NUFFIELD STEM *FUTURES*

TEACHERS' GUIDE

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Nuffield STEM *Futures*

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Why *Futures*?

Nuffield STEM *Futures* is an innovative cross-curricular topic designed to engage young people with a vision of a sustainable and equitable future. Pupils are challenged to rethink a future based on the principles of closed loop systems in nature. The topic is a celebration of human ingenuity rather than a review of ecological collapse.

Futures activities are scaffolded to allow increasing autonomy which prepares pupils to undertake an enquiry-based project of their choice. As they work through activities, pupils begin to take more responsibility for their learning and for their future.

What is STEM?

STEM stands for Science, Technology, Engineering and Mathematics. This Nuffield STEM topic for lower secondary pupils exemplifies a skills-based cross-curricular framework which enables teachers and pupils to work on authentic, purposeful activities extending across the STEM disciplines.

Why cross-curricular STEM?

Nuffield STEM *Futures* encourages pupils to explore problems in depth through a series of Science, Maths and D&T activities. In this way they develop a better understanding of how these disciplines interact in the real world.

Some of the benefits of cross-curricular working include opportunities for:

- pupils to engage with coherent and purposeful STEM learning
- pupils to practise and develop their ability to tackle complex problems
- reinforcing learning across STEM subjects.

What's in it for Science, Technology and Mathematics?

The activities in *Futures* demonstrate the complementary nature of the STEM subjects. They do not explicitly teach sections of the programmes of study. The activities are constructed so that prior knowledge, skills and understanding from the individual subjects can be brought together to explore complex issues relating to sustainability.

The subject teacher must establish the links between prior and future learning for their own subject.

Here are some of the main topics covered in *Futures*.

Science

Carbon, nitrogen and water cycle
Photosynthesis and respiration
Energy from combustion
Renewable energy
Global warming
Pollution
Properties of materials

Design & Technology

Materials
Product life cycle
Car design
Sustainable products
Sustainable systems
Renewable energy

Maths

Interrogate graphs, charts and table
Plan mathematical investigations
Provide mathematical evidence
Use maths to inform design
Use mathematical models to make predictions

How will *Futures* support the wider curriculum?

Over the course of the STEM *Futures* project pupils engage with the curriculum at a number of levels. They will:

- reinforce their subject understanding through engaging with concepts, processes and content for science, mathematics and design & technology.
- develop their personal, learning and thinking skills by working collaboratively on a project of their choice.
- explore the wider curriculum dimensions of healthy lifestyles, community participation and enterprise. In particular pupils use their creativity and critical thinking to consider how key global issues might be addressed through more sustainable living.
- develop aspects of their personal, social and health education through exploring attitudes and values associated with ideas about sustainability. They consider their health and economic role in future societies.
- develop a better understanding of the needs of themselves and other in support of the Social and Emotional Aspects of Learning (SEAL) programme.

What is special about closed loop theory?

Closed loop theory allows us to consider the human impact on the environment. Nature does not produce rubbish – waste becomes food for other processes. Nothing is left over, so the system forms a closed loop. This is true of all of the world's natural ecosytems.

They are all sustainable because in nature:

- waste is food
- cycles are powered by sunshine
- toxins are not allowed to build up.

Human systems are linear

We take → make → dump.

The challenge for pupils is to rethink important human activities to bring them within a closed loop system. To make this work, it is essential that all teachers involved in this topic have a good understanding of closed loop theory. The film 'Get loopy' in the introduction is a good place to start. See also the Background information in this teachers' guide and the CPD toolkit module 2 'Introduction to closed loop thinking'.

To help pupils engage fully with closed loop theory they will be issued with five closed loop cards. These cards carry an icon and notes describing a component of the theory.

The closed loop slides associated with pod 1 'Introduction' carry the same information, and you can use these to reinforce any aspect of closed loop theory during work on the whole *Futures* topic.

What are 'pods'?

