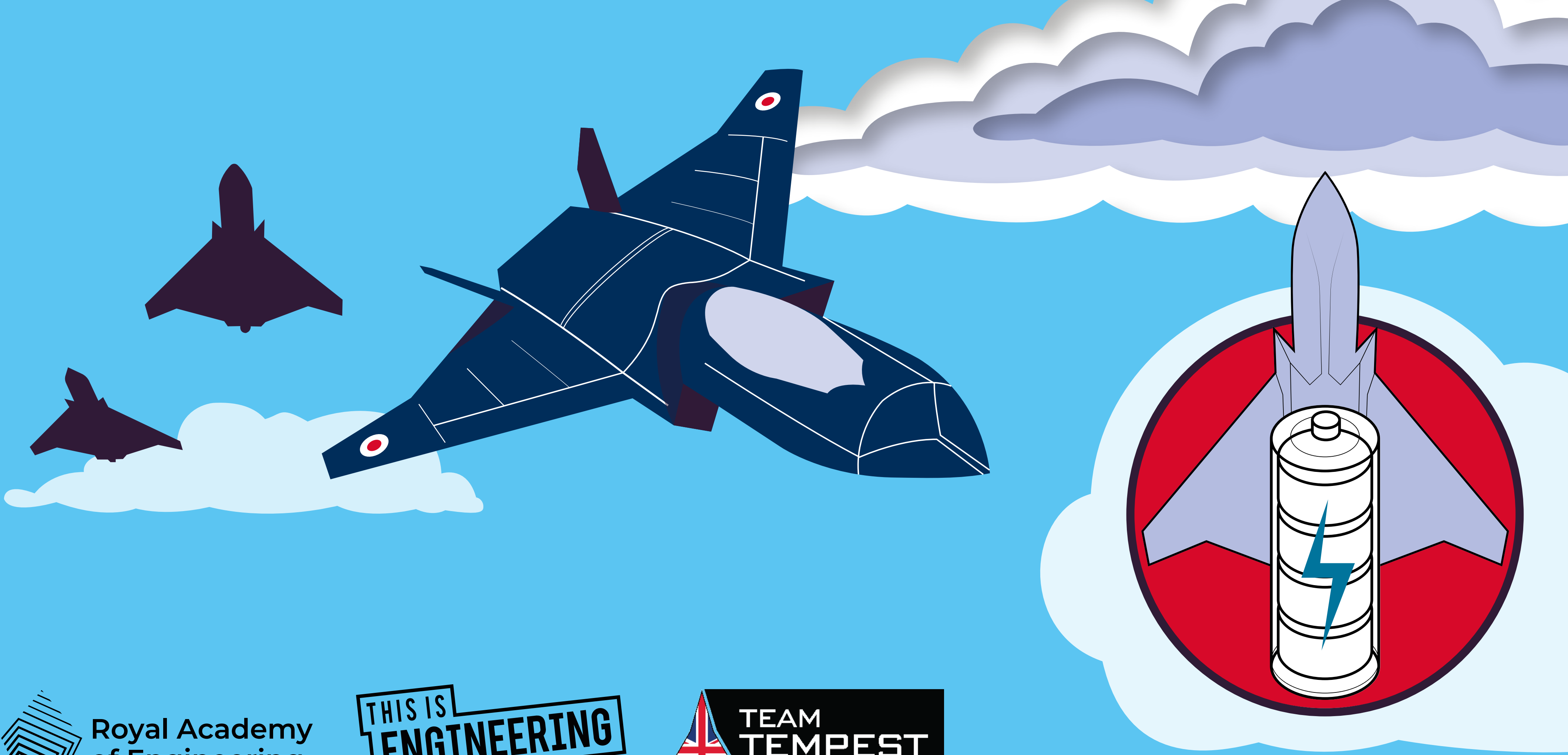
Future of flight:

# Environment



Royal Academy of Engineering

THIS IS ENGINEERING

TEAM TEMPEST

# Introduction

**Throughout all the topics of this resource pack, there is a very important thing that must be considered: our impact on the environment.**

When it comes to an aircraft, there are lots of things to consider around the impact to the environment, including the fuel that is used for propulsion, the materials that are used to make wings and the fuselage, the energy that is used in our factories, and where waste will go when the aircraft is disposed of.

Aircraft components are being designed to run on clean energy, rather than fossil fuels, and hopefully one day soon, a fully electric aircraft!

Whenever an aircraft is no longer safe to fly, it is retired from service and disposed of. However, if aircraft are designed using environmentally friendly materials, as much of it as possible can be recycled to make other products or it can even be reused by turning it into furniture.

# Case study

## Michelle Watiki

**Chemical engineer at Rolls Royce**

**Check out** the full interview with Michelle on Ingenia.

I've always loved sciences. Chemistry was my favourite as I used to watch a lot of science-based TV shows such as Brainiac and MythBusters. I didn't know what an engineer was until the end of my GCSEs when my economics teacher recommended that I investigate it as a future career. The fact that it included science and maths had me sold almost instantly.

I went on to study chemical engineering at Aston University and spent my placement year at Rolls-Royce Civil Aerospace as a manufacturing intern.

Passionate about engineering education, I then spent a month interning abroad at Jomo Kenyatta University of Agriculture and Engineering, Kenya, where I helped support women engineering students.

I am now completing my thesis, which looks at the feasibility and techno-economics of exploiting geothermal power in contribution to 'global net zero' within developing countries situated across East Africa.

I'm due to start a graduate scheme and get hands-on with my career. I've taken a keen interest in sustainability, especially net zero.

I'm also in the middle of creating a one-stop platform to support engineering students during their time at university. I was often confused or lost during my undergraduate degree and only really gained confidence in engineering as my future field of work during the final years. I would like to create a hub that has all the quirky information that engineering students want to know but nobody really addresses.

**"My favourite thing about being an engineer is the flexibility and creativeness when solving problems plus the fact that I can use maths to do so!"**

# What's the damage?

**Reducing the effects of climate change and sustainable development play an extremely important role within the development of Tempest.**

The UK government has committed to reduce its greenhouse gas emissions to net-zero by 2050.

But what do we mean by climate change, sustainability and net zero greenhouse gas emissions?

## What is climate change?

The Earth's average temperature is about 15°C but has been higher and lower in the past. There are natural fluctuations in the climate but scientists say temperatures are now rising faster than at any other time.

This is linked to the **greenhouse effect**. This describes how the Earth's atmosphere traps some of the Sun's energy.

Solar energy radiating back to space from the Earth's surface is absorbed by greenhouse gases and re-emitted in all directions. This heats both the lower atmosphere and the surface of the planet.

