TEACHER NOTES

THE MIGHTY ATOM
ACTIVITY

KS4

SAVE INK - don’t print this first page!

Activity overview

In this activity, students learn about the structure of an atom and how we generate electricity in a nuclear power station. They also learn about the role of nuclear power in the future UK energy mix and the range of job roles in the sector.

Learning objectives:

- Learn about atomic structure
- Understand that there are renewable and non-renewable energy resources
- Learn how the process of nuclear fission occurs
- Work scientifically through practical experiments and report on their findings
- Understand the important role of nuclear power in the UK's future energy mix
- Research jobs in the nuclear power industry

Subjects:

Combined Science
Physics
Chemistry

Gatsby Benchmarks

2: Learning from career and labour market information: Find out about access to jobs and career pathways in the nuclear power sector – particularly at Hinkley Point C.
4: Linking curriculum learning to careers: An understanding of how nuclear power is generated is critical for a career in the nuclear industry.

Timings

- Warm-up activity: 15 mins
- Main activity: 60-90 mins
- Careers in nuclear: 20 mins

Materials and set-up

This **Activity Pack** contains the following materials:

- Teacher notes
- Student worksheet

Materials needed:

- Dominoes (even Jenga blocks) OR magnetic balls and sticks
- Marbles (optional)

This activity can be used in the classroom, led by a teacher. Or share the Worksheet with students for independent learning, with additional support provided in the Teacher notes.

WARM-UP (15 mins)

Shrink to the size of an atom!

Discover what happens inside the core of a nuclear reactor at atomic level in **this film** from EDF. It uses virtual reality, so move the screen around to get a 360° view. Play the film and encourage students to take notes for the quiz at the end.

1. Q. What is uranium?
A. A natural element mined from deep in the ground.

2. Q. Why do we use water in our pressurised water reactors?
A. To slow down neutrons. It also acts as the coolant for the reactor too.

3. Q. How many nuclear fissions take place in each pellet per second?
A. 5 million million.

4. Q. How hot does the water get in the reactor as a result of nuclear fission?
A. More than 300°C.

5. Q. How fast does the heated water travel through pipes out of the reactor vessel?
A. 35mph

6. Q. What happens after the water leaves the reactor vessel?
A. It flows into a steam generator where it heats a separate circuit, heating the water in it to over 300°C.

7. Q. How much electricity is produced by the reactor in this film – and how many homes could it power?
A. More than 1000 MW of electricity – enough to power all the houses in Greater Manchester.

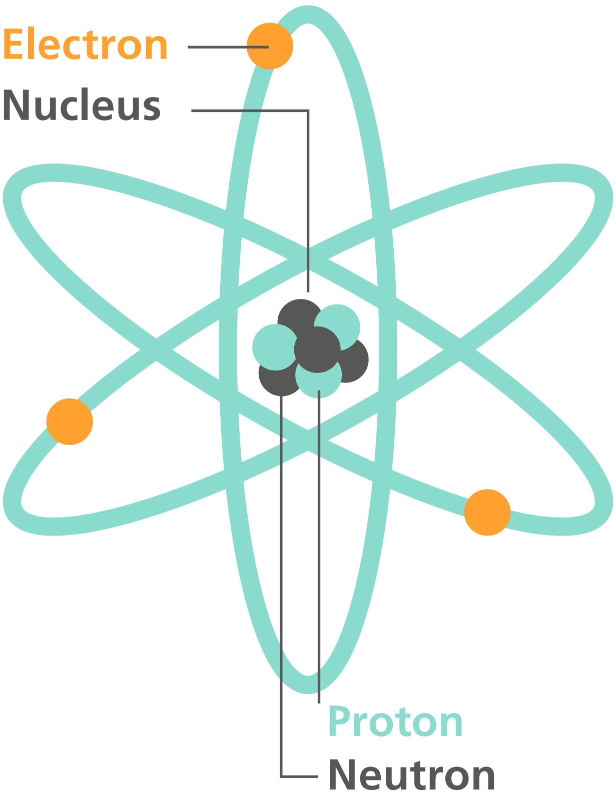
HPC Inspire

We're Hinkley Point C's Education Programme in Somerset and the wider South West region. And we're here to help young people take advantage of the huge opportunities that the construction and operation of HPC has to offer. We do this through a range of fun and innovative activities: including hands-on STEM workshops, careers assemblies and online learning resources.

THE MAIN ACTIVITY

(60-90 mins)

Part 1: Let's talk atoms…



Do you know what an atom is?

