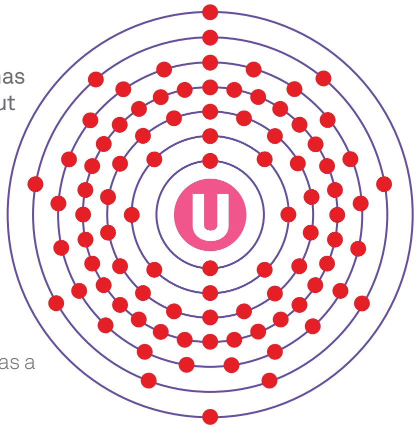
Uranium

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

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

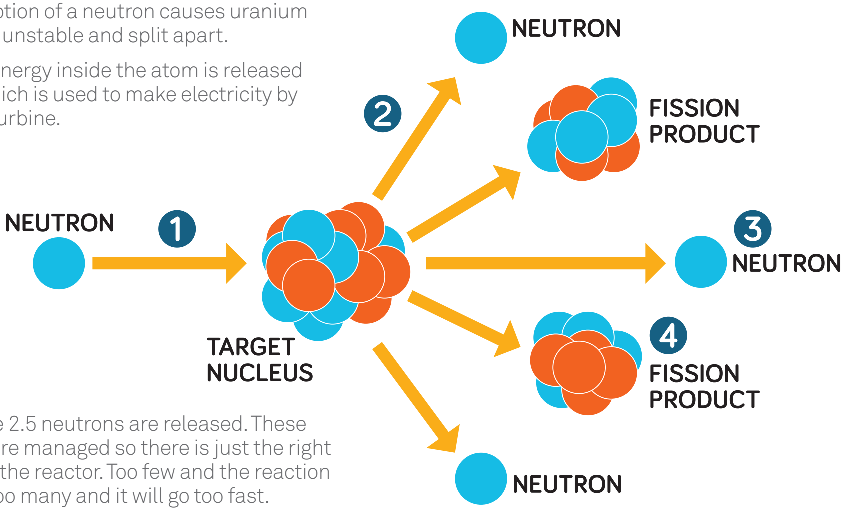
Uranium has several isotopes which have different numbers of neutrons inside their atoms. The isotope uranium -235 is used as a nuclear fuel as it can undergo nuclear fission.



Fission

Fission simply means splitting an atom using a neutron. It was discovered in 1938 and its potential was quickly realised. When atoms fission they release more neutrons, which keeps the reaction going. We use control rods in reactors to absorb excess neutrons and manage 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 is used to make electricity by turning a turbine.

