TORNESS NUCLEAR POWER STATION

A guide to the environmental impacts

Index

About this guide

This guide explains the different ways that generating electricity at Torness power station affects the environment. Understanding this is important to us and being a sustainable and responsible business is at the heart of what we do.

What it covers

This guide presents Torness power station's environmental impact in terms of:

- biodiversity and land use at the Torness site
- substances emitted that have the potential to damage the environment
- radiation and other safety and risk-related issues
- land use
- noise.

This guide covers far more than just what happens at the power station itself. It takes into account the whole life cycle of the electricity Torness produces from mining and manufacturing the fuel, generating the electricity, to safely processing the radioactive waste. Assessing the different stages of the life cycle of the electricity produced by Torness makes it possible to compare stages in the generation process against each other and see where the biggest inputs and impacts are.

A power station not only has environmental impacts but also social and economic impacts. We conducted a study of the socioeconomic impacts of EDF Energy's operations in the UK, which is available on our website.

What it's based on

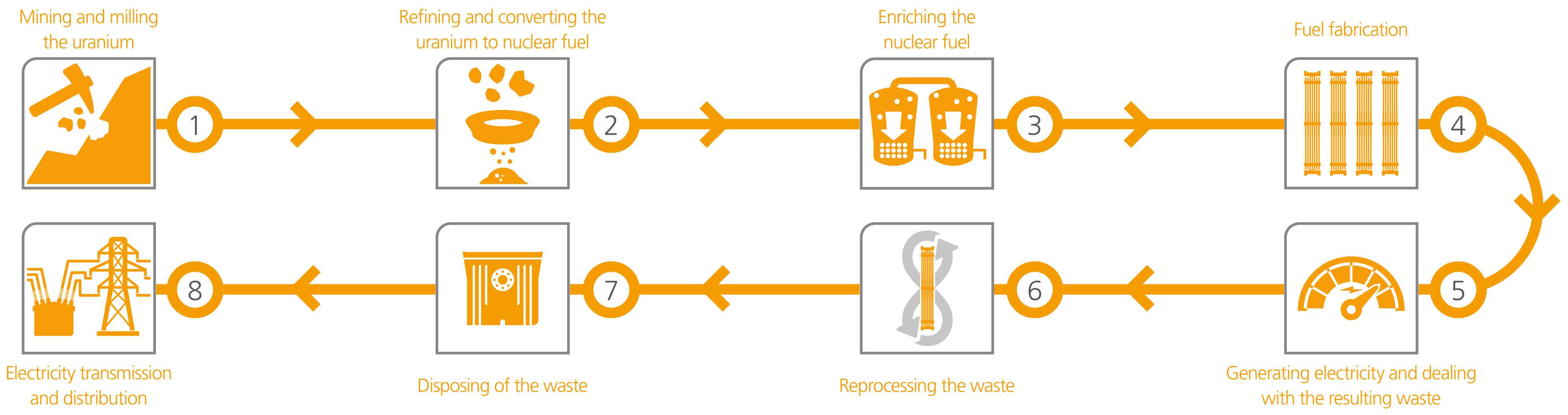
This guide is adapted from an assessment called an Environmental Product Description (EPD) that was originally carried out in 2014 and published in 2015. Most of its facts and figures still apply today – because EPDs deal in life cycles, their results don't change significantly over time. Where necessary however, we've updated the information in this guide to reflect changes that have taken place since then. Torness can be taken as representative of all of our advanced gas cooled reactors.

The original assessment followed established guidelines for producing EPDs – a type of report that helps companies understand the environmental impacts of their products and services. The original EPD was prepared for information purposes only. Whilst due care was taken in compiling and internally peer checking the information, the original report was not independently verified or registered on any EPD databases.

Summary

Where the biggest environmental impacts are

The life cycle of electricity produced at Torness is made up of numerous stages which we explore in this report. They are:



The biggest environmental impacts of the electricity produced at Torness are generated by the first stage - mining and milling the uranium ore. Other stages with big environmental impacts include, building and operating the power station (part of stage 5), and reprocessing the spent fuel (stage 6). These processes have the biggest environmental impacts because they need large amounts of electricity or thermal energy, or use materials like steel or copper, which are energy intensive to produce.

In this report we explain and explore four main environmental impacts of each stage:

- **G** Greenhouse gas emissions
- **A** Acidifying gases
- **O** Ozone depleting emissions
- **E** Eutrophying emissions

We also look at the levels of radiation and radioactive waste that Torness produces and how these compare to national guidelines. While all the stages in the Torness electricity cycle impact biodiversity in some way, in this guide we focus on those impacts on land use and wildlife at Torness power station.

About Torness

Torness is a nuclear power station – one of eight in the UK owned and operated by EDF Energy.

Like most nuclear power stations, its role is to provide base-load: to safely generate electricity 24 hours a day, 365 days a year, to maintain secure supplies at all times and to help meet our minimum everyday electricity needs.

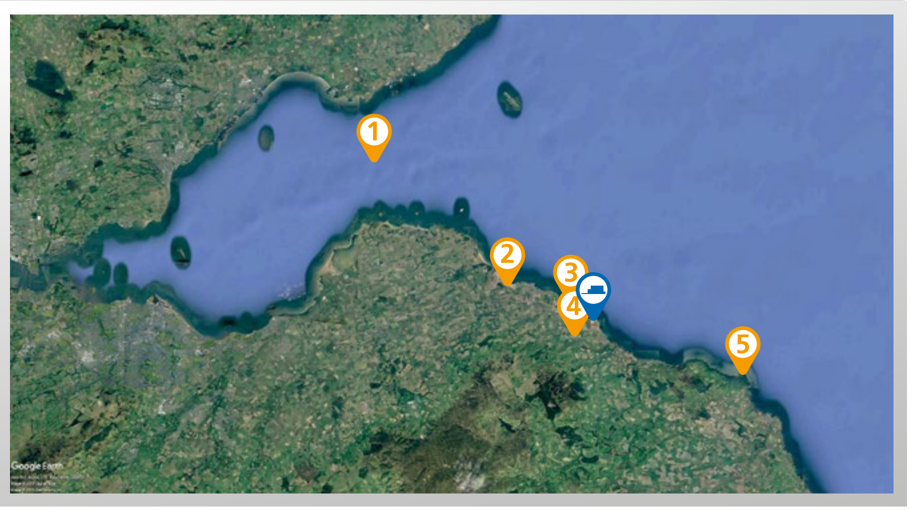
Torness has two reactors. Each one shuts down for a few weeks every three years for routine inspection and maintenance. As Torness refuels at power, the aim is to run continuously for three years.