Without the natural greenhouse effect, Earth would be too cold for life to exist, it would be a solid ball of rock and ice – dropping from 15°C to as low as -18°C. With too much greenhouse effect, planet Earth would be way too hot – a temperature rise of a few °C would make parts of the planet too hot for humans to survive.

Unfortunately, the natural greenhouse process is being disrupted by gases released from industry, agriculture, cutting down forests, burning fossil fuels, and other human activity, causing a rise in temperature.

This is known as climate change, global warming or the climate crisis.

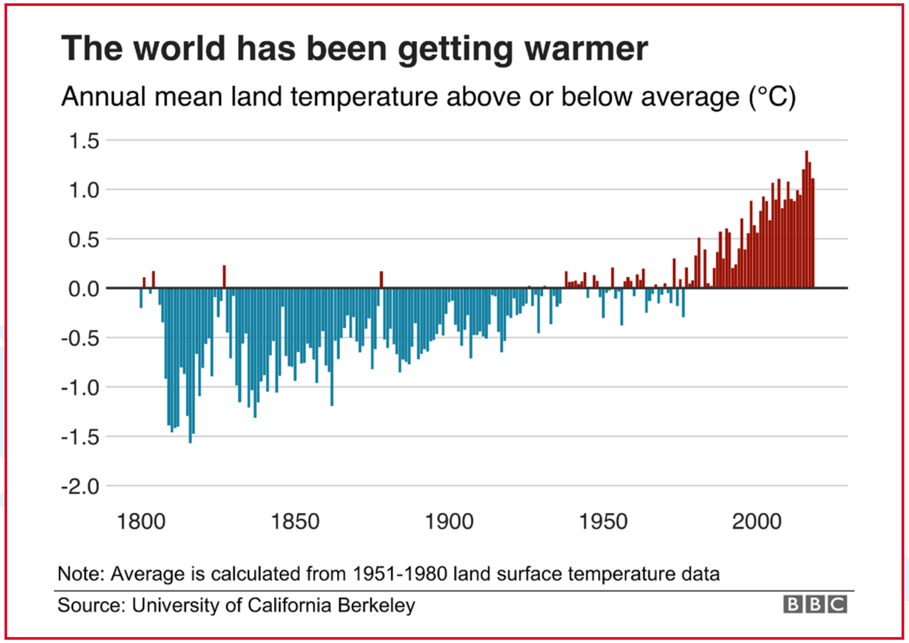
## Time to reflect

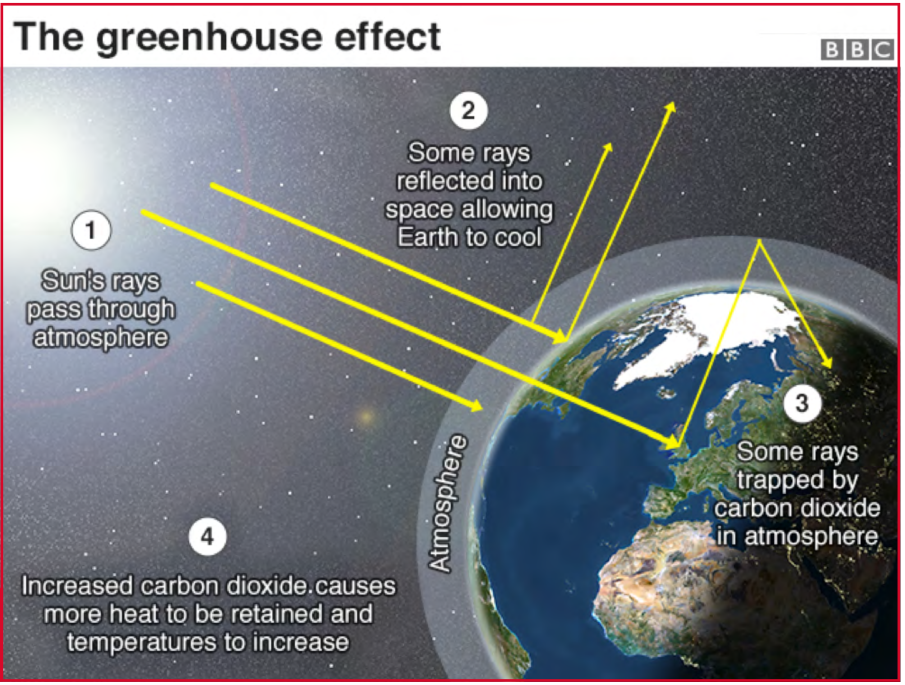
**So what's the problem?**

In small groups, research the impact of climate change on the planet.

- What evidence do we have that the planet is getting warmer?
- What affect has this already had on the planet?
- What do scientists predict will happen to the planet if action is not taken to reduce our gas emissions?

**Image taken from:** www.bbc.co.uk/news/science-environment-24021772

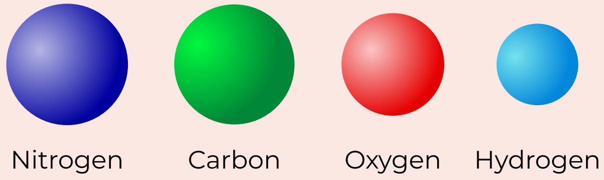


# What are greenhouse gases?

**The main gases responsible for the greenhouse effect include carbon dioxide, methane, nitrous oxide, and water vapour.**

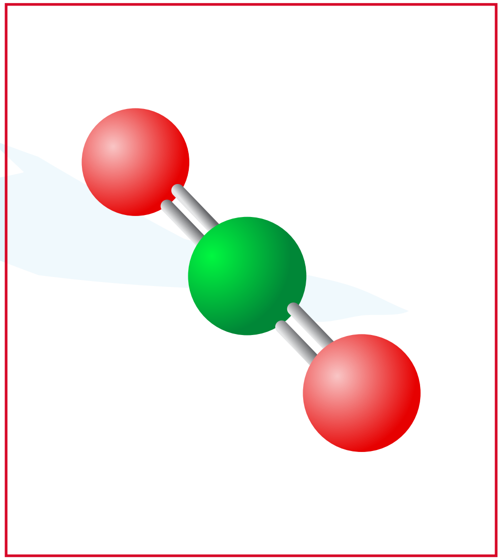
Match the **molecule** diagrams with the description. Can you work out which element each part of the molecule diagram represents?