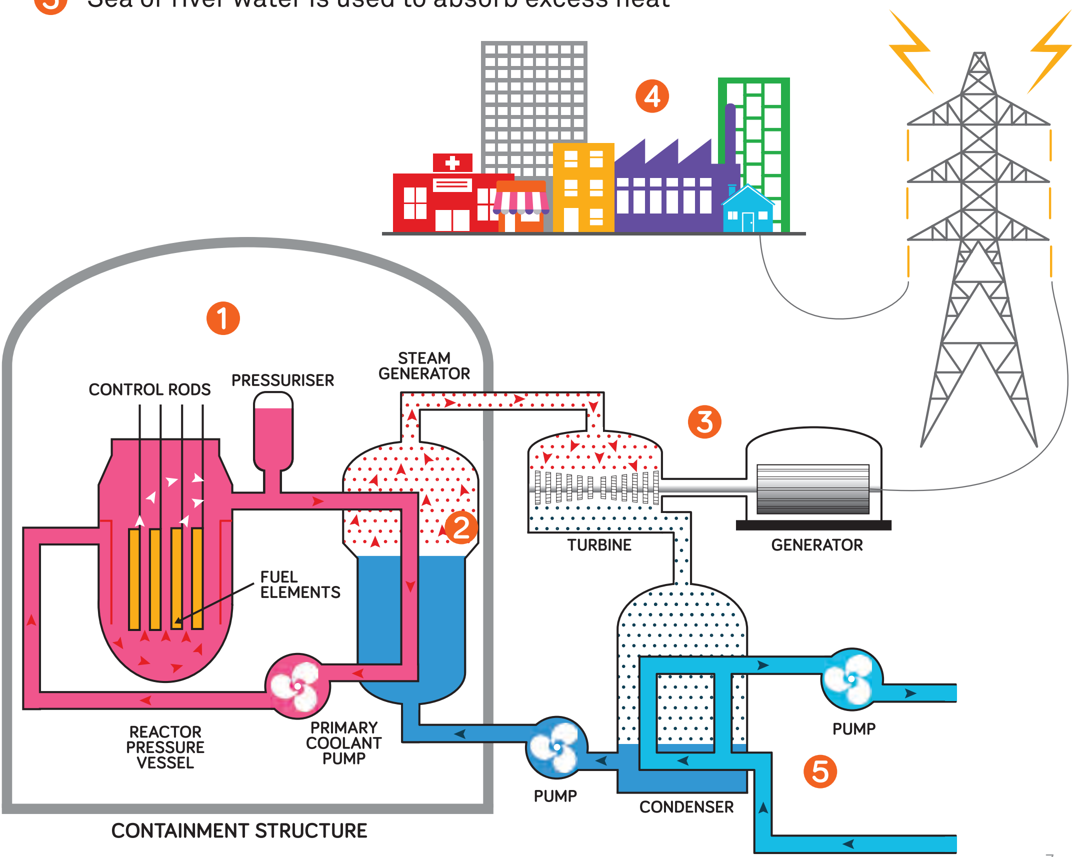


3. On average 2.5 neutrons are released. These neutrons are managed so there is just the right amount in the reactor. Too few and the reaction will stop, too many and it will go too fast.
4. Fission products are created. These also split contributing to about 7% of a reactor's power.

HOW A REACTOR WORKS...

There are many types of nuclear reactor which essentially work the same way, by heating water to **create steam** which turns a generator to **produce electricity**. In a nuclear reactor, heat is produced by **splitting U-235**. Uranium fuel is assembled in a way that a controlled chain reaction is achieved.

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

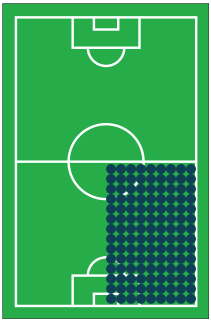


MANAGING WASTE...

What is nuclear waste?

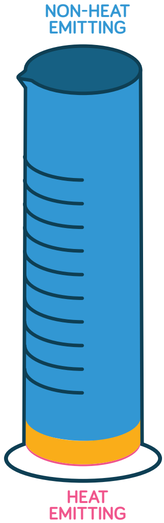
Producing electricity with nuclear energy creates waste that is radioactive. But most of our waste comes from the previous generation of power stations and early nuclear facilities.

A fleet of new plants would only add around 10% to the volume of existing waste over their 60-year lifespan.



Although High Level Waste (HLW) contains the greatest amount of radioactivity, it takes up the least amount of physical space.

If you stored all the UK's HLW in a single layer it would cover 1465 square metres, or one quarter of a football pitch.



LOW LEVEL WASTE (LLW)

Produced by hospitals, industry and nuclear energy. It comprises of paper, rags, tools and clothing. **93% of waste volume** but only 0.5% of the radioactivity.

INTERMEDIATE LEVEL WASTE (ILW)

Made up of resins, chemical sludges and metal fuel cladding, requires shielding.

HIGH LEVEL WASTE (HLW)

Made up of spent fuel, requires cooling, accounts for 95% of radioactivity produced from generating electricity but **less than 1% of waste by volume**.

▲ There are three main types of waste product

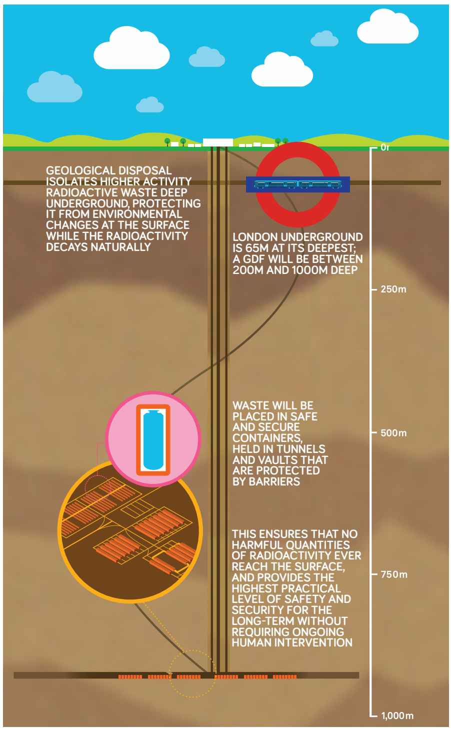
How is waste managed?