Everything in the universe is made of atoms. Your chair. Your mobile. Even your body! An atom is the smallest part of an element that can exist.

But atoms are really tiny, so you can't see them – and they contain even smaller particles, called protons, neutrons and electrons. The protons and neutrons are packed densely in the centre of the atom, forming its 'nucleus'.

Almost the whole mass of the atom is concentrated in this nucleus. But the nucleus is very small compared to the whole.

Question! What do you think the plural for nucleus is? It's 'nuclei'.

Electrons aren't in the nucleus. But orbit around its outside in 'shells'. And their mass is much smaller than the mass of a proton or neutron.

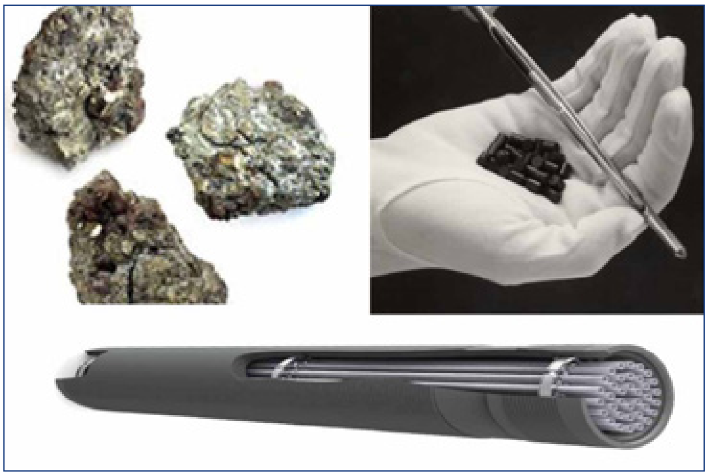
The number of electrons is equal to the number of protons in the nucleus. Neutrons have no charge – they are neutral.

But protons and electrons have opposite electrical charges: protons are positive, while electrons are negative. So atoms have no overall electrical charge.

Ask students to complete the two challenges in their Worksheet.

NAME OF PARTICLE	RELATIVE CHARGE
Proton	+1
Neutron	0
Electron	-1

Part 2: How we generate electricity from nuclear power



Nuclear fission is the process of splitting a large and unstable nucleus – like that found in uranium. This is the metal we use in a nuclear power station.

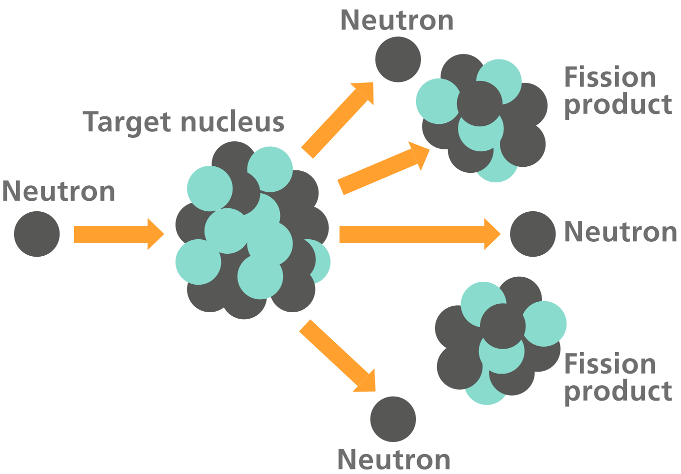
The pictures above show you what uranium looks like. It's a metal dug up from underground. And it's about as abundant as tin; it can even be found in seawater.

In our power stations, we use an enriched form of uranium, that we convert into black uranium dioxide (UO2) powder. This is compressed and baked into ceramic fuel pellets. Uranium is a very special metal, because some of the atoms in uranium are able to release energy and get hot all by themselves. This makes uranium **radioactive**.

It's unusual for fission to occur on its own; the nucleus has to absorb a neutron to initiate nuclear fission. And this is the process that occurs inside a nuclear reactor.

Ask students to take the quiz in their Worksheet (page 2).