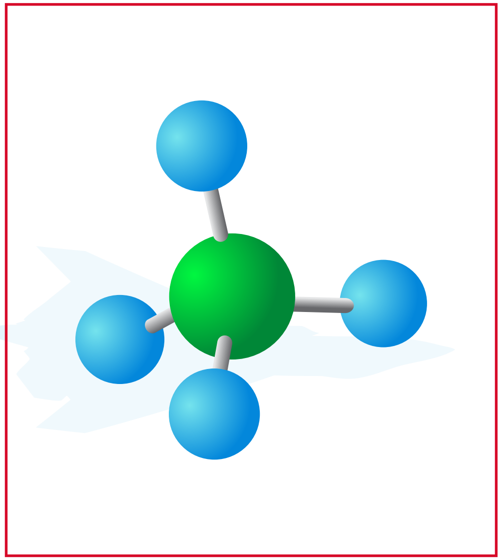


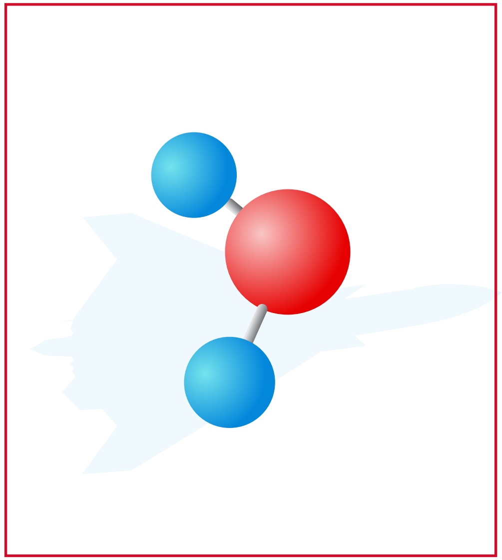

## Mini glossary

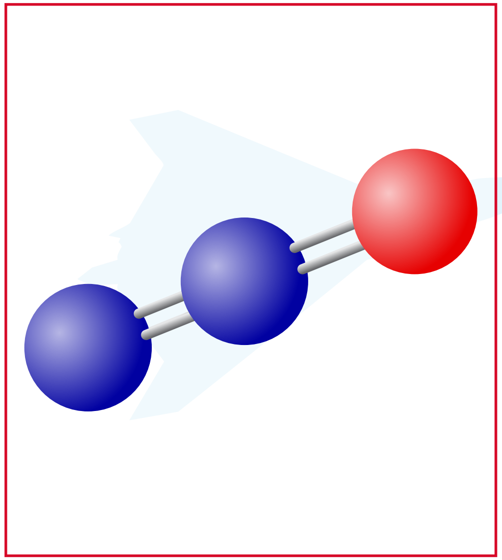
A molecule is made up of one or more **atoms**.

**Atoms** are the basic building blocks for all matter in the universe. Atoms are made up of protons, electrons and neutrons.









### Methane ($CH_4$)

The main component of natural gas, methane is released from landfills, petroleum industries and agriculture. It does not stay in the atmosphere as long as a molecule of carbon dioxide – about 12 years – but it is at least 84 times more potent over a decade. It accounts for about 16% of greenhouse gas emissions.

### Nitrous Oxide ($N_2O$)

A powerful greenhouse gas – 26 times more powerful than carbon dioxide over 20 years – produced by soil cultivation practises, especially use of fertilisation, fossil fuel combustion and biomass burning. It accounts for about 6% of global greenhouse gas emissions.

### Carbon Dioxide ($CO_2$)

It is responsible for about three-quarters of emissions. It can linger in the atmosphere for thousands of years. It is released through respiration, volcanic activity, deforestation, burning fossil fuels, etc.

### Water Vapour ($H_2O$)

Most abundant greenhouse gas. Water vapour also increases in the atmosphere as the Earth warms. Water vapour only remains in the atmosphere for a few days.

# Modelling the greenhouse effect

**To address global warming, engineers of all disciplines must understand the greenhouse effect and its causes, and then creatively design new technologies to reduce the production of greenhouse gases.**

Engineers working across Team Tempest will examine the types of chemicals released in the manufacturing process.

Others redesign engines to make more efficient the fuel burning process and/or reduce chemical emissions.

## Time to investigate

Working in groups, carry out these four experiments that investigate the effects of greenhouse gases and climate change.

As a group, you could carry out all four experiments, or as a class, do an experiment each and share your results with each other at the end.

You will need to carry out this activity on a sunny day as you will need to put your 'greenhouses' in direct sunlight.

On a cloudy day you could use a 100+ watt bulb and lamp.

## Time to hypothesis

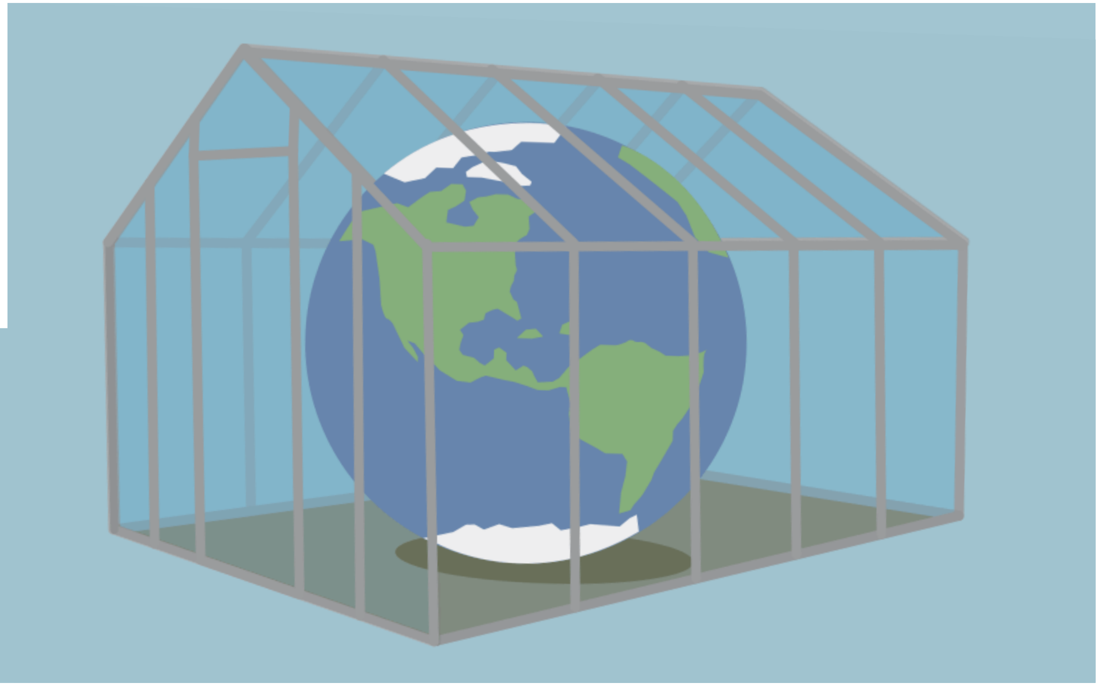
Before you start, what do you think will happen during each experiment? Discuss and write down your predictions.