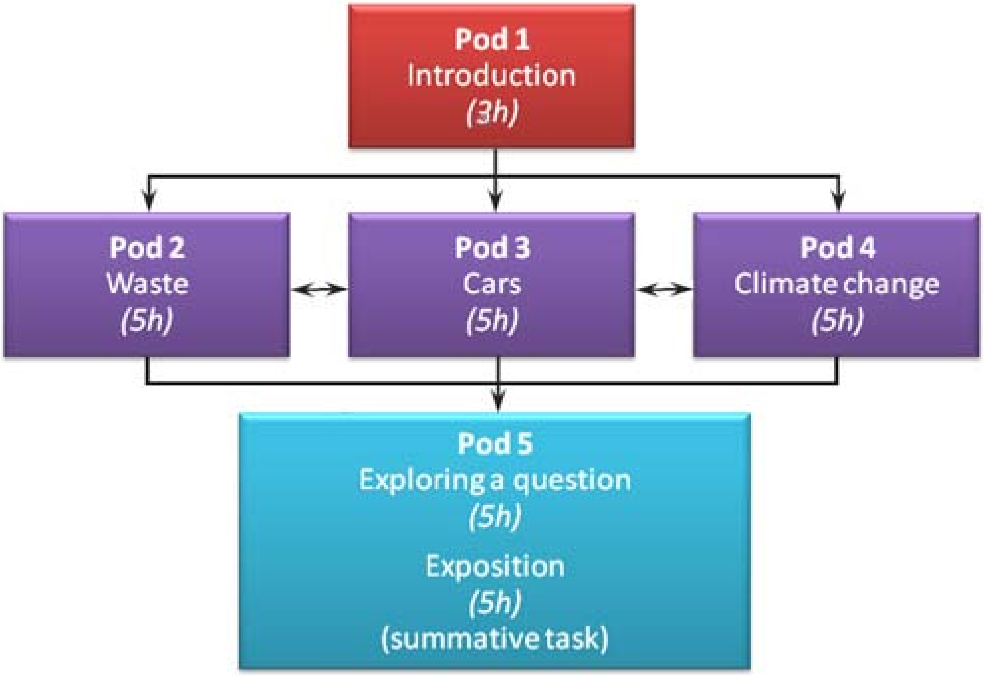
The STEM *Futures* resource is composed of a series of 'pods'. A pod is a series of lessons organised around a particular sustainability theme. Typically a pod contains an overview, teacher notes, pupil tasks, video clips, animations and a pupil presentation. The activities in each pod are ideally conducted in order, to scaffold the concept development.

Pod 1 'Introduction' introduces the *Futures* topic with activities to exemplify closed loop theory.

Pods 2 'Waste', 3 'Cars' and 4 'Climate change' are enabling pods which prepare pupils to undertake the final project (pod 5). The enabling pods start with teacher-led activities and end with a summative project task. Each of the enabling pods are balanced and coded according to the main skill areas (see Learning skills overview below).

In pod 5 'Pupil project' pupils use their knowledge skills and understanding to carry out an open project of their choice.

See the pod structure diagram on the next page.



Futures: overview

Pod 1 Introduction

Pupils are introduced to the idea that many current human problems relate to food, energy and materials. They look at a brief history of civilisation, to emphasise that humanity's quest for resources is nothing new. Advances in technology have increased the depletion rate of fossil fuels and other materials.

Pupils engage with the idea that our linear take → make → dump culture is not sustainable. We need to learn some 'closed loop' lessons from nature where all waste is recycled through natural systems.

Pod 2 Waste

Pupils start by classifying debris on a beach according to whether it will decay or not. Pupils analyse product life cycles and generate questions about natural closed loop systems. They consider how cradle to cradle design could help provide closed loop systems for human activities.

Pod 3 Cars

Pupils consider conventional car engine design and review new green alternatives. They collect evidence for pollution in their local area and analyse the data.

Pupils interpret graphs showing past and predicted oil consumption. They use reports and data to assess the impact of legislation on traffic pollution. Pupils produce and present suggestions for alternative closed loop approaches to local transport.

Pod 4 Climate change

Pupils investigate the key components of the carbon cycle. They analyse evidence relating CO_2 to climate change. Pupils compare the carbon footprint of different activities and different societies. They use closed loop thinking to consider new ways of reducing CO_2 in the atmosphere. Finally they present the case for the construction of a local wind farm.

Pods 5 Pupil project

Pupils use the learning skills they have acquired in earlier pods to carry out a piece of project work. Pupils identify a problem or question relating to sustainability, and use STEM knowledge and understanding to present a closed loop solution. Their project involves research, analysing, evaluating and synthesising information, and communicating possible solutions creatively through a variety of media.

How many pods should I do?

There is a variety of delivery models for this topic. Pupils must engage with the introductory pod to gain the necessary knowledge for later pods. Each of the enabling pods (2, 3 and 4) exemplifies one aspect of closed loop systems. In any enactment of *Futures*, pupils should have the opportunity to carry out their own project in pod 5.

We recommend that the shortest enactment would take about 10 hours and include three pods:

1. Introduction
2. An enabling pod
3. The project pod

The full enactment, including all the pods, would take roughly 28 hours.