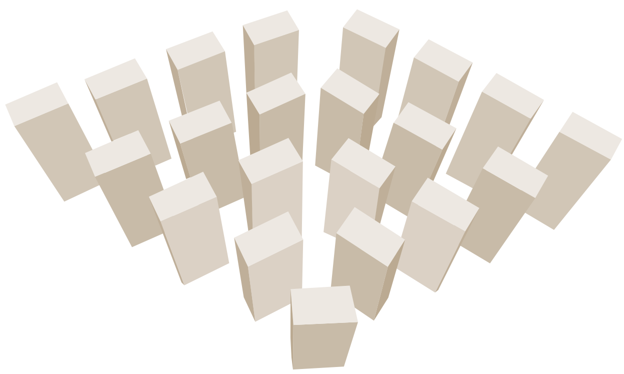
Create a chain reaction



When the nucleus of a uranium atom is hit by a neutron it splits into two. This is the process of **nuclear fission**.

These two smaller atoms are a similar size and still contain some energy. So that when another neutron bumps into them, they continue splitting and bumping into one another. This process is called a **chain reaction**.

Ask students to replicate this process using marbles, dominoes (even Jenga blocks) or magnetic balls and sticks (to replicate loosely neutrons and protons).



E.g. roll a single marble into a cluster of marbles. They should all scatter and go on to hit other marbles. Or set up dominoes in a formation like the one on the left.

Or, using magnetic balls and sticks, build a structure like the one above of a single bar with four balls attached to represent the unstable nucleus of a radioactive atom. Drop a single ball onto the model – it should fall apart.

Now, investigate what happens if lots of unstable atoms are near to one another. Build at least five of the unstable nuclei structures (like those above) and lay them down carefully one below another on a sloped surface (start building them from the top!). Drop a single ball from the top, letting it roll down into the unstable nuclei. More and more 'neutrons' (i.e. balls) ought to be knocked free in a chain reaction.

What happens? Can they rejig the marbles/dominoes/ magnetic balls and sticks if the chain reaction doesn't occur?

***Health and safety!* If marbles fall on the floor, they could cause somebody to slip.**

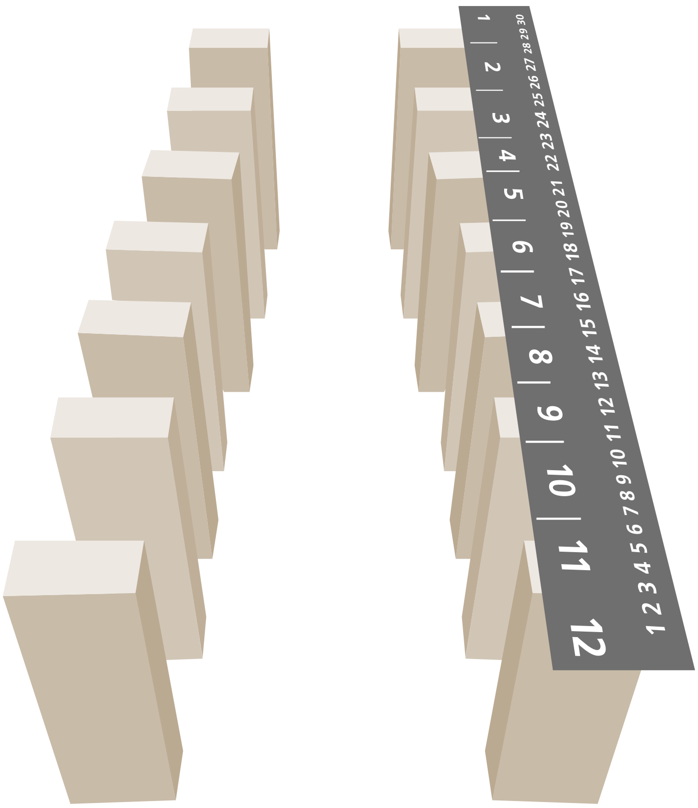
Ask students to label the diagram of a chain reaction in their Worksheet.

Controlling the chain reaction

In a real chain reaction, trillions of atoms could be decaying within a fraction of a second, creating an enormous amount of heat and energy. This can be dangerous, if lots of energy is released in an explosion.

That's why we control the chain reaction in a nuclear power station, to manage the energy that's released. We do that using boron control rods between the atoms to absorb excess neutrons.

Let's look at how this works… Ask students to line up two rows of dominoes (or Jenga blocks). On the second row, lie a ruler on top. Now what happens when they knock over the first domino/block in each row?



Or build some 'control rods' using the magnetic bars, like below:

Insert them between each pair of 'nuclei'. Depending on the slope, they'll probably need to hold each bar, or use a spot of Blu-tack, to stop them rolling. Now, repeat the previous experiment i.e. ask a student to drop a single ball from the top, letting it roll down into the unstable nuclei. What happens this time? (fewer 'neutrons' (balls) should be knocked free, as the rods block their path.)