## Materials

- 2-Litre plastic bottles cut in half, cling film and rubber band to use as a lid
- Plastic containers with lids
- Thermometers
- Baking soda
- Vinegar
- Masking tape (which will be used for labels)
- Hot water
- Cold water chilled with ice cubes
- Garden soil


### Health and safety

Take care when working with hot water as part of this investigation. Speak to an adult when preparing for this activity.



## Investigation one – vinegar and baking soda

1. Using the masking tape, label one container **vinegar** and another **vinegar + baking soda**.
2. Place a thermometer in each jar.
3. Place 100ml of **vinegar** in each container.
4. Securely seal the **vinegar** container with cling film and a rubber band.
5. Put 25g of **baking soda** in the **vinegar + baking soda** container and securely seal it with cling film and a rubber band.
6. Put the containers in bright sunlight and record the temperature every minute for about 30 minutes.
7. Place the containers in the shade (out of direct sunlight) and continue to record the temperature every minute for about 15 to 20 minutes.

**What is happening?**

Make a graph showing the temperature in each container during the entire observation period.

Be sure to indicate on the graph when you moved the containers from the sun to the shade.

You can use the graph template on page 7 to help you with this.

Describe how your experiment modelled how air pollution affects global warming.

- Was there a greenhouse gas present?
- How fast did the containers heat up?
- How fast did they cool down?
- What was the difference between the two containers?

## Investigation two – hot water

1. Using the masking tape, label one container **open** and another **covered**.
2. Place a thermometer in each container.
3. Fill both containers 2/3 full of hot water.
4. Cover the container labelled **covered** with cling film and secure it tightly
5. Place the containers in shade (out of direct sunlight). Record the temperature in each container every minute for about 30 minutes.
6. Put the containers in bright sunlight and record the temperatures every minute for about 15 to 20 more minutes

**What is happening?**

Make a graph showing the temperature in each container during the entire observation period.

Be sure to indicate on the graph when you moved the containers from the sun to the shade.

You can use the graph template on page 7 to help you with this.

Describe how your experiment modelled how air pollution affects global warming.

- Was there a greenhouse gas present?
- How fast did they cool down?
- What was the difference between the two containers?
- Did placing them in the sun seem to have an affect?


## Investigation three – cold water

1. Using the masking tape, label one jar **open** and another **covered**.
2. Place a thermometer in each jar.
3. Fill both jars 2/3 full of the cold water (without ice cubes).
4. Cover the jar labelled **covered** with cling film and secure it tightly.
5. Place the jars in direct sunlight. Record the temperature in each jar every minute for about 30 minutes.
6. Place the jars in the shade and record the temperatures every minute for about 15 to 20 more minutes

**What is happening?**

Make a graph showing the temperature in each jar during the entire observation period.

Be sure to indicate on the graph when you moved the jars from the sun to the shade.

You can use the graph template on page 7 to help you with this.

Describe how your experiment modelled how air pollution affects global warming.

- Was there a greenhouse gas present?
- How fast did they cool down?
- What was the difference between the two jars?
- Did placing them in the sun/shade seem to have an affect?

## Investigation four – soil

1. Using the masking tape, label one jar **open** and another **covered**.
2. Place one cup of soil in each jar.
3. Place a thermometer in each jar.
4. Cover the jar labelled covered with cling film and secure it tightly.
5. Place the jars in direct sunlight. Record the temperature in each jar every minute for about 30 minutes.
6. Place the jars in the shade and record the temperatures every minute for about 15 to 20 more minutes

**What is happening?**

Make a graph showing the temperature in each jar during the entire observation period.

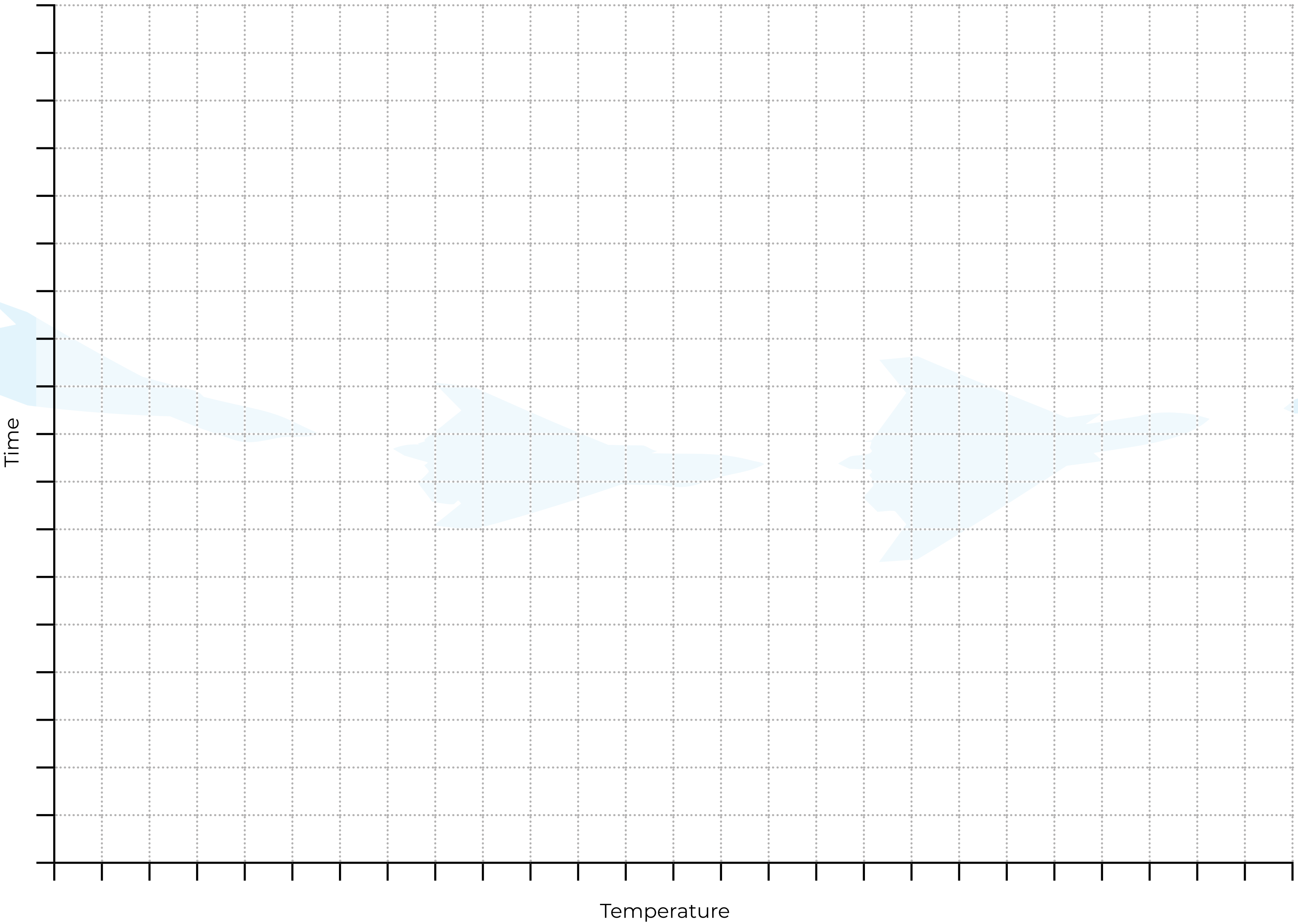
Be sure to indicate on the graph when you moved the jars from the sun to the shade.