Learning skills for STEM

Futures challenges pupils to conduct their own project work. For pupils to carry this out effectively and tackle complex problems, they need to develop specific learning and enquiry skills. These skills are explicitly developed within the programme. In particular they help pupils to:

- plan and organise their own learning
- formulate their own questions or design briefs
- discuss and plan collaborative work
- research and critique information from books, newspapers, websites and television
- analyse and represent data
- develop frameworks for thinking about any topic
- record and evaluate their learning journey
- present and explain their ideas.

These learning skills are developed in context. They are coded using five categories:

I Information retrieval
C Communication
T Teamwork
M Modelling
P Planning

See the pod overviews on the next pages.

The Learning Journey: 'Nutshells'

As pupils work through the pods they widen their knowledge, skills and understanding.

It is important to provide plenty of opportunities for pupils to reflect on their learning.

Pupils should be issued with a ‘Learning Nutshell’ at the start of each pod. This is used to reflect during learning, and to review progress at the end of each summative task.

Pod overviews

Pod 1 Introduction

I = Information retrieval
T = Teamwork
P = Planning
C = Communication
M = Modelling

Lesson	Activity	Learning outcomes	Learning skills	Code
1 The ages of human civilisation	**1.1** The Four Ages of Civilisation	Describe life in other areas. Explain the links between oil production and the development of human civilisation.	Conduct internet research. Write a creative script. Extract information from an animated presentation.	I C, T I
2 What do humans need?	**2.1** Humans and oil **2.2** How does stuff flow? **2.3** Get loopy	Explain the main differences between linear and closed loop systems.	Extract information from a graph. Watch a film with a purpose. Construct a flow chart.	I I C, T
3 Cycles	**3.1** Woodland flows **3.2** What powers natural systems? Plenary: How does a forest work?	Describe how natural systems move materials between the living and non-living environment. Explain that energy is needed to power natural systems.	Construct a concept map. Explain a concept using a working model.	C, T C, M

Pod 2 Waste

I = Information retrieval
T = Teamwork
P = Planning

C = Communication
M = Modelling

Lesson	Activity	Learning outcomes	Learning skills	Code
1 Natural systems	**1.1** Is waste a problem? **1.2** Natural processes	Classify waste items as 'technical' or 'natural'. Show the role of processes in natural closed loop systems.	Sort images according to category. Listen in order to extract information. Represent information in the form of graphic notes.	C I C
2 Sustainable use of resources	**2.1** How much do we recycle? **2.2** Can recycling create a closed loop system for aluminium drink cans?	Estimate the number of drink cans used in the UK. Model the effectiveness of different recycling rates. Suggest strategies to help create a closed loop system for drinks containers.	Extract information from a bar chart. Use a spreadsheet to engage with a mathematical model.	I M
3 Cradle to cradle design	**3.1** Can we make torches more sustainable?	Explain the source, use and destination of some materials in a product. Suggest how precycling could improve the sustainability of a product.	Construct an exploded diagram of an artefact. Extract information from a fact file. Work as a member of a team to create a product. Carry out internet research.	C I T, P I
4 and 5 Dragons' Den: making a pitch for funding	**4.1** Making a pitch for funding	Use closed loop systems thinking to design a sustainable product.	Making a presentation. Conducting an effective internet search. Planning and evaluating presentations.	C, T I P

Pod 3 Cars

I = Information retrieval
T = Teamwork
P = Planning

C = Communication
M = Modelling

Lesson	**Activity**	**Learning outcomes**	**Learning Skills**	**Code**
1 Cars in our lives	**1.1** The history of the motor car **1.2** Top Trumps	Explain the relationship between car ownership and oil production. Make a choice from someone else's perspective. Explain how some features of modern car design are helping to bring cars into a closed loop system.	Record information from video clips. Select data for a purpose.	I, T I, C
2 Investigating air pollution	**2.1** Soot from cars	Plan an investigation. Evaluate the reliability of the investigation. Draw conclusions from data.	Use a standard technique to collect and compare samples along a transect. Assume a role in a team. Evaluate teamwork.	I, T T T
3 Traffic pollution	**3.1** Traffic pollution in Mumbai	Show how maths can be used to help solve a STEM problem on sustainability. Explain how traffic pollution can damage health. Suggest strategies to reduce traffic pollution in Mumbai.	Use a flow chart to plan a mathematical solution. Collaborate to write a report.	C, P C, T
4 and 5 Sustainable transport	**4.1** A sustainable school run	Demonstrate the need for a sustainable school transport plan. Propose a set of closed loop transport solutions. Explain how a sustainable school transport plan will help reduce use of buried sunshine.	Establish criteria for assessing a presentation. Evaluate a presentation and give feedback.	P C, P

Pod 4 Climate change

I = Information retrieval
T = Teamwork
P = Planning
C = Communication
M = Modelling