Since 1959, most LLW from across the UK has been diosposed of at the Low Level Waste Repository in Cumbria. Initially placed into landfill-style trenches, LLW is now grouted in metal containers then stacked in concrete lined, highly engineered vaults. A cap will cover the containers when the vaults are full.

ILW is generally packaged and vacuum dried or encapsulated in grout to immobilise the waste. The packages ensure that the ILW can be safely stored, transported and disposed of.

To prevent HLW escaping into the environment it is 'vitrified', turned into glass, so it is impermeable to water and chemically stable. This process currently takes place at the Sellafield site in Cumbria.

To develop a permanent solution for ILW and HLW, Government plans to build a geological waste repository. Isolating waste deep underground to ensure no harmful quantities of radioactivity ever reach the surface environment. In Finland, a facility is currently under construction near Olkiluoto nuclear power plant.



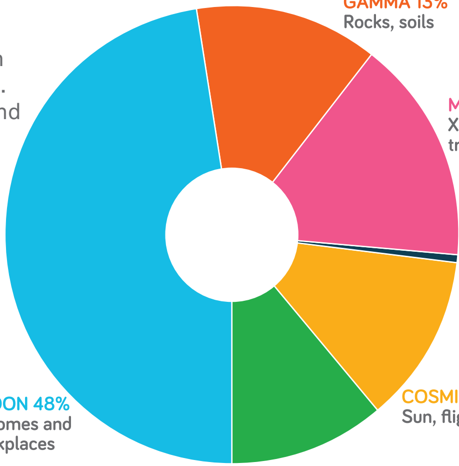
RADIATION EXPLAINED...

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 radiation has on living matter is the **millisievert** (mSv).

Where does radiation come from?

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

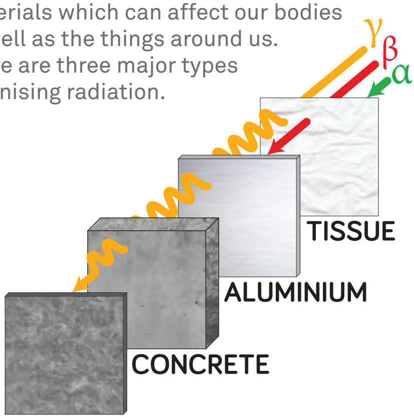
Radiation generated from nuclear energy is very small. A return flight to New York, for example, would expose you to almost as much radiation as a nuclear worker's dose over an entire year.



► 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.