Harnessing the energy from nuclear fission

All of the fission products created during a nuclear reaction have kinetic energy. In a nuclear power station, this is transferred into thermal energy and heats the water circulating around the reactor vessel into steam.

The water passes through pipes before circulating back to the reactor vessel. A second stream of water flows through the steam generator, around the outside of the pipes. This water is heated up and turns into steam.

The steam passes into a series of turbines and the heat energy becomes mechanical energy in the turbine and they spin. In turn, this makes a rod connected to the turbine spin really quickly too.

At the other end of the rod is a generator. This turns this mechanical energy into electrical energy (electricity), using an electromagnetic field. This electricity is now ready to be delivered to homes and businesses around the country.

The hot steam that's been used is cooled down with sea water, which is why nuclear power stations – like HPC – are usually built on the coast. This turns it back into water, so it can be reused in the process all over again to produce more electricity.

Ask students to annotate the image below in their Worksheet with the different steps:

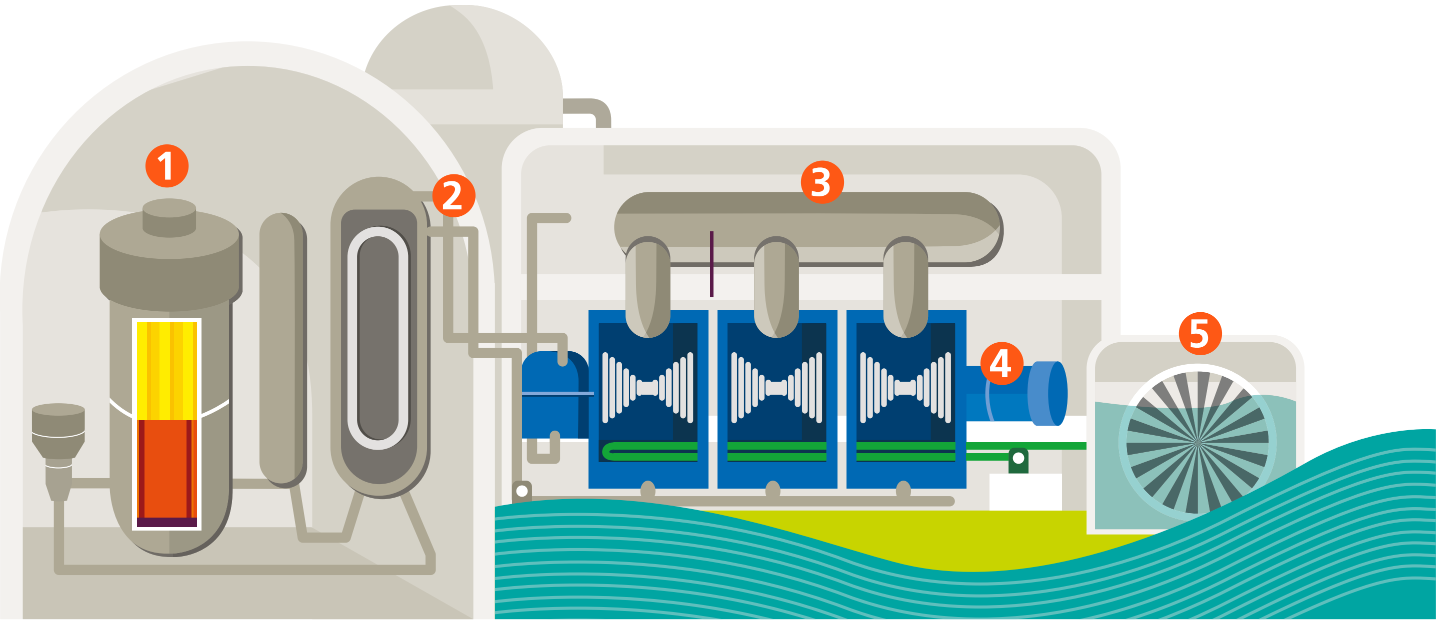
Step 1: The fuel rods are packed into a nuclear reactor. This is where nuclear fission occurs.

Step 2: The heat turns water into steam and it rushes out of the steam generator through pipes.

Step 3: The pipes carry the steam into turbines, which causes them to spin. And turns the rod connected to the steam turbine too.

Step 4: At the other end of the rod is a generator. This turns the kinetic energy into electrical energy (electricity).