Lesson	Activity	Learning outcomes	Learning skills	Code
1 Carbon cycle	**1.1** Building an action model of the carbon cycle **1.2** Predicting changes in the carbon cycle	Explain the main processes in the carbon cycle and the links between them. Show how humans are affecting the carbon cycle. Suggest how humans can intervene to reduce the amount of carbon dioxide in the atmosphere.	Demonstrate understanding of the carbon cycle using a kinaesthetic model. Use an animated model to make predictions.	I, T, M, P I, C, M
2 Exploring global warming	**2.1** Is carbon dioxide a greenhouse gas? **2.2** What is the evidence for global warming?	Explain how evidence from a laboratory model supports the theory that CO_2 causes global warming. Identify evidence that the concentration of CO_2 in the atmosphere is increasing and that it is having an effect on the global climate. Describe some of the possible effects of climate change.	Use a laboratory model to illustrate a scientific phenomenon. Collate and summarise scientific evidence from text, charts and graphs.	M I, C, T
3 Carbon footprints	**3.1** What's your carbon footprint? **3.2** One Earth	Make estimates of carbon footprints for familiar activities. Explain why some countries have bigger carbon footprints than others. Demonstrate what changes countries would need to make for energy use to be more equitable and sustainable.	Use an electronic carbon calculator. Use a spreadsheet to model mathematical solutions.	I, M I, M
4 and 5 The wind farm	**4.1** Installing a wind farm	Produce and work to a plan for a group project. Justify a wind farm referring to closed loop theory.	Use a project management tool. Assemble a 3D exhibition to communicate closed loop ideas to a specific audience.	I, T, P, C, M I, T, P, C, M

FILM CLIPS SUMMARY

Introductory film clip 1

The introductory films in *Futures* are starters for each lesson. Three characters are introduced in this first clip. They create a narrative that runs right the way through the first four pods. The narrative starts with George and Hannah discussing their history project. An alien (Spek) appears. Spek can offer George and Hannah help on both their history and their future.

Use the clip to impress on pupils that a new vision of the future will depend on an understanding of the past.

Introductory film clip 2

Nature produces in great abundance and yet there is no piling up of material. All waste is food for other organisms. Because of this, nutrients travel in cycles that are driven by sunshine.

Introductory film clip 3

George, Hannah and Spek the alien are on a beach in Cornwall. They discuss the place called ‘away’ where humans send their rubbish, and whether or not there is a place called ‘away’ where rubbish can be thrown. Spek points out that in natural systems waste is food for other organisms. Discuss ‘Is waste a problem?’ to establish some of the main problems such as build-up of toxins and depletion of limited resources.

Introductory film clip 4

Spek points out to George and Hannah that metals are valuable and need to be recovered. In poor countries, people scavenge rubbish tips for valuable waste that others have thrown away. The three discuss how you could reduce the need to mine new metals if they were not wasted by throwing them away. After the film ask pupils what other metals are important to humans, and what would be the consequences of these materials running out.

Introductory film clip 5

Hannah is about to get an upgrade on her mobile phone. Spek the alien points out to George and Hannah how many components and materials in a mobile phone could be recycled. The idea that technical materials should be recycled in the same way as the nutrients in natural systems is introduced.

Introductory film clip 6

In the film, George and Hannah are designing a sustainable chair for their D&T lesson. Spek tells them about the ‘Think chair’ and introduces the idea of ‘precycling’.

Follow this up by discussing briefly how the Think Chair is produced within a closed-loop system. Remind pupils of the conditions for closed-loop systems (waste is food, reduce toxicity, move towards renewable energy and services, not products). Emphasise the idea that we should consider whole systems rather than individual products.

Introductory film clip 7

In this clip George and Hannah are being driven to school by George’s dad. They complain about the traffic holding them up, but also complain about walking. Eventually they think of some good reasons for walking and get out of the car. Get pupils to think about whether all the journeys they make are necessary.

Introductory film clip 8

This film begins a discussion about what a perfect car would be like. Is it possible to have a car that looks good, is cheap to run, has high performance and is also sustainable?

Introductory film clip 9

This film opens up a discussion about what kind of chemicals there might be in car pollution and how they might affect us.

Discuss with pupils what they already know about pollution from combustion engines, and how it can affect health and the atmosphere.

Introductory film clip 10

In this film Spek transports George and Hannah to the streets of Mumbai. The discussion introduces the friction between personal convenience and social impact. Making cheaper cars that are affordable for more people risks producing more pollution. Ask pupils if they think everyone should have a car.