About the area

location: Near Dunbar, East Lothian coast, Scotland.

Torness nuclear power station.

1. **Firth of Forth:** Special Protection Area and internationally important wetland site. Supports large numbers of wintering wildfowl and wading birds.
2. **John Muir Country Park**: established 1976, Important for wildfowl and wading birds.
3. **Barns Ness Coast:** Site of Special Scientific Interest.
4. **Thornton Glen:** Scottish Wildlife Trust nature reserve.
5. **St Abbs and Eyemouth Voluntary Marine Reserve:** part of the Berwickshire and North Northumberland Coast Special Area of Conservation.



FACT BOX

FUEL: Enriched uranium oxide

REACTOR DESIGN: Twin advanced gas-cooled reactors (AGRs)

NET CAPACITY: 1,190 megawatts (MW)

AVERAGE GENERATION: 8,800 gigawatt-hours (GWh) a year

STARTED GENERATING: 1988

DESIGNED TO LAST FOR: minimum of 35 years

The breakwater at Torness provides an extra line of protection for the station from the North Sea

Skylark

Land use and biodiversity

Using old aerial photographs of Torness, we can compare the use of the land today and in 1977 before the power station was constructed. The total area of EDF Energy's landholding at Torness is around 144 hectares of which 29.7 hectares are occupied by our operations.

Besides the construction of the power station itself, the most significant changes at the site have been along the coastline with the construction of the breakwater, harbour and heavy load berth. Otherwise, non-operational land has changed relatively little with most of the former construction areas restored to arable farmland. There has been some increase in semi-natural grassland, mainly on the site that was used for the contractor's compounds during the building of the power station.

EDF Energy is committed to conserving and enhancing biodiversity at Torness by actively managing the different habitats including woodland, scrub, grassland and the coastal foreshore. Our Biodiversity Action Plan sets out our objectives, actions and targets for achieving this. We also monitor the wildlife on the site to help us to understand what progress we are making in meeting our objectives and targets.

Much of the foreshore and coastal fringe of the site forms part of the Barns Ness Coast Site of Special Scientific Interest (SSSI), which is notable for the geological and botanical interest of its coastal habitat. The East Lothian coastline has long been a popular destination for tourists enjoying the wildlife and scenery. EDF Energy works with Scottish Natural Heritage and the East Lothian Countryside Ranger Service to ensure that visitors can enjoy the coastline and its wildlife, whilst ensuring that the special interest of the SSSI is protected.

Once the station was built, some woodland and shrub planting was undertaken along the station access road. In 2002, an additional 3,000 native trees and shrubs were planted on the former contractor's area. These woodland and scrub habitats provide landfall shelter and food for passage and migrant birds in spring and autumn including several rare species like yellow-browed warbler, rustic bunting and barred warbler.

Bird and bat boxes have been installed in the woodlands around Torness. Some of the bird boxes were quickly adopted by nesting tree sparrows, a species that's on the Scottish Biodiversity List. The List comprises animals, plants and habitats that Scottish ministers consider to be of principal importance for biodiversity conservation in Scotland.

The rough grassland of the former contractor's area and the coastal margin provides habitat for good numbers of ground nesting skylark (another Scottish Biodiversity List species) and meadow pipit. Some of the grassland is only mown once a year; the aim of letting the grass grow is to increase the numbers of wildflowers including bird's-foot-trefoil, pyramidal orchid, northern marsh orchid, lady's bedstraw, restharrow and hairy tare. In all, fifteen butterfly species have been recorded including small heath and wall brown (another Scottish Biodiversity List species). Rock roses have been planted with the aim of attracting the northern brown argus butterfly.

Northern marsh orchids

Narrow bordered five spot burnet moths

Burnet moth pupal cases can be seen on plants and posts around the station

At Torness, a wild bird feed crop is planted to provide a winter food source for nationally declining farmland birds like reed bunting, skylark, yellow hammer and grey partridge. Winter stubbles in some of the arable fields are also beneficial for these species.

EDF Energy looks to identify ways in which staff and visitors can enjoy the diverse wildlife of Torness through education, participation and partnership. Interpretation panels and a self-guided leaflet highlight some of the wildlife to be seen around the site.

Burnet month caterpillar

FACT BOX

UNITS PER KILOWATT-HOUR:

Rather than show the total amount of each substance that will be emitted over Torness's whole life cycle, we show how much is emitted for each kilowatt-hour (kWh) of electricity the power station generates. This makes it possible to compare Torness's emissions with other power stations of different types and designs.

E: Many of the units in this guide contain a small "e" or "eq" for "equivalent". When emissions of several different substances all contribute to the same effect, we use this to show their combined impact as a single figure. For example, carbon dioxide and methane both contribute to climate change. Instead of reporting Torness's carbon dioxide and methane emissions separately, we:

- work out the impact of the methane emissions on climate change
- work out how much carbon dioxide would have the same impact
- add that amount to the carbon dioxide equivalent figure.

The station's impact on the environment

Generating electricity at Torness releases different substances that affect the environment in various ways. These figures include emissions not just from the Torness site itself, but from every facility and process involved in enabling electricity to be generated there – from uranium mines to radioactive waste repositories.

All the different stages of Torness's life cycle combined release a wide range of potentially harmful substances, but at each individual stage the amounts released are very small.

Producing electricity from uranium – a life cycle approach

Adopting a life cycle approach to how electricity is produced at Torness means looking at all the activities involved in producing electricity from uranium, from mining uranium ore to safely disposing of spent nuclear fuel, along with their environmental impacts. The diagram shows the usual nuclear fuel cycle and the environmental impacts that result from each stage.

In reality, Torness's specific nuclear fuel cycle is more complex. For instance, not all of its fuel may have come straight from uranium mines; some might have been recycled from other uses. Similarly, some of its own spent fuel might be recycled and reused instead of going straight to disposal.