Step 5: The hot steam is cooled down with sea water. So it turns into water and can be reused again in the process.



Did you know? Don't confuse nuclear fission with nuclear fusion… Nuclear fusion is the **joining** of two light nuclei to form a heavier nucleus. Whereas nuclear fission is the **splitting** of the nucleus into smaller atoms.

Part 3: Why is nuclear power important to the UK?

We need energy for almost everything we do on Earth.

Ask students to write down in their Worksheet as many things as possible that we need energy for in one minute.

Broadly, the main things we need energy for are:

- **Heating** – not just for our homes, but businesses too.
- **Transport** – there are vehicles that only use electricity (like electric cars). But all types of transport need some form of fuel source.
- **Electricity generation** – this is probably the thing students said we need the most! And our reliance on electricity is growing, as we switch to electric heating, electric cars etc.

Nuclear power is one of the main energy resources we use on Earth. Other resources include **fossil fuels** (coal, oil and gas), **biofuel**, **wind**, **hydro** (water), **geothermal**, **tidal**, **solar** and **waves**. Energy resources can be divided into renewable and non-renewable.

A **renewable energy resource** is one that is being (or can be) replenished as it's used.

Non-renewable energy resources won't last forever, as they're based on materials we get from the Earth.

Ask students to categorise the energy resources on their Worksheet as renewable or non-renewable.

RENEWABLE ENERGY RESOURCE	NON-RENEW-ABLE ENERGY RESOURCE
Solar	Coal
Wind	Oil
Tidal	Gas
Wave	Nuclear
Hydro	
Biofuel	
Geothermal	

The UK Government wants to achieve net-zero carbon emissions by 2050. This means we need to **reduce** the amount of electricity we generate from fossil fuels. Since these release significant amounts of carbon emissions to produce electricity.

And **increase** the amount of electricity we generate from low-carbon energy resources, like renewables and nuclear. Nuclear might use a non-renewable resource (uranium) but the nuclear fission process doesn't generate carbon emissions, so we call it a **low-carbon energy resource**.

CAREERS IN NUCLEAR
(20 mins)

The move to generate more electricity from low-carbon energy resources brings new job opportunities – particularly for future generations, like you! Watch **this film** about the important role Hinkley Point C will play in delivering low-carbon energy to the UK. And how the nuclear power station will provide new jobs for today's students during its construction and operation.

Did you know? The nuclear power industry in the UK employs nearly 60,000 people. This includes nearly 2,000 apprenticeships and more than 900 graduates.

At Hinkley Point C, we'll be training 1,000 apprenticeships during the build and operation of the new power station. Here are some of the job roles that will be available:

During the build:

Once the power station is operational:

Ask students to investigate three jobs in the nuclear industry. Can they give details of the career pathways into each role, what the job involves and the types of skills and knowledge required?

1) **Engineering maintenance apprentice** (take a look at **this link**);
2) **Nuclear technician** (**this site** is helpful);
3) **Nuclear engineer** (find out more **here**, on the **Start website**, and on **this site**).

More general information on working in the nuclear industry can be found on EDF's **Early Careers pages**.

Homework activity

Ask students to complete the table in their Worksheet listing the pros and cons of different energy resources:

ENERGY RESOURCE	PROS	CONS
Nuclear	▶ Low carbon ▶ Not likely to run out any time soon ▶ Reliable: provides baseload electricity ▶ Higher output and less land space required than for renewables	▶ Uses a non-renewable fuel (uranium) ▶ Building a nuclear power station is a big investment project, involving government and other organisations ▶ Nuclear waste remains radioactive, so the waste products require long-term management in special facilities
Gas	▶ Reliable ▶ Flexible ▶ Fairly low-cost way to generate power	▶ Gas is a non-renewable resource, so it will run out ▶ Not low carbon ▶ It produces pollution and contributes to climate change
Wind	▶ Low carbon; no pollution. The UK is also the windiest country in Europe ▶ Offshore wind turbines can generate more electricity than onshore wind ▶ Relatively low cost to run and no fuel costs	▶ Variable power source (no wind = no electricity) ▶ Limited development onshore due to available land space ▶ Offshore wind farms are trickier and more expensive to build
Solar	▶ Low carbon; no pollution ▶ We get enough sunlight in the UK to make it a viable energy source ▶ No fuel costs	▶ Variable (it doesn't work well in cloud or at all at night) ▶ Restricted by the amount of land space required ▶ Solar power can't be stored very easily or cheaply over a long period