Introductory film clip 11

In this clip Spek shows George and Hannah some successful sustainable transport solutions that are already in place. Use this to open up a discussion about sustainable transport systems that pupils are already familiar with.

Introductory film clip 12

George, Hannah and Spek the alien are discussing how trees grow in a forest. They work out that trees need carbon dioxide, water and sunlight. They speculate about what would happen to all the carbon in trees if they were cut down.

Take this opportunity to remind pupils about respiration, photosynthesis, combustion and decomposition.

Introductory film clip 13

In this clip George and Hannah work out that there might be a relationship between deforestation and global warming. They wonder if this might be a good thing since they both like warm weather. Spek explains that effects of global warming will be uneven and unpredictable.

The film shows footage of some of the serious effects of global warming that scientists and other observers believe are already taking place.

Use the film as a stimulus to find out what pupils already know about global warming. What are the causes? What are the effects? What is the evidence?

Introductory film clip 14

The clip shows George and Hannah squabbling over their share of marshmallows. Spek moves this on to the question of sharing the Earth's natural resources. He points out that some countries are using much more fossil fuel than others while at the same time emitting more CO_2. Many poor countries have little fossil fuel, but are suffering from the threat of climate change.

Introductory film clip 15

In this clip Spek compliments George and Hannah on humans' use of wind turbines. He then shows them images of other types of renewable energy, explaining that they are all dependent on the Sun. If we can capture this energy we won't need to burn fossil fuels and pump CO_2 into the atmosphere. Spek also suggests that humans can use current energy sources in a more closed loop system by reabsorbing some of the carbon dioxide through forestation.

Use the film as an opportunity to introduce the mini-project. Pupils are going to promote a wind farm. What are the objections likely to be, and how will they be able to persuade people?

Final film clip 16

George and Hannah talk about the changes they are making towards a closed loop system. Spek tells George and Hannah about model closed loop systems in Sweden. They tell Spek about the changes they have already made, but he suggests that they need to go further. Their next school project needs to be to design planet.

CPD modules to support *Futures* delivery

These CPD modules help teachers prepare to deliver *Futures*. Teachers can choose the modules they and their organisation need.

There are two versions of each module. One is for independent or small group completion by teachers. The other includes facilitator guidance and can be used for a facilitated session with a group of teachers in one organisation or at a training event.

1. STEM audit

This explores the subject knowledge in STEM areas needed to deliver the module. It will help those teachers working out of their usual specialist areas, for example, a maths teacher working across STEM. It encourages teachers to work collaboratively.

2. Skills audit

Teachers audit the functional and personal, learning and thinking skills needed by pupils to complete a *Futures* pod. They consider which skills their pupils already have and which need to be developed. There is a template for pupils to audit their own skills.

3. Developing the reflective learner

In *Futures*, pupils are encourages to use a learning journal to reflect on their work and further development. It is often difficult for learners to distinguish between what they did and what they learnt. This CPD module helps teachers find strategies to train pupils in reflective practice.

4. Running the pupil project

Teachers completing this module will consider the implications of running a project on managing time, pupils and resources. Teachers spend time considering likely topics and planning the project pod.

5. Action planning

This introduces three different models for delivering a *Futures* pod. Teachers study the models and determine the advantages and disadvantages of each. They then plan delivery of a chosen pod using the model most suitable for their situation.

6. Support materials for helping pupils to develop their skills

The 2008 National Curriculum incorporates and emphasises a skills-based approach to the curriculum. Where teachers or pupils have identified that specific skills need development in order to succeed in *Futures* (in 'Skills audit'), pupils may be supported with supplementary activities to help them develop skills.

7. Promoting *Futures* to stakeholders

This prepares teachers for presenting the case for introducing the *Futures* topic in a school, usually in a situation where managers are not familiar with the resource. It aims to raise awareness of the features of *Futures* and likely benefits of this topic to pupils and to a school. The slide presentation can be customised to suit local need.

8. Education for Sustainable Development – the context of Nuffield STEM *Futures*

Teachers who wish to explore the background to the development of initiatives in education in sustainable development will find this module useful. It provides the context of STEM programmes and in particular *Futures* by showing how the programme supports objectives across the curriculum.

9. Introduction to closed loop thinking

In order to deliver *Futures* effectively, it is essential that teachers understand the principles of closed loop thinking. This module supports teachers in undertaking an introductory activity which illustrates closed loop principles and promotes discussion of the topic.

10. Teaching and learning strategies

A variety of approaches to teaching and learning is used in *Futures*. This CPD module allows teachers to reflect on the approaches they commonly use and encourages them to try out new approaches. A checklist of teaching and learning strategies is included.

Background Information

Closed loop theory

We need to move towards a sustainable civilisation based on the ecological principles of nature.