You can use the graph template on page 7 to help you with this.

Describe how your experiment modelled how air pollution affects global warming.

- Was there a greenhouse gas present?
- How fast did they heat up? Cool down?
- What was the difference between the two jars?


# Modelling the greenhouse effect – graph template



# Lifecycle of an aircraft

**Engineers are working hard to ensure that once an aircraft reaches the end of its life, that the different components of the aircraft can be reused and recycled.**

Check out an old Boeing 727 which is now being used as a hotel in Costa Rica.

The **fuselage** (frame of an aircraft) is one accommodation offered by Hotel Costa Verde.

And a group of BAE Systems apprentices turned a fan from a Tornado engine into a really cool table for the office!



## Time to upcycle

**Create something new out of something old!**

There is a wealth of materials already in circulation in our homes, schools and secondhand shops.

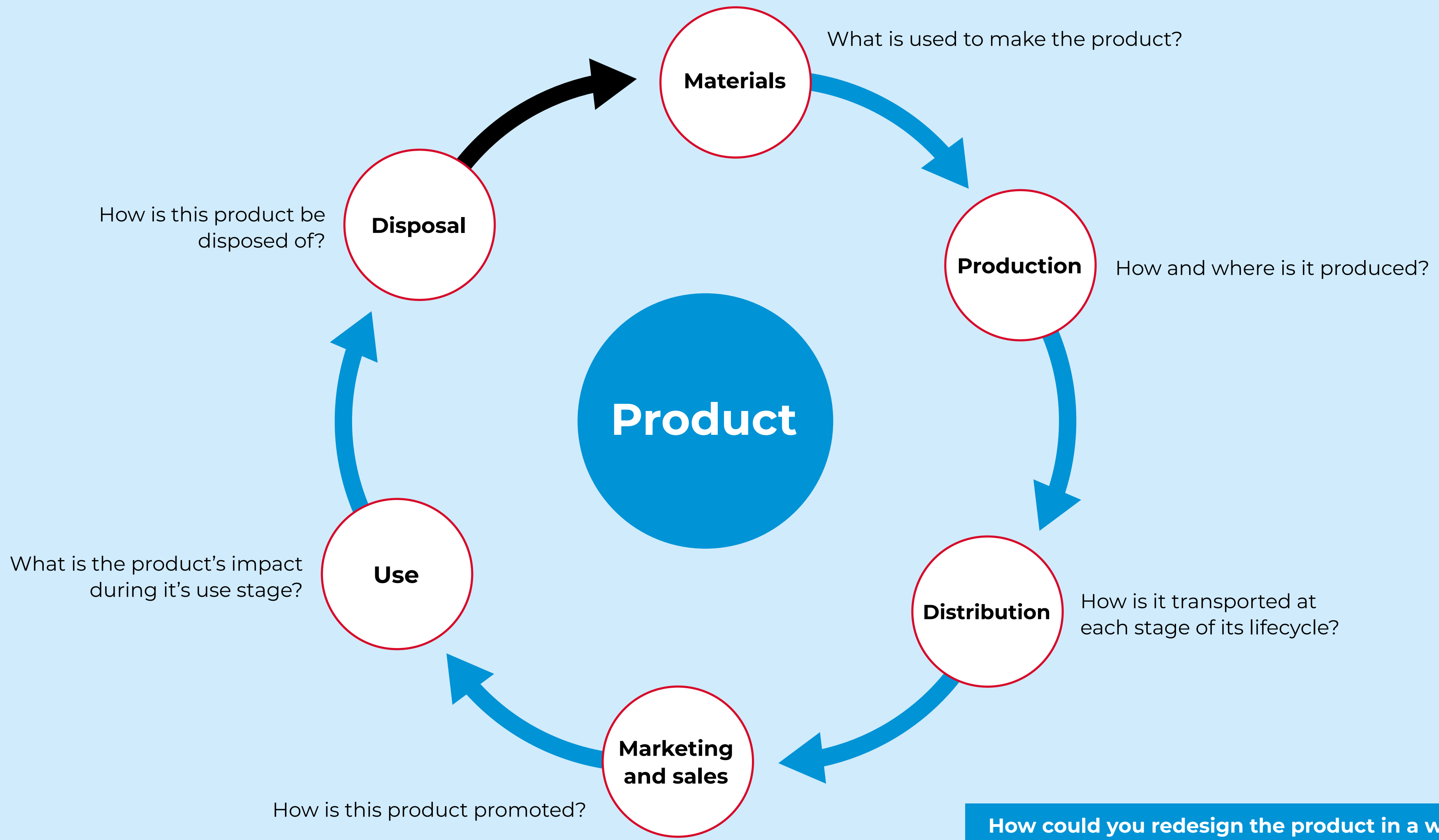
Can you find something to redesign and remake into something new?


Show an image of your item 'Before' and 'After' you have finished your **upcycle**.

| Before | After |
|---|---|
| | |

# Product lifecycle

**Complete this product lifecycle diagram for a product of your choice.** Is the product's life-cycle **circular**?




**How could you redesign the product in a way to reduce the impact on the environment?**

# Electric travel

**We are getting closer and closer to having fully electric aircraft.**

It is predicted that most short-haul flights are likely to go electric within the next few decades and this will transform the way we think of air travel.

## What has already been happening?

Rolls-Royce is developing an all-electric plane 'Spirit of Innovation' that will be aiming for the record books with a target speed of more than 300 mph, setting a new world speed record for electric flight.