Curriculum links

This activity meets the following exam board criteria in England:

AQA GCSE Combined Science: Synergy
Working scientifically; Atomic structure; Energy resources

AQA GCSE Combined Science: Trilogy
Working scientifically; Chemistry – Atomic structure and the period table; Physics - National and global energy resources

AQA GCSE Physics
Working scientifically; Atomic structure; Nuclear fission and fusion; Energy – energy demands

AQA GCSE Chemistry
Working scientifically; Atomic structure and the periodic table

Edexcel GCSE (9-1) Combined Science
Physics: Topic 3 – Atoms and Conservation of energy; Topic 6 – Radioactivity

Edexcel GCSE (9-1) Physics
Working scientifically; Topic 3 – Conservation of energy – energy sources; Topic 6 – Radioactivity

Edexcel GCSE (9-1) Chemistry
Working scientifically; Key concepts in chemistry – atomic structure

Find out more about **Hinkley Point C** and **careers in the nuclear industry**

WARM-UP

Shrink to the size of an atom!

Now you've watched **this film** about the nuclear generation process, see how much you can remember with this quiz…

1. Q. What is uranium?

A. ______________________________

2. Q. Why do we use water in our pressurised water reactors?

A. ______________________________

3. Q. How many nuclear fissions take place in each pellet per second?

A. ______________________________

4. Q. How hot does the water get in the reactor as a result of nuclear fission?

A. ______________________________

5. Q. How fast does the heated water travel through pipes out of the reactor vessel?

A. ______________________________

6. Q. What happens after the water leaves the reactor vessel?

A. ______________________________

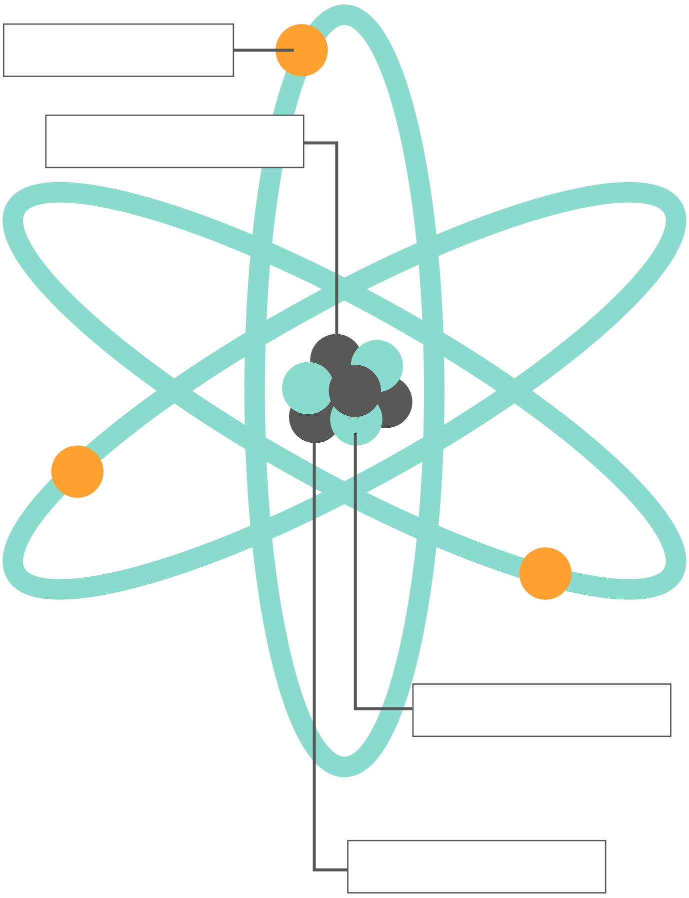
7. Q. How much electricity is produced by the reactor in this film – and how many homes could it power?

A. ______________________________

THE MAIN ACTIVITY

Part 1: Let's talk atoms...