Key principles

Waste is food

Use renewable energy

Non-toxic

Closed loop systems

In nature there is no such thing as rubbish. Nature frequently produces a surplus of items such as pollen, leaves and eggs. But this extra is not rubbish but becomes food for other organisms or systems. In this way, materials such as carbon, nitrogen and water do not build up but are cycled in 'closed loops'. These sustainable cycles and loops are powered by sunshine.

Linear systems

Current manufacturing processes require a constant supply of new raw materials. They require large quantities of fossil fuels to mine, process and transport materials. Manufactured products are often dumped as waste when their useful life is over. This process is linear since it involves a take → make → dump system.

Is waste a problem?

Waste is not necessarily a problem if it is 'food' for another part of the system. Materials cycle in this way in natural systems.

Waste in human systems is a problem when it is not biodegradable, as it builds up and may become toxic.

It also means that rare resources such as metals are depleted if not recovered and reused.

Waste is a good thing in natural systems, but not in human systems where it becomes rubbish.

Rubbish is problem since it means that we have to deplete natural resources to produce new products. This process also uses up precious oil reserves. When rubbish accumulates it can become harmful to wildlife and toxic.

Natural and technical materials

Natural materials

In natural systems materials are cycled in 'closed loops'. Waste acts as 'food' for a range of processes. Some manufactured objects are made of natural materials. These can easily return into natural systems, for instance, wooden furniture and paper products can be composted. However if we do not dispose of these products carefully they can cause hazards and waste energy.

Natural materials can still cause problems since fossil fuels may still be used in their manufacture, transport, use and disposal.

Technical materials

Technical materials are either new materials that have been manufactured by humans, or materials that have been refined and concentrated. Often manufactured products containing technical materials are simply dumped as waste when their useful life is over. Most technical materials such as plastics are not biodegradable and cannot return to natural systems. Some technical materials such as metals do occur naturally, but have been refined and processed. They can be toxic if allowed to build up.

The use of fossil fuels in their manufacture, use, transport, and disposal should also be considered.

Recycling, downcycling and upcycling materials

Recycling is used as a generic term for reusing materials. It is often not sustainable because materials become downgraded as they are recycled. This is a particular problem where materials are mixed to make a product, so difficult to retrieve in their pure form.

Aluminium is an example of a material which could be recycled successfully, since for instance cans are a single material (aluminium).

Glass and plastics are usually **downcycled**, because different glasses and different plastics are mixed in waste disposal. These hybrid materials have their uses, but the quality is poorer than the original. Paper is usually downcycled, and can't be recycled endlessly. Downcycling is not sustainable.

Upcycling is often seen more in developing countries where the economic situation encourages it. Materials used in products are collected and processed to make a good quality second product. Examples of upcycling are:

- making wallets from old tyres
- using old pallets to make furniture or signposts
- using reclaimed yarn to knit 'new' clothing

These same materials are frequently downcycled – for instance tyres are granulated and made into carpet underlay or surfaces for playgrounds.

Recycling aluminium

Aluminium recycling rates are high (around 90% for buildings and over 99% for cans in some countries). However the proportion of recycled aluminium in annual production may not rise beyond a third. This is partly because it is very abundant in nature (8%–10% of the Earth's crust by mass). At present, the main driver for recycling aluminium is not limited availability but significant energy savings and environmental benefits. Energy requirements for production and greenhouse gas emissions from recycled aluminium are 5% of that for primary (new) aluminium.

Cradle to cradle design

In nature there is no rubbish since all materials are cycled in 'closed loops'. On the other hand, manufactured products are simply dumped as waste when their useful life is over. By mimicking the closed loop systems of nature it is possible to design products and systems so that useful materials can be reclaimed. Design of products with consideration of their whole life cycle requires 'precycling' (see above). This process is sometimes referred to as cradle to cradle design.

Products can be redesigned at various stages of their product life cycle. For example, the packaging or transport that they require could be re-thought. Some products lend themselves to containing solar panels or wind-up generators, or to reusing/ recycling parts.

Teachers could use examples such as wind-up torches, the Trevor Baylis eco wind-up radio and Think Chair to discuss how these products have 'closed the loop' compared with a traditional product. They may avoid the need to use electricity generated using fossil fuels, or the product may be designed so it can be dismantled for recycling individual materials or parts.

However use of energy is associated with all parts of a product's life cycle.

Closed loop systems move towards use of renewable energy sources. Materials should be reusable, recyclable, upcyclable or compostable. Closed loop design avoids use of toxic materials.