Working in collaboration with Prismatic, BAE Systems have developed a solar electric unmanned air vehicle called PHASA-35. As it will be using advanced solar technology, PHASA-35 has the potential to stay airborne for up to a year.

ZeroAvia has developed an aircraft with a hydrogen-electric (fuel cell) powertrain capable of carrying up to 20 passengers around 650km.

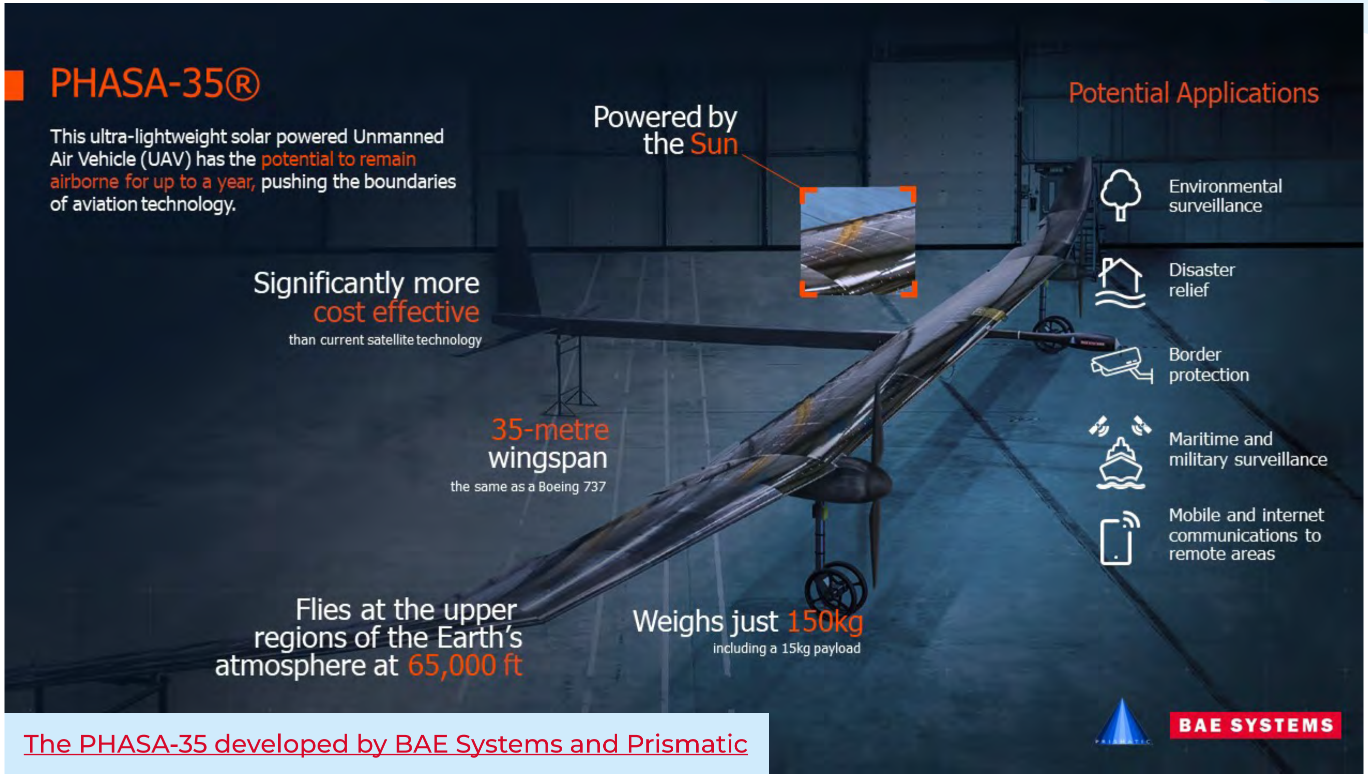
Solar impulse 2 completed the first round-the-world flight by a solar-powered aeroplane in 2016. The aircraft carries more than 17,000 solar cells on its wings and spent more than 23 days in the air.

## Time to reflect

Sustainability and the impact we have on the environment is playing a huge part in future travel innovations.

*What do you think the future of travel will look in 10, 20 and 50 years?*


Rolls Royce – 'Spirit of innovation' aircraft




The PHASA-35 developed by BAE Systems and Prismatic

# How do we generate electricity?

**Fully electric vehicles are said to be better for the environment.**

But what makes them more sustainable? Are they always sustainable?

Electricity needs to be generated from other sources of **energy**. This includes burning coal, natural gas, oil, nuclear power, and other natural sources.

Large machines called turbines are turned very quickly to produce continuous power. This requires a lot of energy from high pressure steam, wind or moving water.

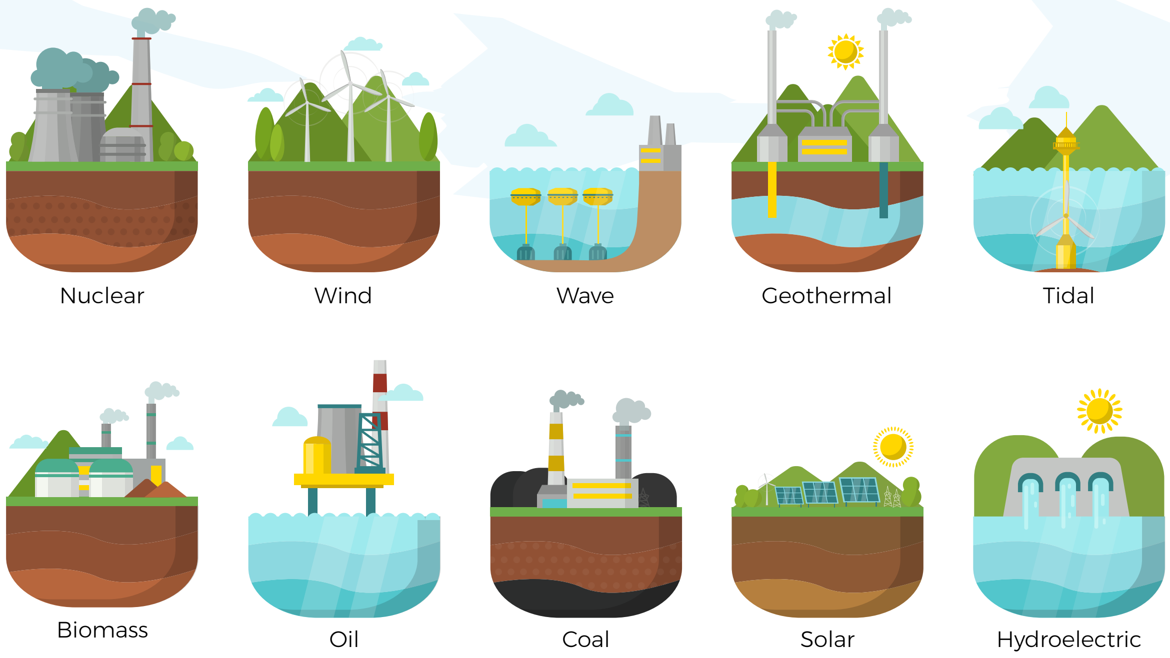
The spinning turbines cause large magnets to turn within copper wire coils – these are the **generators**.