1. Label the different parts of the atom:



2. Complete the table:

NAME OF PARTICLE	RELATIVE CHARGE
Proton	
Neutron	
Electron	

Part 2: How we generate electricity from nuclear power

Answer the questions below:

1. Q. What is nuclear fission?

A. ____________________

2. Q. What makes uranium radioactive?

A. ____________________

3. Q. What is a chain reaction?

A. ____________________

4. Q. What is nuclear fusion?

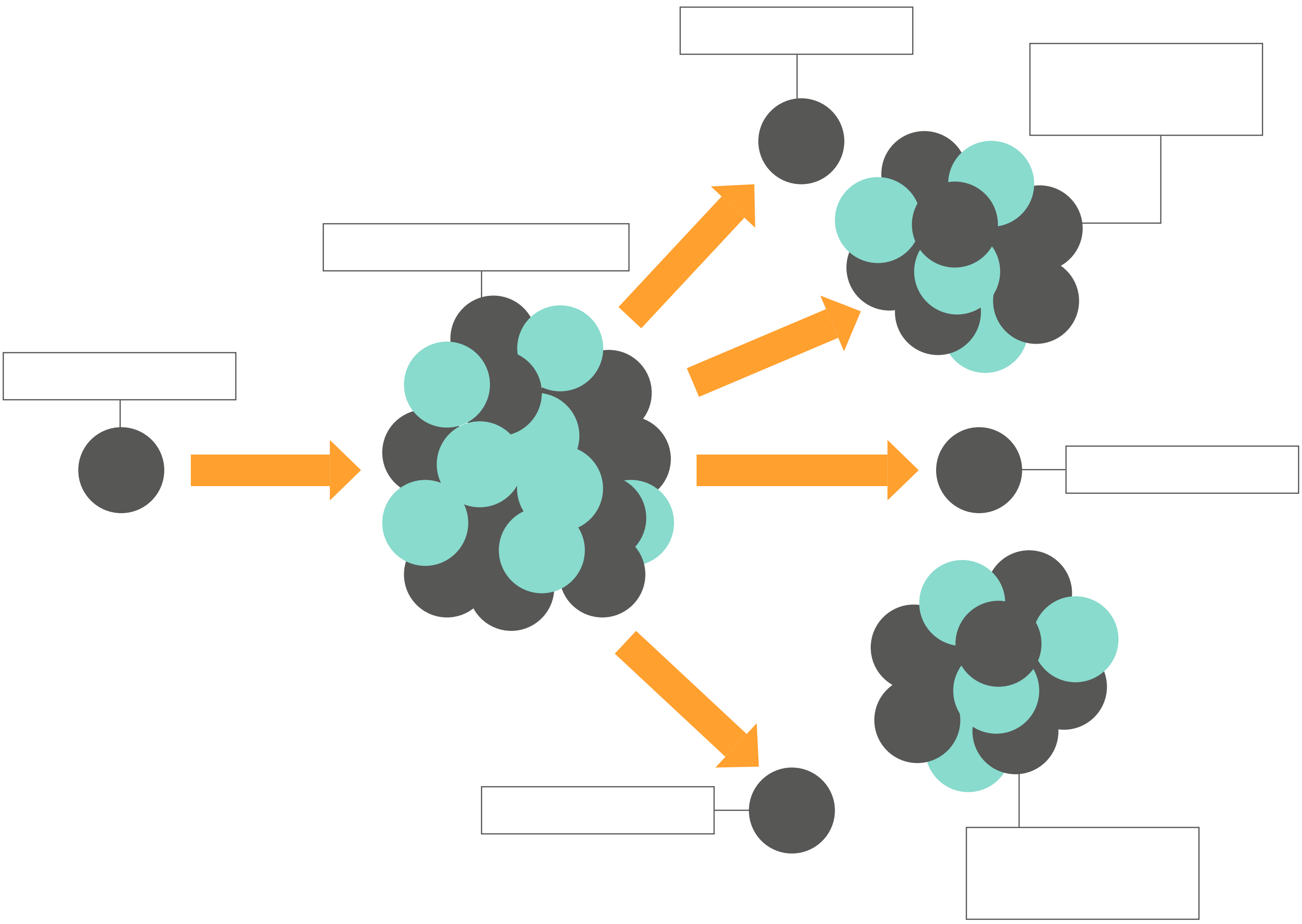
A. ____________________

Practical time!