Environmental impacts of each stage – what this guide looks at

In this guide, we are looking at four main types of emissions produced at each stage of the electricity production life cycle. They are:

G **Greenhouse gas emissions** – which can contribute to climate change when they're released into the atmosphere.

O **Emissions of ozone-depleting substances** – ozone-depleting substances (ODS) damage the stratospheric ozone layer, a part of the atmosphere that protects us from harmful ultraviolet radiation. ODS include halons, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

A **Acidifying gas emissions** – acidifying gases cause acid rain, which can harm plants and aquatic wildlife, and erode buildings.

E **Eutrophying emissions** – eutrophication describes when water is overwhelmed with nutrients. This leads to the excessive growth of organisms like algae which can deplete the supply of oxygen in the water. In turn, this can harm aquatic animals. Eutrophying emissions are those that contribute to eutrophication.

Torness: key environmental impacts

FACT BOX

THE DIFFERENCE BETWEEN MICROGRAMS AND MILLIGRAMS:

- 1 milligram is equal to 1000 micrograms
- Milligrams are abbreviated as mg
- Micrograms are abbreviated as µg

IN SIMPLE TERMS THE MASS IN MG IS EQUAL TO THE MASS IN µG TIMES ONE THOUSAND.

G **Greenhouse gas emissions**

8.35 grams per kilowatt-hour

Carbon dioxide (CO_2) is one of the most common greenhouse gases. CO_2 emissions alone make up more than 92% of the greenhouse gas emissions related to Torness.

O **Emissions of ozone-depleting substances**

1.03 micrograms per kilowatt-hour

Ozone-depleting substances (ODS) damage the stratospheric ozone layer, a part of the atmosphere that protects us from harmful ultraviolet radiation. They have contributed to the ozone hole over the Antarctic. ODS include halons, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Use of ODS gases is being phased out at Torness and across off-site activities.

A **Acidifying gas emissions**

63.4 milligrams per kilowatt-hour

Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) account for more than 98% of acidifying gas emissions related to Torness. The rest is mostly ammonia (NH_3).

E **Eutrophying emissions**

20.7 milligrams per kilowatt-hour

Phosphates make up around 62% and nitrogen oxides (NO_x) make up roughly 21% of the eutrophying emissions related to Torness.

What is covered by each stage?

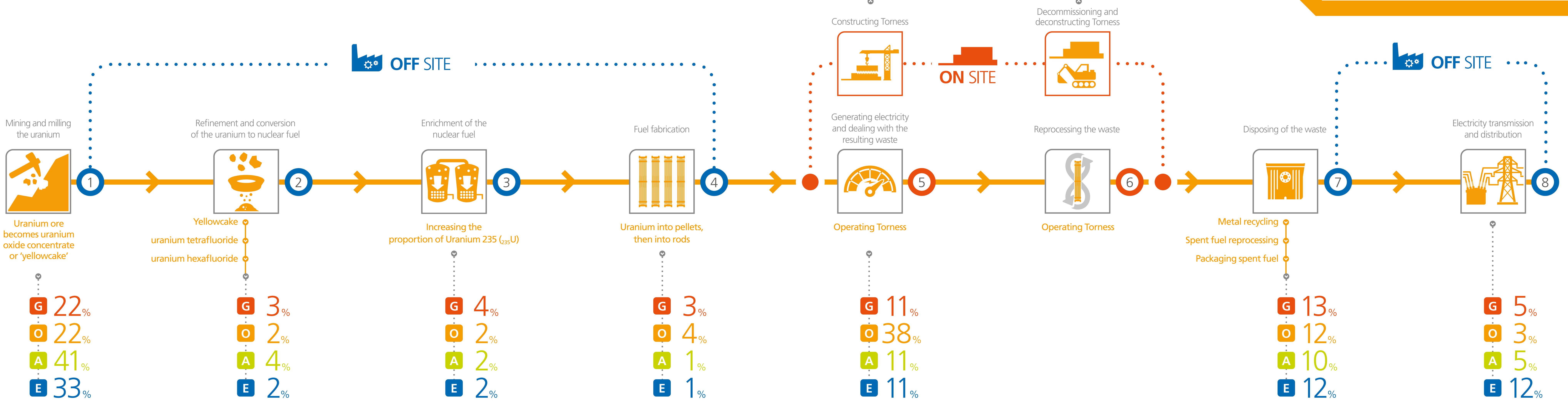
Stage	Activities	Activities of suppliers
1	Extracting natural energy resources to mine and mill uranium. Preparing and processing resources.	
2	Preparing and processing uranium to become fuel. Transportation: extraction ➡ refinery ➡ conversion plant.	
3	Preparing and processing fuel. Transporting fuel.	
4	Preparing and fabricating fuel. Transporting fuel.	
5	• Building reactor and other infrastructure including digging, foundations, roads etc. within the site, and respective construction processes. • Reactor, machinery, cables, tubes and other equipment needed for the conversion process and reserve power. • Fuel storage process. • Energy conversion process of plant(s). • Maintenance (for example lubrication, but not reinvestment of components). • Reserve power and reserve heat including test operation. • Transporting waste. • Handling/treating/disposing of other operational waste. Reinvestments of material and components during the estimated technical service life. • Facilities for handling of radioactive waste (on site and elsewhere) and facilities on site for handling of waste, residues and wastewater. • Connecting to the power network. Defuelling.	Factory buildings. Machines. Extraction of natural resources for fuels, materials and chemicals used by suppliers. Production of fuels and electricity used by suppliers producing other inputs into power station. Transporting goods and services to and from power station.
6	• Reprocessing spent fuel. • Facilities for handling and/or reprocessing spent fuel.	
7	• Handling/treatment of spent nuclear fuel and radioactive waste. Transporting waste	
8	Average transmission / distribution losses associated with the transmission and distribution of electricity to a consumer, defined with respect to connection voltage. Infrastructure of the distribution system, construction, reinvestments and dismantling.	

In this guide we quantify the main emissions and substances produced during the electricity life cycle in grammes, milligrams or micrograms. However, the impacts of each one varies considerably; microscopic amounts of one substance or emission type may be far more significant than larger amounts of another. Quantifying emissions and substances provides scale and context, but is no guide to significance.