**Generators** are machines for converting **kinetic energy** into electricity.

The moving magnets within the coil of wire cause electrons (charged particles) to move within the wire – this is the electricity.

## Resources that generate electricity

Sort the energy sources (below) into renewable and non-renewable.




## Time to research

In small groups, choose one renewable and non-renewable from the group above.

- How does it generate electricity?
- Where is it often used?

**See our resource** Power Up! For more about generating electricity from renewable energy.

## What do we mean by...

**Renewable energy?** Renewable energy comes from sources that are constantly and naturally renewed.

**Non-renewable energy?** Non-renewable energy comes from sources that will eventually run out.

**Electric current?** An electric current is the movement of charged particles (electrons) mainly in a wire.

**Electricity?** Energy is transferred electrically from where it is generated to where we use it in our homes and schools.

**Kinetic energy?** The kinetic energy of an object is the energy it possess when it is moving.

**Energy** is stored as different ways and transferred from one store to another.

The faster energy is transferred, the greater the power.

# Every decision counts to the environment

**Your opportunity to manage the £700,000,000 annual Rolls-Royce research and development budget over 30 years.**

How do your decisions impact $CO_2$ levels and NOx levels?

Use the information in the bottom left of the screenshot (right) to help you make your decisions about what you will spend your annual budget on over the next 30 years.

Look carefully at the cost, time and benefits to the business and environment to choose your strategy.

You must make decisions in accounting periods (Aps). Each accounting period lasts for three years so you have 10 rounds of decisions to make.

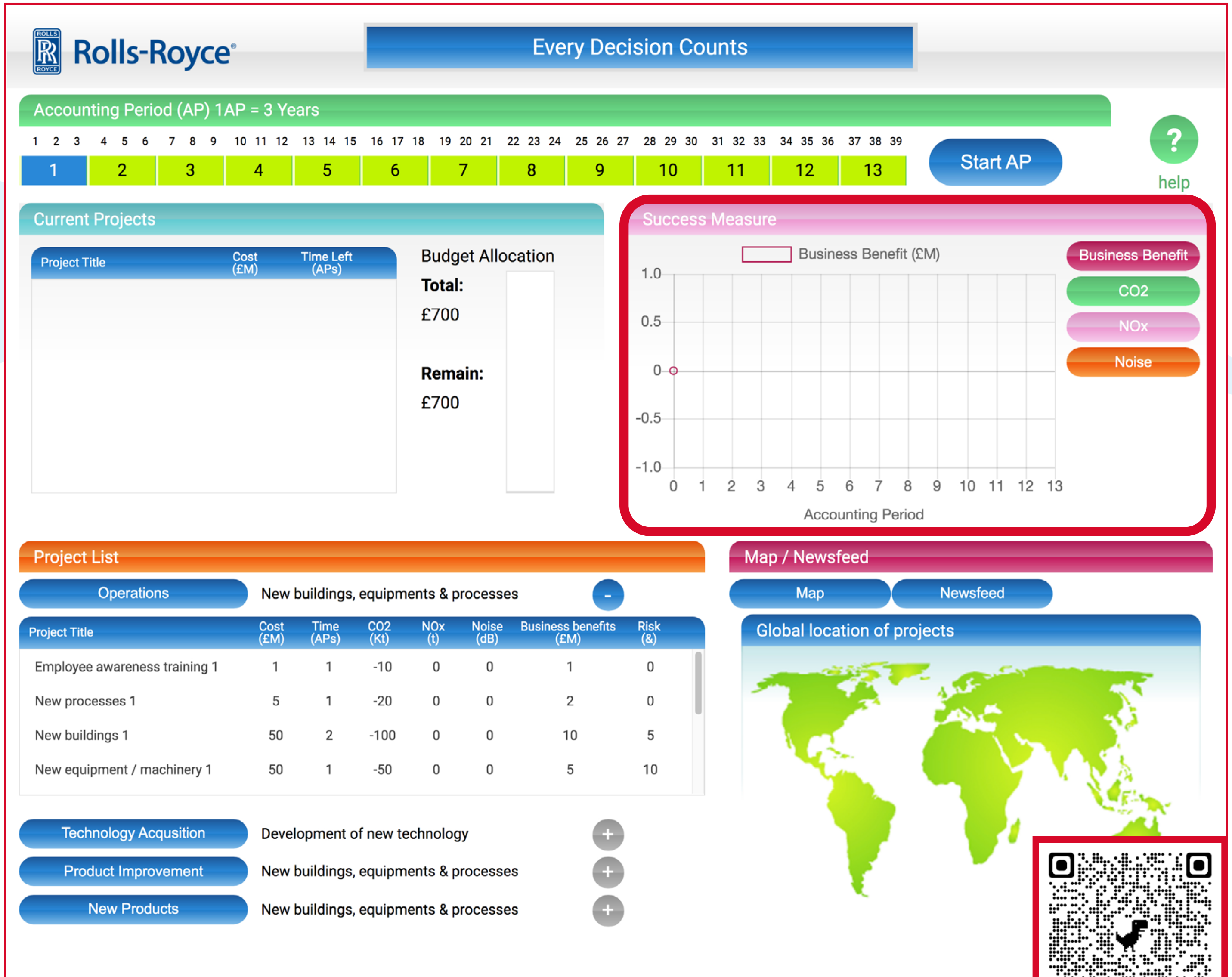
Don't forget some projects must be completed before new products become available. Watch out for targets you must reach and delays to programmes as you play.

*Plan ahead and good luck!*

## Mini glossary

**$CO_2$** stands for **carbon dioxide**. Although it is an important gas in Earth's atmosphere, rising $CO_2$ levels are causing the planet to heat up.

**NOx** is released into the atmosphere when fuels are burned. NOx is made up of nitric oxide (NO) and nitrogen dioxide ($NO_2$).




Find the **'Every Decision Counts'** interactive at Rolls-Royce.