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

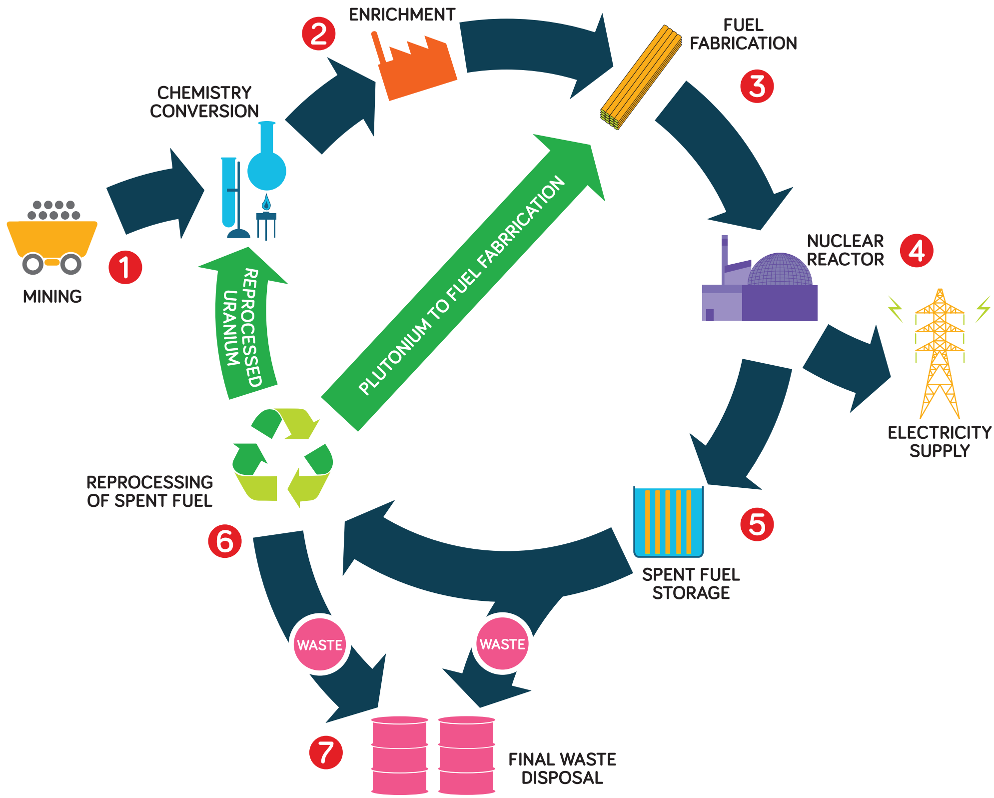
Gamma is an electromagnetic wave, like light or a radio signal, but it has a very small wave length. It interacts the least and lead or lots of concrete is needed to absorb it.

◄ Different types of radiation have different penetrating powers.

THE NUCLEAR FUEL CYCLE...

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

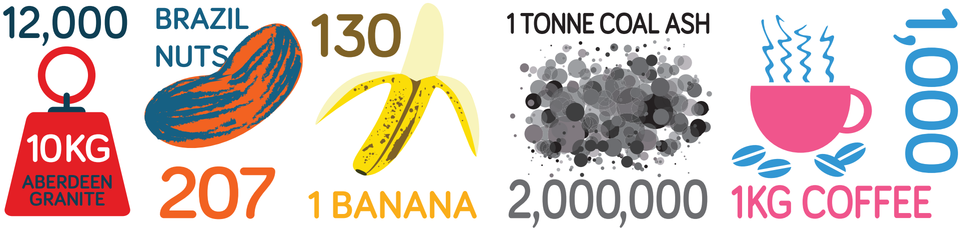
1. Uranium is **mined** in places like Australia, Canada and Kazakhstan. It is usually refined at the mine into a stable form called Yellowcake. This is refined further and converted into uranium hexafluoride gas, ready for enrichment.
2. The proportion of uranium-235 in the fuel is increased through a process called **enrichment**, making fuel last longer and making it easier to achieve a chain reaction. Enrichment and fuel fabrication takes place at specialist facilities such as the Springfields plant in the UK.
3. Enriched 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 burning fuel builds up radioactive fission products.
5. Spent fuel is removed from the reactor and put into **wet storage** to cool and allow its radioactivity to reduce slightly before it is reprocessed or disposed.
6. Used fuel can be **reprocessed** to extract unused uranium-235 and plutonium to make more fuel.
7. In the long term, Government is looking to store waste in **deep underground** impermeable rock.



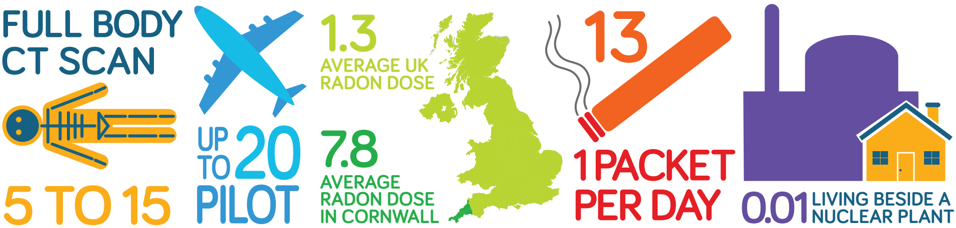
Our average annual radiation dose in the UK is 2.7 mSv. Typically, we get about **85% of it from natural sources** such as rocks, the sun and radon in the air.