KEY

- **G** Greenhouse gas emissions
- **O** Ozone depleting emissions
- **A** Acidifying gases
- **E** Eutrophying emissions
- Life cycle emissions

* All figures have been rounded up to the nearest percent.



Environmental impacts of each stage of the electricity life cycle at Torness

BEFORE TORNESS

In this section, the emissions figures cover the construction and operation of the facilities involved – but not their eventual dismantling.

Stage 1: Mining and milling

THE PROCESS

Mining produces uranium ore. In its natural state, uranium ore may contain as little as 0.1% uranium, often less.

At the milling stage, the ore is crushed, ground up and sulphuric acid is added to enable the uranium to be separated from the rock. The resulting solution is dried and then heated to produce U_3O_8, which is also known as uranium oxide concentrate or 'yellowcake'. This typically contains over 80% uranium.

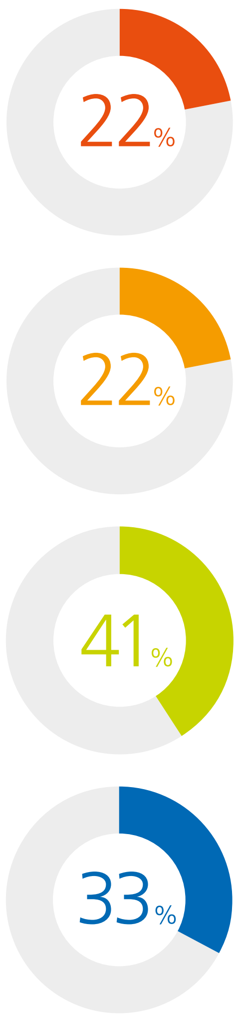
FACT BOX

ABOUT URANIUM

Uranium is a slightly radioactive metal found in the Earth's crust. It's around 500 times more abundant than gold and about as common as tin. It is present in most rocks and soils as well as in many rivers and in sea water. It is, for example, found in concentrations of about four parts per million (ppm) in granite, which makes up 60% of the earth's crust.

There are various sites around the world with sufficiently high concentrations of uranium in the ground to make its extraction for nuclear fuel economically feasible. Such concentrations are called ore.

Uranium mines



Mining and milling: impacts and causes

As the mining and milling stage is responsible for a significant proportion of emissions associated with producing electricity at Torness, we explore the details here. This stage is the largest emitter of acidifying gases in the electricity life cycle at Torness, and is one of the main sources of the station's ozone depletion and eutrophication impacts.

G Greenhouse gas emissions

The mining and milling stage is responsible for 22% of the total greenhouse gas emissions of the life cycle of the electricity produced at Torness. These GHGs are generated from the use of fossil fuels at the mines and from producing certain chemicals used in this stage.

O Emissions of ozone-depleting substances

This stage produces 22% of Torness' total emissions of ozone depleting substances.

A Acidifying gas emissions

This stage accounts for 41% of the acidifying gases produced during the electricity life cycle at Torness. These acidifying gases are created from producing sulphuric acid – which is used to bring out the uranium from the ore, which emits sulphur dioxide (SO_2). A small amount of nitrogen oxide (NO_x) emissions comes from chemicals used to make explosives for blasting (part of the mining process).

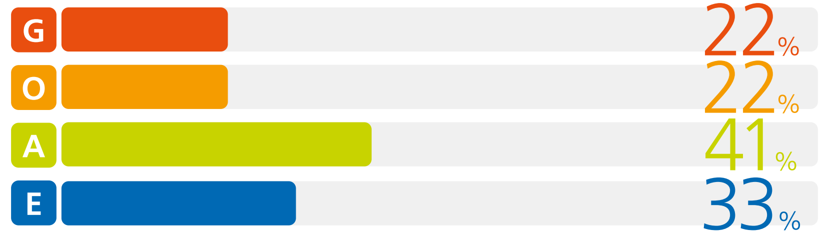
E Eutrophying emissions

The mining and milling stage generates a third of the eutrophying gases produced during the electricity life cycle at Torness. Extracting the valuable minerals from mined ore creates by-products known as tailings. Disposing of mine tailings creates 41% of this stage's phosphate emissions. Primary fuels used in the construction of mines also produce waste. Disposing of this waste also generates phosphate emissions.

Other waste

This stage is one of the main sources of rock and mineral waste in the electricity life cycle at Torness. It also generates the most particulate emissions – microscopic airborne solid matter like soot. These particulates are produced by the movement of rock and the incomplete combustion of fossil fuels.

IMPACT AT A GLANCE



Stage 2: Refinement and conversion

THE PROCESS

Once the uranium ore has been crushed, ground up and sulphuric acid added to enable it be separated from the rock, the resulting solution is dried and heated to produce U_3O_8. This also known as uranium oxide concentrate, or 'yellowcake' and typically contains over 80% uranium.

As yellowcake contains impurities it cannot be used directly as fuel in a nuclear reactor. The refinement process purifies the yellowcake by converting it into UF_4, uranium tetrafluoride. After that it is then converted into a gas, UF_6 or uranium hexafluoride.

Stage 3: Enrichment

THE PROCESS

In its natural state, only 0.7% of uranium is capable of undergoing fission, the process that creates energy in a nuclear reactor. This fissile type of uranium is called ^{235}U. The enrichment stage involves increasing the levels of ^{235}U in the uranium hexafluoride gas (UF_6). Typically, this can involve enriching the ^{235}U content from between 3% and 5%. In the case of Torness, in 2011 and 2012, the UF_6 was enriched to around 3%. This was done using gas centrifuges.

Stage 4: Fuel fabrication

THE PROCESS

Fabrication involves converting enriched UF_6 into uranium dioxide powder (UO_2). This powder is compressed into ceramic pellets which are then encased in metal tubes to form fuel rods. These rods are packed together to form fuel assemblies several metres long. Once this is done, the fuel is ready to go into the reactor.

This process has the potential for very rare but significant radiological safety incidents, so EDF Energy is extremely careful about its choice of suppliers. We vet suppliers and their facilities to make sure they have all the appropriate safety measures in place to prevent and cope with incidents.