Activity 1:

Use marbles, dominoes (or Jenga blocks) or magnetic balls and sticks (so they loosely replicate neutrons and protons) to demonstrate a chain reaction. ***If you need help, refer to the Teacher notes.***

Label the diagram below to show the products of a chain reaction:

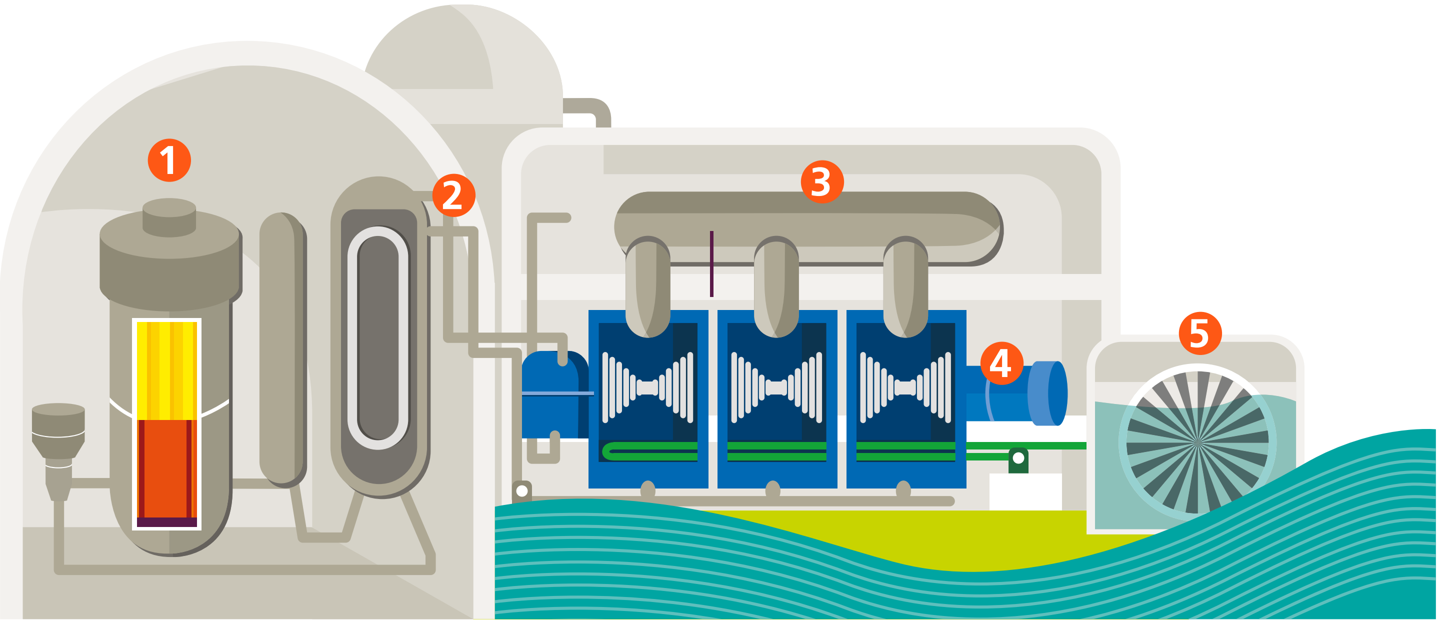


Activity 2:

Investigate what happens when you include a 'control rod(s)' and replicate the chain reaction again. ***If you need help, refer to the Teacher notes.***

Harnessing the energy from nuclear fission

Explain what happens at each of the stages in the diagram below to generate nuclear power:



Step 1:

Step 2:

Step 3:

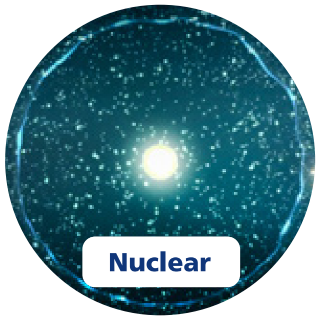
Step 4:

Step 5:

Part 3: Why is nuclear power important to the UK?

1. List as many things as possible that we need energy for in one minute.

2. Categorise these energy resources as renewable or non-renewable, in the table below:



RENEWABLE ENERGY RESOURCE:	NON-RENEWABLE ENERGY RESOURCE:

CAREERS IN NUCLEAR

Watch **this film** about the important role Hinkley Point C will play in delivering low-carbon energy to the UK. And how it'll provide new job opportunities for young people... like you!

Investigate three jobs in the nuclear industry below. For each, give details of the career pathway into the role, what the job involves and the types of skills and knowledge needed:

1) Engineering maintenance apprentice (take a look at **this link**);

2) Nuclear technician (**this site** is helpful);

3) Nuclear engineer (find out more **here**, on the **Start website**, and on **this site**).

Homework activity

Fill in the table below listing the pros and cons of different energy resources:
If you need help, take a look at BBC Bitesize.

ENERGY RESOURCE	PROS	CONS
Nuclear		
Gas		
Wind		
Solar		

Find out more about **Hinkley Point C** and **careers in the nuclear industry**