Unsustainable linear systems can be changed into sustainable closed loop systems. For example a sustainable closed loop furniture company might have the following components:

- a sustainable source of timber
- furniture which can be easily dissembled so parts can be reused and replaced
- loan scheme to offices to allow easy retrieval
- collection of component parts for recycling once worn out
- the use of renewable energy in all parts of the product life.

Product life cycle

The materials and components used to make a product start as raw materials extracted from the natural world. This process requires energy.

The raw materials are then converted into the materials and components needed to make the product. This process requires energy.

These materials and components are then assembled to make the product. This process requires energy.

The product may require packaging which is made using energy and materials.

The product may need transporting which requires energy.

During its useful life the product may use energy and materials.

Once the useful life of the product is over it will be disposed of by recycling, burying in the ground or incinerating.

The entire process, from raw materials extraction, through manufacture, distribution, use and final disposal is called the product life cycle. The process uses energy at all stages, and may use additional materials depending on the methods of disposal.

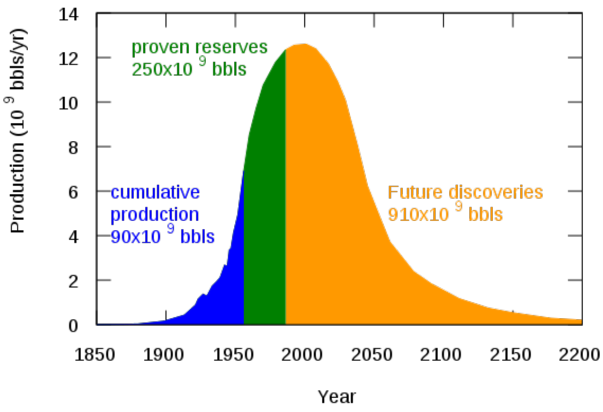
The process may disperse materials so that they cannot be reclaimed and reused.

By looking in detail at the life cycle of a product, designers can modify the design so that less energy and fewer materials are used during the life cycle.

By linking product life cycles together, designers can ensure that the materials and energy that might be wasted in the life cycle of one product are used in the life cycle of another.

Peak oil

Peak oil is the point in time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline. This concept is based on the observed production rates of individual oil wells, and the combined production rate of a field of related oil wells.



Oil production graph by Hank Wang

Peak oil is often confused with oil depletion; peak oil is the point of maximum production, while depletion refers to a period of falling reserves and supply.

Pollution from cars

Nitrogen oxides (No_x)

Nitrogen oxides NO and NO_2 react with ammonia, moisture, and other compounds to form nitric acid vapour. This can penetrate deep into the lung tissue, causing respiratory diseases such as emphysema and bronchitis. It may also aggravate existing heart disease.

Carbon monoxide (CO)

Carbon monoxide is colourless, odourless and tasteless, but highly toxic. Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries. It combines with haemoglobin to produce carboxyhaemoglobin, which is ineffective for delivering oxygen to bodily tissues.

Particulate matter (soot)

The effects of inhaling particulate matter include asthma, lung cancer, cardiovascular diseases, and premature death. Because of the size of the particles, they can penetrate the deepest parts of the lungs.

Carbon dioxide (CO_2)

Carbon dioxide is a greenhouse gas. Motor vehicle CO_2 emissions are part of the contribution to the growth of CO_2 concentrations in the atmosphere. This is believed by a majority of scientists to play a significant part in climate change.

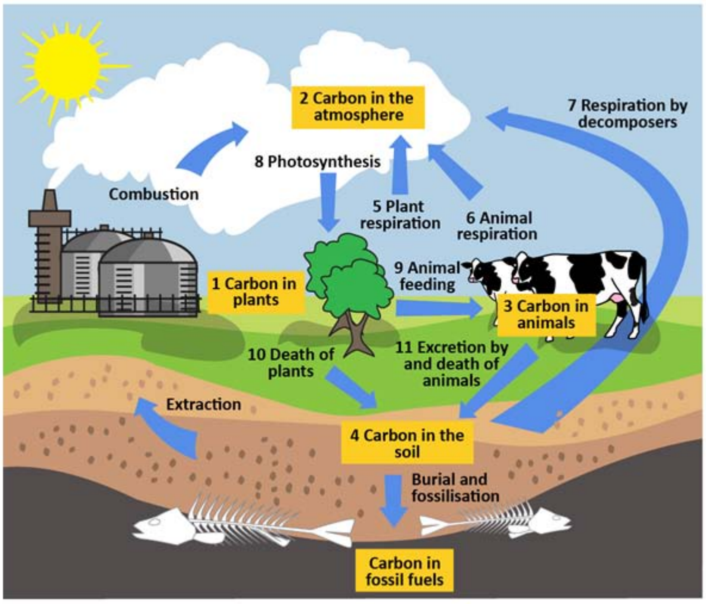
Compressed natural gas (CNG)

CNG produces less CO_2 and NO_X than petrol. CNG is provided in cylinders. These need to be refuelled at petrol stations that have this new facility.