At Torness

Stage 5 and 6: Generating electricity and dealing with waste

GENERATION - THE PROCESS

Through a process of fission, uranium atoms are split within the nuclear reactor in a controlled way, releasing energy which powers turbines, generating electricity. A single pellet of uranium contains as much energy as 149 gallons of oil, 480 cubic metres of natural gas or 807 kilogrammes of coal.

After it has been used, nuclear fuel remains radioactive and hot. To be stored safely it needs to kept cooled. To protect workers from radiation, the spent fuel needs to be encased in a dense material like steel, concrete or a few metres of water. A typical AGR power station will remove its fuel from the reactor whilst maintaining CO_2 cooling and then keep it underwater in a storage pond. After about five years the fuel can be put into dry, ventilated containers, but otherwise it can remain safely in storage pools. Spent fuel is stored temporarily at Torness before being transferred to Sellafield for reprocessing.

IMPACTS AND CAUSES

Generating electricity in a nuclear power station creates by-products including spent fuel rods and various other types of radioactive waste. These types include:

- **Low activity waste (LAW)**
  This type of waste tends to be made up of things that have become contaminated with small amounts of radioactivity like paper, rags, tools and protective clothing. Low-level waste (LLW) is stored temporarily at Torness before being sent for processing or disposal. Some is disposed of in a dedicated LLW repository in Cumbria. The majority is sent for processing or recycling at suitably licenced facilities.

- **High activity waste (HAW)**
  There is no HAW at EDF Energy power stations as it arises from fuel reprocessing. This type of waste is LLW with no current disposal route, intermediate-level waste (ILW) or high-level waste (HLW). This waste is mostly retrieved when a nuclear power station is decommissioned at the end of its working life. The reactor's metal cladding is classified as intermediate-level waste for example. Intermediate-level waste is stored at Torness until national authorities decide where to locate final disposal facilities.

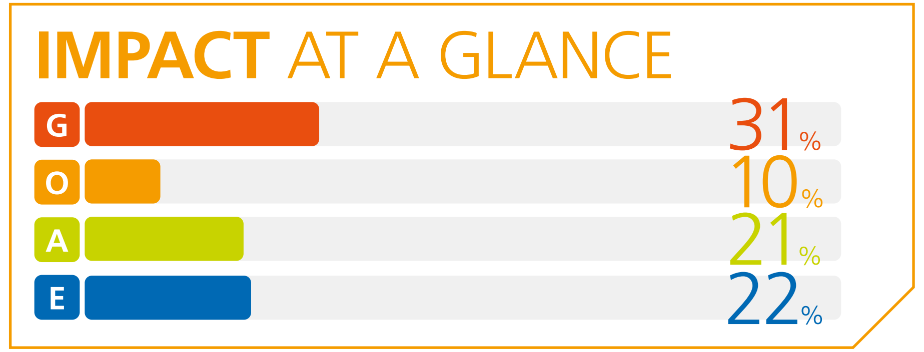
The construction of Torness

Before electricity can be generated, the station has to be constructed. Building a power station consumes electricity. As construction is responsible for a significant proportion of the environmental impacts associated with producing electricity at Torness, we explore the main impacts here.

G **Greenhouse gas emissions**
Overall, the construction phase is responsible for 31% of all the greenhouse gas emissions of the electricity produced at Torness. Generating the electricity needed to construct Torness accounts for 58% of the total CO_2 produced during this stage. The CO_2 emissions that are not due to electricity consumption arise mainly from manufacturing of steel and concrete that are used in the construction.

E **Eutrophying emissions**
Building Torness is responsible for 22% of all the eutrophying gases produced during the electricity life cycle at the station. Constructing Torness power station is one of the main contributors to eutrophication impacts of the electricity produced at Torness. Generating the electricity needed for construction creates tiny emissions of mercury and polycyclic aromatic hydrocarbons, known as PAHs. This is the name given to a group of over 100 different chemicals that are produced during the incomplete burning of organic materials (e.g. plant matter). These combustion processes produce a mixture of chemicals - soot is one example. Impacts at the construction phase are associated with various sub-processes that involve the combustion of fossil fuels – including the production of copper and steel. Manufacturing reinforced steel also contributes to mercury and PAH emissions.

Other waste
Surplus material from construction is one of the main sources of non-radioactive waste.



What resources are used in construction?

The environmental impact of the construction stage is as much about the materials and resources used as it is about the substances emitted.

Material resources

Used to manufacture building materials, materials needed to operate the power station and materials needed for waste disposal:

- Gravel
- Calcite
- Iron
- Clay
- Nickel
- Chromium
- Barite
- Aluminium
- Fluorspar
- Copper
- Magnesite
- Zinc
- Kaolinite
- Uranium
- Zirconium
- Wood (renewable)

Energy resources

Consumed directly (in heating and cooling, for example) and indirectly – when Torness uses materials that took energy to produce ("embedded energy").

- Coal
- Crude oil
- Natural gas
- Uranium
- Energy in biomass
- Converted kinetic energy in wind power
- Converted potential energy in hydropower
- Converted solar energy

WATER RESOURCES

- Freshwater
- Saltwater

FACT BOX

RADIATION EXPOSURE

The facilities involved in generating electricity at Torness deal with various radioactive substances. These substances emit ionising radiation, which could affect people both inside and outside the facilities. All the facilities have regulations to keep working people's radiation exposure well within safe limits.

In the UK, the annual statutory radiation dose limit for classified workers is **20 millisieverts (mSv)**. Everyone is exposed to a certain level of background radiation from the landscape. Radiation exposure can also occur through medical treatments and other sources. The UK dose limit only applies to exposure from non-medical, non-background sources.

The UK limit is deliberately set so that even if someone receives the maximum allowed dose, their risk of harm is still low. Even so, UK legislation requires us to keep doses to workers as low as reasonably practicable, so we set our self-imposed Company Dose Restriction even lower, at **10 mSv a year**.