# Factory of the future

**Welcome to the Factory of the Future – a place where revolutionary technologies meet adaptable and digitally minded engineering workforce to create solutions to the problems of tomorrow.**

An important part of a structural and civil engineer's role is to consider the environmental design of buildings. What is the most effective use of space?

How can they design a building so that it receives the most natural light and does not waste energy.

## Design for light

Design a room with straight walls in which there is a position for a single light source that leaves part or every wall in shadow.

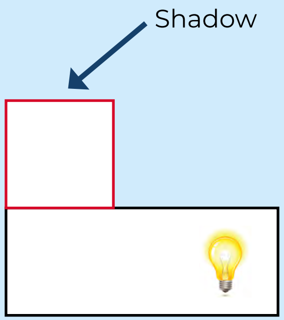
The walls of the room must all join. Freestanding walls or edges that stick out are not allowed.

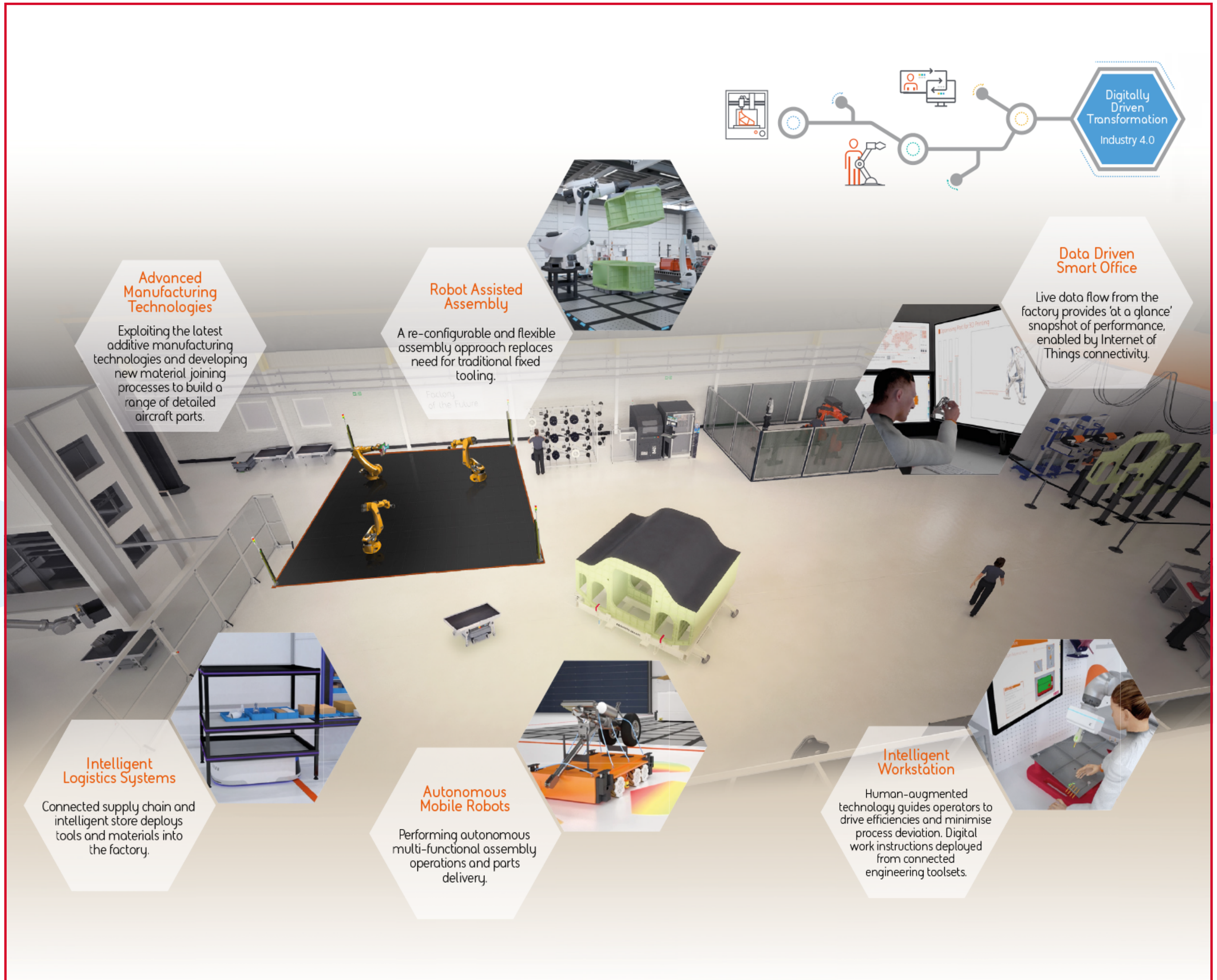
A point is in shadow if there is no direct line from the light source to it.

The straight wall sections need to join, so the cross-section of the room is a **polygon**. You can't have a free-standing wall.

**This image** is of the horizontal cross section of a room. The bulb shows the position of the single light source.

**When the light is switched on**, the walls (marked in red) remain completely in shadow.




**This challenge is taken from** Alex Bellos, Guardian Puzzle 'Design a room where everything is not illuminated', published Feb, 2016.

# Working with robots

**Robotics will play a key role in the Tempest 'Factory of the Future'.**

Robots will assist in the assembly and manufacture of aircraft. The robots will allow for a flexible approach to assembly, which will replace the need for traditional fixed tooling. This will significantly reduce wastage, and make the manufacturing process much more efficient, reducing carbon emissions.

Engineers working on the 'Factory of the Future' can monitor and control robots to make tiny adjustments with great accuracy (sometimes with tolerances less than a third of the width of a human hair!).

## Time to design

Design and make a device that will carry out certain manufacturing tasks from a distance and with accuracy.

Your device will need to carefully pick up objects and accurately place them in another place.

The two objects you will be moving are:

- Tennis ball
- Ping-pong ball

### Existing mechanisms

Investigate existing tools that are used to pick up objects. Using a computer, tablet or smartphone find images of these tools.

- How do the different tools work?
- Where are they used?
- Where would they not work?

## Time to make

From your research around different types of tools that can pick things up, design your own device.

It must:

- be operated from a distance of one metre away
- be controlled in order to perform small and accurate movements
- move in horizontal and vertical plane
- pick up two different sized objects (tennis ball and ping pong ball)
- be designed and manufactured so that objects, once picked up, will not be dropped or touch the surface around the space where it needs to be lowered.

### Materials

- Cardboard
- Split pins
- Drawing pins
- Elastic bands
- Scissors/craft knife

**For more information on** different types of levers check out the levers poster from Technology Student.


# Royal Academy of Engineering

**The Royal Academy of Engineering** is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

## What we do

### Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

### Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

### Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

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