Sources of radiation?

EXAMPLES OF RADIOACTIVITY (in Bq)



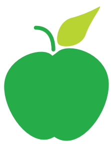
AVERAGE ANNUAL DOSES (in mSv)



Uses of radiation?

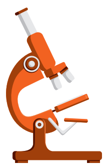
RADIATION PLAYS A VITAL ROLE IN ESSENTIAL TECHNOLOGIES OF THE 21ST CENTURY:

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

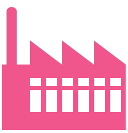


Food preservation: Food irradiation is an alternative to using chemicals to kill bacteria and stop foodborne diseases. It also preserves food for longer.

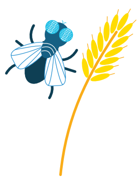
Fire alarms: Small amounts of radioactive material are used in some fire alarms to detect the presence of smoke.



Science: Academic and scientific institutions use nuclear materials in course work, laboratory demonstrations, and experimental research.



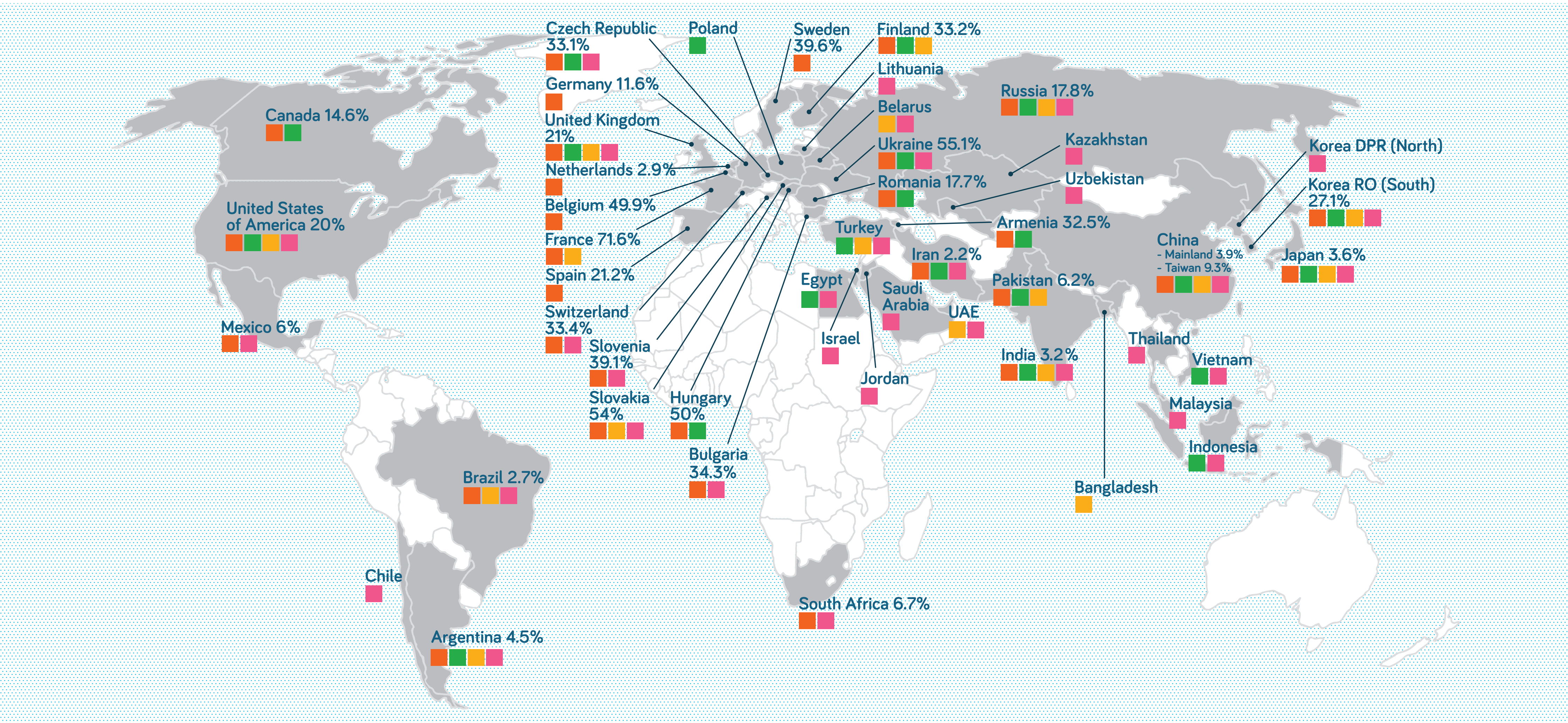
Industry: Some kinds of radiation can be used to measure the thickness and structure of materials and detect defects.