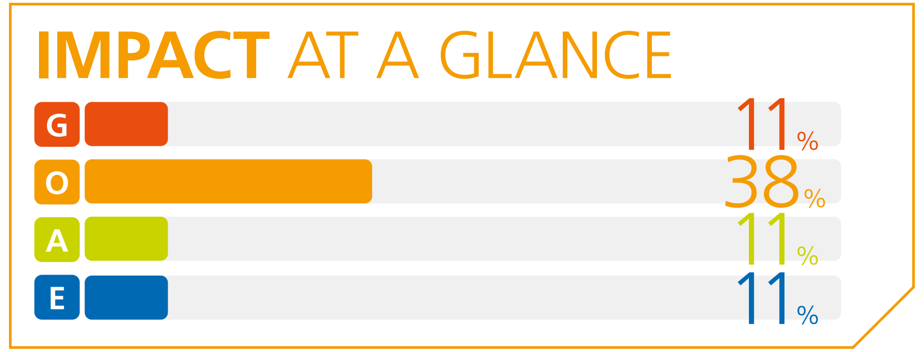
Operating Torness

O **Emissions of ozone-depleting substances**

Overall, the operating stage of the life cycle accounts for over a third of the total ODS emissions for Torness. However, over the past few years, ODS have been phased down and very little remains in use at any of our power stations.

A **Acidifying gas emissions**

Manufacturing sodium hypochlorite and anionic resin also produces acidifying gases, as does sulphuric acid production. In total, operating Torness is responsible for 11% of the total acidifying gases.



Radiological Safety

AVERAGE ANNUAL RADIATION DOSE TO PEOPLE WORKING AT TORNESS: 0.023 mSv.

Operating a nuclear power station has the potential for very rare but potentially high consequence radiological safety incidents, so we and the Government take safety at Torness very seriously. This section explores the legislatory and practical measures in place to maximise safety and minimise risk as much as possible.

FACT BOX

REGULATING NUCLEAR ELECTRICITY GENERATION

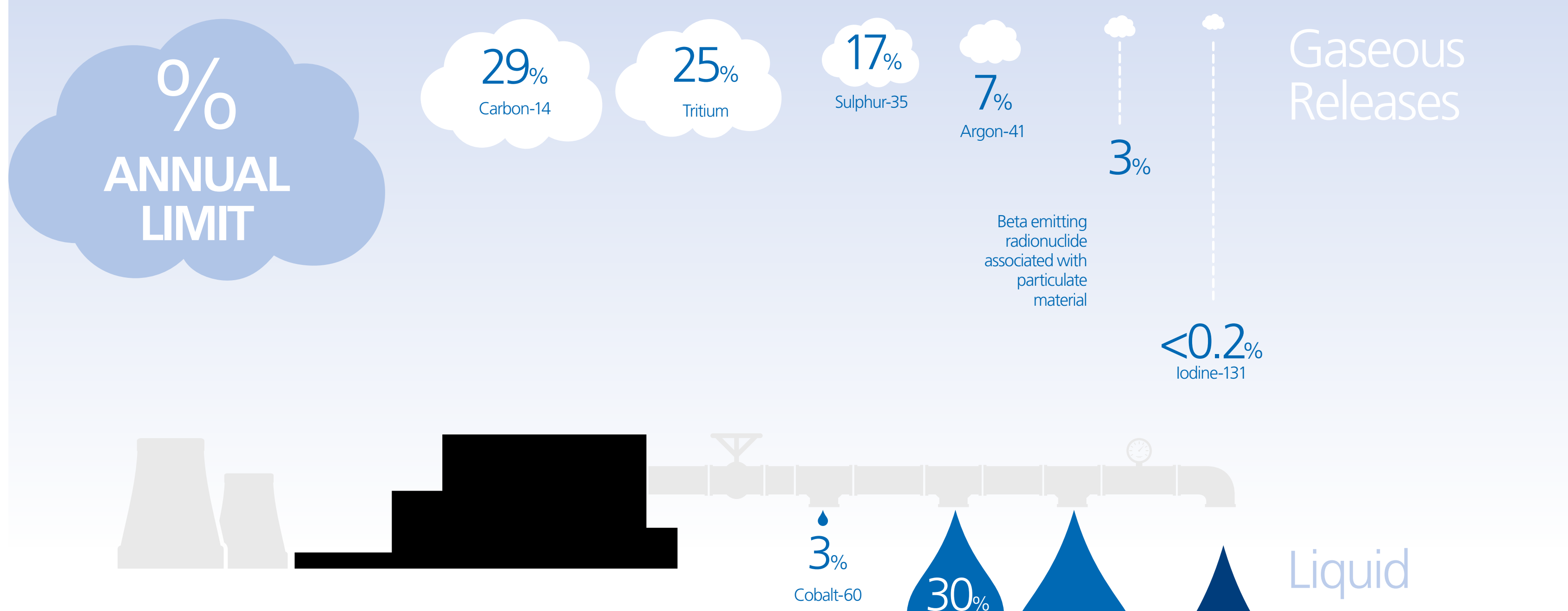
Operations at Torness are regulated by the Office for Nuclear Regulation (ONR) and governed by various acts of parliament. The main one is the Nuclear Installations Act 1965 (as amended), which means no one can construct, operate or decommission a nuclear site without a licence. Nuclear site licences place conditions on the licensee that ensure they will manage the site safely. The Scottish Environment Protection Agency (SEPA) is required to ensure that no members of the public is exposed to more than 1 mSv a year from the authorised disposal of radioactive waste. SEPA requires us to monitor and strictly control radioactive discharges from Torness. It also carries out monitoring around the station to determine the effect of any discharges on the general public.

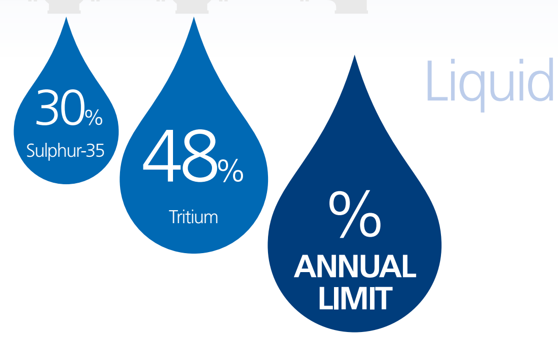
How do Torness' radiological impacts compare to national limits?

Controlled release of radioactive substances in the air and water within clearly regulated and safe limits is normal during nuclear electricity production. But how does an average yearly release from Torness compare to public dose limits and other, natural sources of radioactivity?