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 452 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 55 more reactors are under construction.



452 — OPERATING REACTORS
151 — PLANNED REACTORS
55 — UNDER CONSTRUCTION
337 — PROPOSED REACTORS

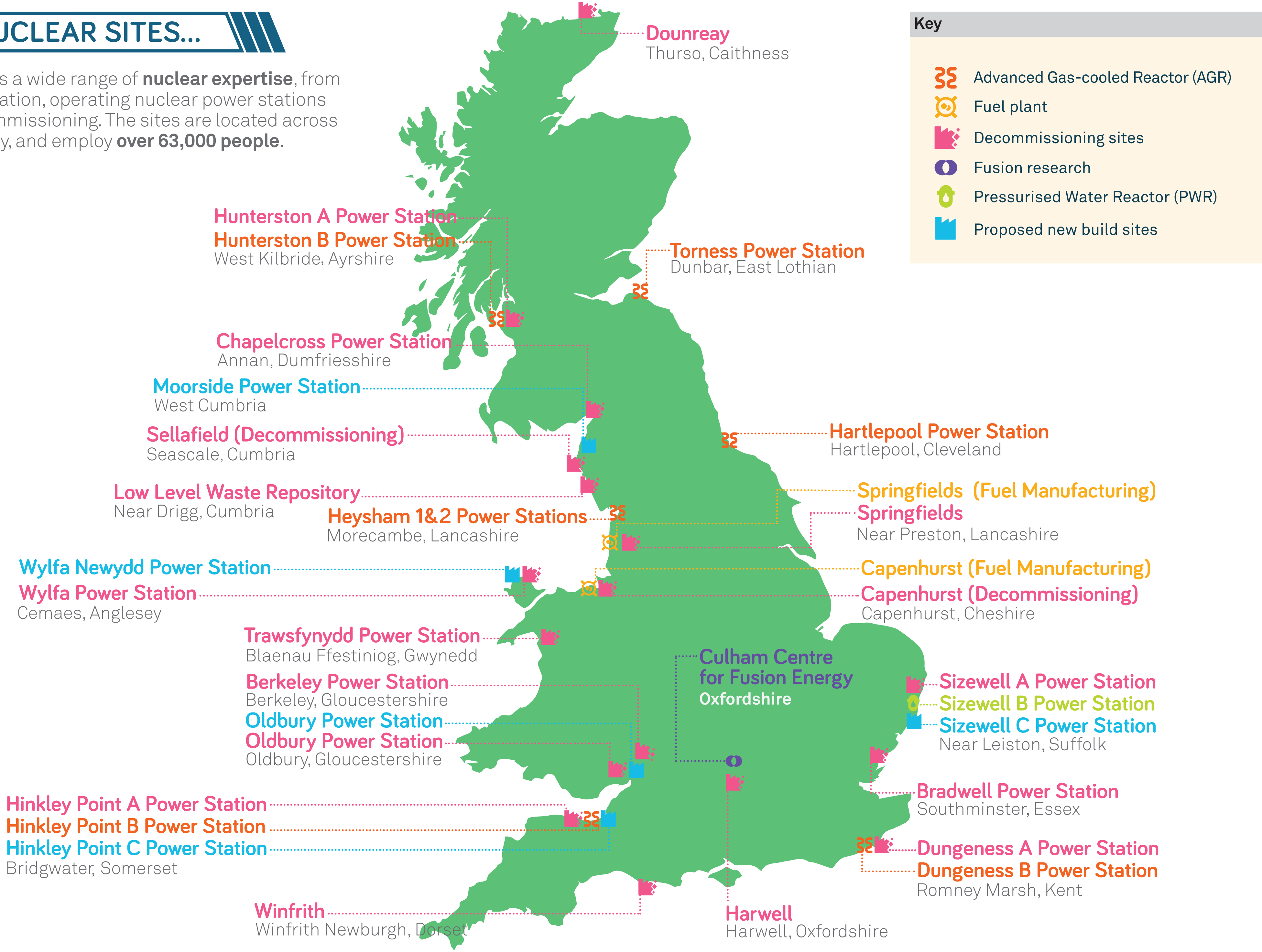
This map shows which countries around the world use nuclear energy as part of their energy mix as well as the percentage of that contribution where applicable. It also displays the countries planning to introduce nuclear energy.

(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 26 October 2018. Percentages of energy mix from IAEA figures for 2016.

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 63,000 people**.



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 close between 2023 and 2035. This means new nuclear power needs to be built to replace the lost capacity, provide secure always available electricity, and help meet targets to reduce the amount of carbon emissions from generating energy.

New nuclear power stations to replace the current fleet will be built on six existing sites across the UK; Anglesey, Cumbria, Essex, Gloucestershire, Somerset and Suffolk, with each project at varying stages of development.

The new build programme could create more than 50,000 job opportunities across the UK during construction, with at least 3,000 permanent roles once sites are operational.

Construction has begun at Hinkley Point C, the site of the first new nuclear station in more than 20 years. 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 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 new reactors in Cumbria and China General Nuclear, working with EDF Energy, also has plans to build Hualong One (HPR1000) reactors at Bradwell in Essex.



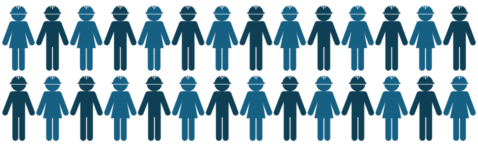

Images courtesy of: EDF Energy — www.edfenergy.com/energy; Horizon Nuclear Power — www.horizonnuclearpower.com

NEW BUILD IN NUMBERS...

Hinkley Point C

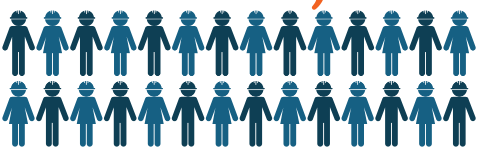
9MN tonnes of CO_2 avoided annually

64% project construction value predicted to go to UK companies

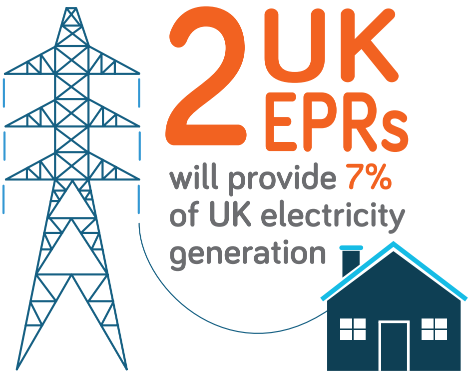


People currently working on site

OVER 3,100



2 UK EPRs will provide 7% of UK electricity generation



enough low carbon electricity to power around 6 million homes

Wylfa Newydd

Will operate for

60YRS

Technical Apprenticeship Scheme created in 2016 to support the next generation of workers

Main construction will see up to

£200 MN investment in Anglesey region

850 JOBS created once operational with the majority held by local population

LOOKING TO THE FUTURE...

Along with the ambitious new build programme, the UK aims to develop **small modular reactors** and continue to contribute to **fusion technology** research and development.

Small modular reactors are manufactured primarily in a factory, the completed components are transported in large modules to site for final simple assembly.

Gen IV advanced reactor designs focus on improving sustainability, safety, economics, reliability and proliferation-resistence. The UK has a stockpile of plutonium which can be used in conventional reactors, as mixed oxide fuel, or in new reactors which 'burn' plutonium to make energy.

The world's largest and most powerful fusion reactor, the JET Tokomak, is at the Culham Centre for Fusion Energy in the UK. The UK is also contributing significantly to ITER, a €6.6 billion international project, which will be the first fusion device to produce more energy than it consumes.