To put Torness' radioactive discharges into context, the public dose limit from artificial sources is 1 millisieverts (mSv) a year. The typical dose from natural sources is 2.2 mSv a year. Using typical figures from 2012, the diagram below shows that radioactive discharges from Torness fall well below existing discharge limits. The dose to the public from these discharges was about 0.003 mSv, less than 1% of the public dose limit from artificial sources.

Radiological discharges from Torness





Radiological discharges from Torness are monitored and strictly controlled by the Scottish Environment Protection Agency (SEPA) which also issues permits specifying the maximum limits within which the discharges should be kept. SEPA also monitors the area around Torness power station. SEPA's role is to ensure that discharges released by Torness do not exceed existing limits.

What safety measures are in place at Torness?

All nuclear power stations are designed and operated with multiple levels of protection against technical faults and hazards including fires, floods and earthquakes. These systems are intended to prevent radioactive emissions being released into the environment.

PREVENTION

We have identified and analysed possible fault scenarios and put procedures in place to prevent them from happening. These scenarios are reviewed regularly.

PROTECTION

Torness is equipped with essential safety functions including trip, shutdown, post-trip cooling and reactor monitoring, which protect against all potential faults. These protection systems are also designed to minimise the probability of them all failing at once.

MITIGATION

In the unlikely event that the prevention and protection systems fail and radioactive emissions are released, arrangements are in place to minimise the risk of exposure for the plant operator, the public and the environment. These include recovery and accident management instructions for the plant operator and an emergency plan.

Torness also has the following specific barriers in place to prevent the release of radioactive emissions.

- The solid fuel itself provides containment. The hard, stable ceramic pellets contain the fission products from the nuclear reaction.
- The pellets are clad in stainless steel fuel rods. These are designed to be leak-tight and to resist heat, corrosion and radiation damage.
- The fuel rods sit inside a steel-lined concrete pressure vessel. Its walls are more than five and a half metres thick and reinforced with more than 100 kilometres of steel cables. The vessel also serves as a biological shield that reduces radiation emissions.

All that said, the controlled release of radioactive substances into the air and water – within safe and clearly regulated limits – is a normal part of operations at nuclear fuel cycle facilities.

The Environment Management System at Torness

Torness has an Environmental Management System which is certified and registered to ISO 14001: 2015 (the international standard for such systems). It is an integral part of Torness's overall management system, which covers planning, accountability, routines and processes for the whole organisation.

The aims of the Environmental Management System are:

- to comply with and maintain EDF Energy's environmental policy
- to address radiological and conventional environmental issues.

Other environmental impacts

FACT BOX

REGULATING ELECTROMAGNETIC FIELDS

At the moment, we manage electromagnetic fields at Torness according to three sets of guidelines:

- the Health and Safety at Work etc Act 1974
- the Management of Health and Safety at Work Regulations 1999
- the International Commission on Non-Ionising Radiation Protection (ICNIRP) guidelines for the frequency range 1–100 hertz (Hz), published in 2010.
- the Control of Electromagnetic Fields at Work Regulations 2016 (the CEMFAW Regulations).

The energy industry and the Health and Safety Executive both use the ICNIRP guidelines to assess the risks of exposure to electromagnetic fields. For occupational exposure they set limits of 1,800 microteslas (μT) for magnetic fields and 46 kilovolts per metre (kV/m) for electric fields.

Electromagnetic fields

When Torness's generator converts kinetic energy into electricity, it creates an electromagnetic field. Electromagnetic fields are emissions in the lower frequency range of the electromagnetic spectrum: 0 to 300 gigahertz (GHz). Fields of different frequencies interact with the body in different ways.

Electromagnetic fields are omnipresent in our environment. Some are natural, and some are man-made; some are generated intentionally (such as radio signals), some unintentionally or as a by-product (such as in power transmission and electrical appliances).

Noise

Noise is often considered a nuisance and it can also be a potential health and safety issue.

Before giving us permission to build Torness, the planning authorities set out the maximum permissible levels, duration and timings of noise. We incorporated noise control measures at the design stage.

Deconstruction and decommissioning of Torness

While inevitably, there are some environmental impacts associated with the deconstruction and decommissioning stage of electricity production at Torness, they are relatively low compared to the mining and milling and construction stages.

After Torness

Radioactive waste produced by Torness and its suppliers can be transported by road, rail or sea – as long as stringent international regulations are observed. For example, the more hazardous categories of waste must be transported inside containers designed to withstand:

- a nine-metre free-fall onto a rigid surface
- 30 minutes in an 800°C fire, a normal fire burns at around 400-500 °C
- immersion in water up to 200 metres deep.

Our transport arrangements have been assessed and show that the risk of a radiological accident is very low – far below the level the Health and Safety Executive considers "broadly acceptable" (that is, low enough that we don't need to take any further action to reduce it).

Stage 7: Reprocessing

THE PROCESS

Reprocessing involves recovering uranium and plutonium and recycling this into new fuel. We expect about half the spent fuel produced over Torness's lifetime to be reprocessed at the Thermal Oxide Reprocessing Plant (Thorp) at Sellafield.

In 2011 we also started reprocessing and recycling metallic LLW waste at the Cyclife metallic recycling facility in Cumbria.

IMPACTS AND CAUSES

G Greenhouse gas emissions

Reprocessing spent fuel generates significant CO_2 emissions, which are produced by:

- consuming diesel and electricity to operate the facilities
- manufacturing chemicals used in the reprocessing operation
- manufacturing chemicals used in the production of steel, cement and glass – all of which are used in the conditioning of high and intermediate level waste (HLW and ILW)
- the solid waste streams (radioactive and non-radioactive)
- transporting fuel, wastes and other materials.

O Emissions of ozone-depleting substances

Reprocessing spent fuel uses bentonite, a type of clay. Processing bentonite uses hydrochloric acid and producing hydrochloric acid emits ozone depleting substances, so this stage contributes particularly to ozone depletion. Reprocessing spent fuel also produces LLW, ILW and some HLW.

Other waste

Encapsulating spent fuel uses copper, and refining copper produces minute emissions of arsenic, cadmium and lead.

Stage 8: Disposal

THE PROCESS

How waste is categorised determines how it is treated and where it goes. The sites and specific packaging arrangements for the final disposal of spent fuel, HLW and ILW in the UK are still to be determined. The Nuclear Decommissioning Authority (NDA) has proposed a deep geological repository for spent fuel and HLW, and a phased geological repository for ILW and some LLW.