The UK Government is keen to support SMRs, Gen IV and fusion technology. In December 2017, the Government pledged funding of over £140 million to support research and development in these areas.

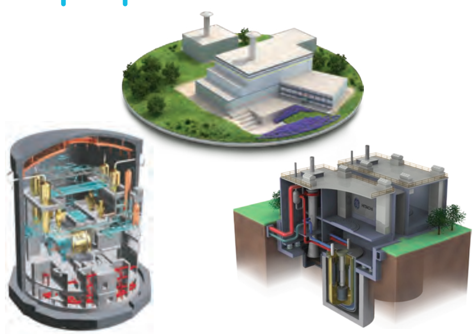
SMALL MODULAR REACTORS (SMRS) ARE MANUFACTURED IN A FACTORY AND COMPLETE COMPONENTS ARE TRANSPORTED TO THE SITE FOR FINAL ASSEMBLY

MANUFACTURE — TRANSPORT — ASSEMBLE

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...

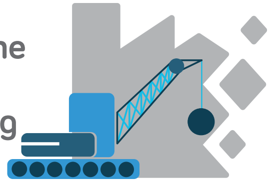
The first generation of nuclear power stations and early research facilities **left a legacy that requires management**. As a nuclear pioneer the UK has a particularly challenging portfolio to decommission.

Unfortunately waste storage and treatment was not well planned for, and in places there are no accurate blueprints for buildings or inventories, increasing the complexity of the work. The UK has become a world leader in decommissioning and is able to export expertise around the world.

The Nuclear Decommissioning Authority (NDA) was set up to manage the UK's legacy nuclear decommissioning challenges. Many of the challenges faced require innovative, unique, high-tech engineering solutions combined with expert people. By 2020 the final nuclear fuel from the UK's first nuclear power stations will have been processed and the radiological hazard on all Magnox sites reduced by 99%.

For future projects the cost of decommissioning reactors and sites will be funded by the operator, with money set aside over the years the reactor is generating. The taxpayer will not pay a penny.

17 sites across the UK undergoing decommissioning



More than £1.5 million saved across Magnox fleet by reusing equipment on site

The NDA have awarded R&D contracts worth up to £12 million

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** in a variety of roles.

The industry is looking for those with an interest in science and technology. However, careers are not limited to technical and engineering roles, with demand also in legal, finance and communications.

The industry looks for people with analytical and problem-solving skills, the ability to manage complex projects and good written and verbal communications.

Routes into the nuclear industry can vary with some people completing an apprenticeship, where you learn while you work. Others will complete a degree and then take on a graduate position. The grades needed will vary per company and the type of role.

Visit the career advice links on the following page for more information on your vocational options in the UK civil nuclear industry.

Need to recruit 7,000 workers annually

Nuclear workforce pay scales can range from £24,000 to £70,000 per year

2,895 people in apprenticeships and graduate schemes

Images courtesy of: EDF Energy — www.edfenergy.com/energy; Horizon Nuclear Power — www.horizonnuclearpower.com; Sellafield Limited — www.gov.uk/government/organisations/sellafield-ltd

FURTHER INFORMATION...

Visit the following websites for more information on the civil nuclear industry in the UK and overseas.

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

Learn about how Industry is governed:

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

Learn about operations, new build and decommissioning:

- www.edfenergy.com/energy
- www.horizonnuclearpower.com
- www.nugeneration.com
- www.gov.uk/government/organisations/sellafield-ltd
- www.gov.uk/government/organisations/nuclear-decommissioning-authority
- www.magnoxsites.com
- www.urenco.com/about-us
- www.westinghousenuclear.com/springfields
- www.oranoprojects.uk
- www.framatome.com/EN/home-57/index.html
- www.hitachi-hgne.co.jp/en
- en.cgnpc.com.cn
- www.ukhpr1000.co.uk/about-us
- www.westinghousenuclear.com/New-Plants/AP1000-PWR

For research & development:

- www.nnl.co.uk
- https://www.woodplc.com/capabilities/clean-energy-solutions/analytics,-technology-and-laboratories
- www.namrc.co.uk
- www.ccfe.ac.uk
- www.nirab.org.uk

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.

NIAUK.ORG

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