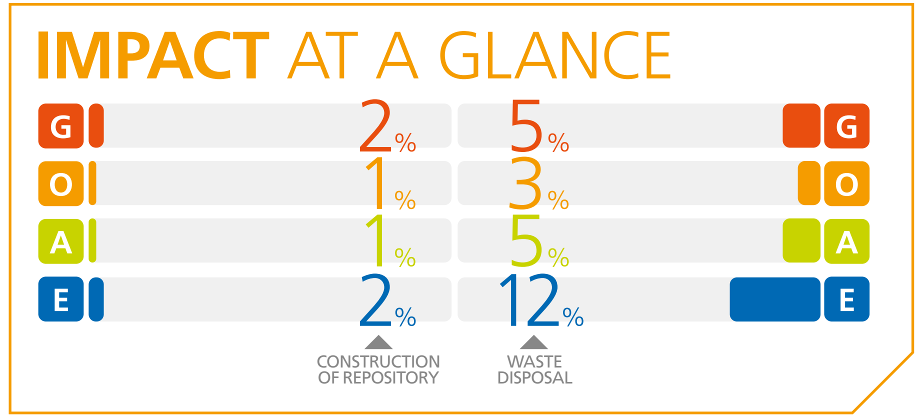
The Scottish Government requires ILW from Torness to be disposed of through "near site, near surface storage". Exactly what type of storage this will entail is still uncertain.

LLW is either disposed of in the LLW repository near Drigg in Cumbria low level waste repository (LLWR) or incinerated at the Fawley Incinerator in Hampshire. Some LLW is sent for processing before disposal, this includes super compaction to reduce volume. As much waste as possible is diverted from LLWR.

RADIOLOGICAL SAFETY

The final waste disposal facility will have several effective barriers against radioactive emissions, including:

- **physical containment –** packaging waste in steel or concrete containers
- **geological isolation** – placing the waste packages in deep underground vaults in a suitable geological environment
- **geological containment** – a suitable geological environment is one that will naturally contain the waste, after future generations have finally sealed and closed the repository
- **chemical conditioning** – eventually, at a time determined by future generations, backfilling the vaults with a cement-based material.



Stage 9: Transmission and distribution

The UK's electricity transmission and distribution systems are made up of lines, cables, transformers and substations. The environmental impact of this stage relates to the construction and maintenance of the grid, as well as overall losses of around 8% associated with the transmission and distribution of electricity.

About EDF Energy

The Better Plan

The Better Plan is EDF Energy's framework for being a sustainable and responsible business. Our Better Energy Ambitions set out our short, medium and long-term goals and targets for improving our social, economic and environmental performance.

For more about our sustainability programme, visit www.edfenergy.com/sustainability

Our nuclear power stations

We own and operate eight nuclear power stations in the UK. Their combined capacity is almost nine gigawatts (GW).

STATION	REACTOR TYPE	NET CAPACITY IN 2016 (MW)
Hunterston B	2 AGRs	965
Hinkley Point B	2 AGRs	955
Hartlepool	2 AGRs	1,180
Heysham 1	2 AGRs	1,155
Dungeness B	2 AGRs	1,050
Heysham 2	2 AGRs	1,230
Torness	2 AGRs	1,190
Sizewell B	1 PWR	1,198
	Total	**8,923**

Appendix 1: Methodology

What is life cycle assessment?

Life cycle assessment (LCA) is a standard method of quantifying and assessing the environmental impact – including emissions and resource use – of generating and distributing electricity. It captures the full nuclear fuel cycle and associated processes, from cradle to grave.

The reference period for the LCA was 24 months during 2011 and 2012, a period that captures the complete impacts of the AGR fuel cycle.

Approach

There are two possible approaches to LCA:

- Process chain analysis (PCA) – this is a bottom-up approach. Data is collected on each of the main production processes (or life cycle stages) and aggregated together to assess the impacts of the product as a whole. This allows for very detailed analysis, but data is not always available for the earlier stages of the life cycle, so may suffer from incompleteness.
- Input–output analysis (IOA) – this involves combining data aggregated at sector or sub-sector level with expenditure data to estimate the direct and indirect impacts of different sectors. This approach allows for analysis of the complete life cycle, but relying on sector average emissions introduces uncertainties, especially where environmental performance varies significantly within a given sector.

Our life cycle assessment used the PCA approach. As is usual for this approach, it was not possible to collect enough reliable life cycle data to fully capture the impact of every process or product. This may lead to an underestimate of the total impact, but we do not expect this to be significant.

Where products other than uranium are involved in the process, we included inputs and outputs that relate to activities involved in the uranium cycle, and excluded those that do not. Where this data was not available, we split emissions according to the economic value of the products.

Appendix 2: Glossary

Acronyms

AGR	advanced gas-cooled reactor
CFC	chlorofluorocarbon
CO_2	carbon dioxide
EPD	Environmental Product Declaration
GHG	greenhouse gas
HAW	high activity waste
HCFC	hydrochlorofluorocarbon
HLW	high level waste
ILW	intermediate level waste
IOA	input-output analysis
LAW	low activity waste
LCA	life cycle assessment
LLW	low level waste
LLWR	low level waste repository
NDA	Nuclear Decommissioning Authority
NH_3	ammonia
NO_x	oxides of nitrogen
ODS	ozone depleting substance
ONR	Office for Nuclear Regulation
PAH	polycyclic aromatic hydrocarbons
PCA	process chain analysis
PWR	pressurised water reactor
SO_2	sulphur dioxide
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
^{235}U	fissile uranium
U_3O_8	triuranium octoxide (uranium oxide concentrate)
UF_6	uranium hexafluoride
UF_4	uranium tetrafluoride.
UO_2	uranium oxide

Abbreviations and units

°C	degrees centigrade
e / eq	equivalents
μT	microteslas
μg	micrograms
g	grammes
GHz	gigahertz
GW	gigawatts
GWh	gigawatt-hours
Hz	hertz
kg	kilograms
kV	kilovolts
KV/m	kilovolts per meter
kWh	kilowatt-hours
m	metres
mSv	millisieverts
MW	megawatts
ppm	parts per million

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