The carbon cycle

Carbon is an important element. All life forms are based on carbon. Carbon joins with the element oxygen to form carbon dioxide (CO_2) and becomes part of the atmosphere. Some carbon in plants gets turned into coal and oil (fossil fuels) when the plants die. This takes millions of years. Plants take in carbon dioxide. Animals and plants give out carbon dioxide.

Taking in and giving out carbon used to balance, and the amount of carbon dioxide in the atmosphere stayed constant. Recently things have begun to change. People have been burning the fossil fuels. The Earth's balancing mechanism can't cope with the extra carbon dioxide being produced. Now carbon dioxide is causing a problem. Most scientists think that too much carbon dioxide in the atmosphere is causing the temperature to rise and this is having a big effect on sea levels and the weather.



Photosynthesis

Photosynthesis involves chemical reactions which reduce carbon dioxide from the air by adding hydrogen from water. The reaction uses energy from light. This makes a hydrocarbon fuel (glucose) which can be broken down to release energy in respiration.

The equation for photosynthesis is:

carbon dioxide + water (+ light energy)
→ glucose + oxygen

In bright light there is more photosynthesis than respiration.

This means that more carbon dioxide is absorbed by the plant than is given out. The level of carbon dioxide around the plant is reduced.

Respiration

Respiration involves chemical reactions which break down glucose (or other fuel molecules) to release energy for reactions in the cell.

The equation for respiration is:

glucose + oxygen
→ carbon dioxide + water (+ energy)

Both plant and animal cells respire. Plants respire all the time, whether it is dark or light. They only photosynthesise when they are in the light. Animals respire all the time. In the dark there is no photosynthesis, only respiration. Respiration produces carbon dioxide, and the level of carbon dioxide around plants increases.

Decomposition

Decomposition is the breaking down of dead organisms by decomposer organisms such as bacteria, fungi and invertebrates. The processes involved are digestion of large molecules, and respiration of fuel molecules. These chemical reactions are catalysed by enzymes.

Yeast has an enzyme called zymase and this catalyses the decomposition process. Ethanol is also produced. This example of decomposition is also called fermentation. Beer and wine are produced by fermenting glucose with yeast.

glucose →ethanol + carbon dioxide

$C_6H_{12}O_6\,(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Combustion

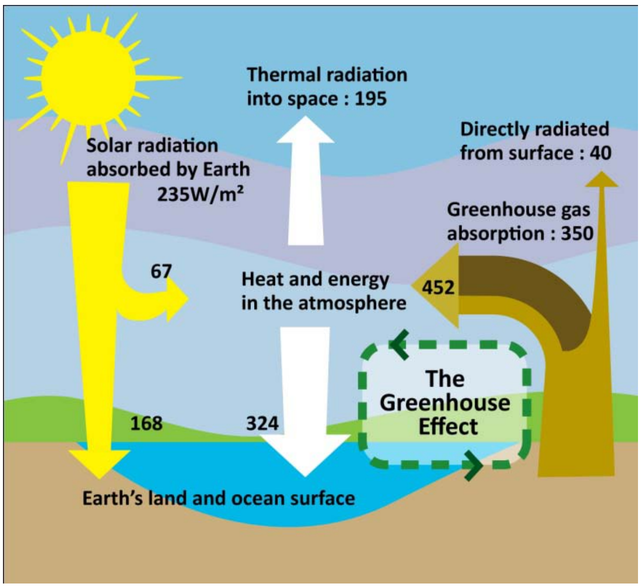
Combustion, or burning in air, is a reaction with oxygen. It is the same reaction as respiration:

(fuel) + oxygen → carbon dioxide + water (+ energy)

The element carbon is present in the fuel. Candle wax (unless made with beeswax) and petrol are both examples of hydrocarbon fuels. Pupils should already know that carbon reacts with oxygen to form carbon dioxide. Other fuels containing carbon include coal, peat and wood.

Greenhouse effect

Energy leaving the surface of the Earth is absorbed by some atmospheric gases, including carbon dioxide, water and methane. These are called greenhouse gases. The gases reradiate the energy, so it warms up the atmosphere and the surface of the Earth. The picture below represents the exchanges of energy between the source (the Sun), the Earth's surface, the atmosphere, and outer space. Units of energy are watts per square metre.



Carbon footprints

A carbon footprint is a measure of the impact our activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day-to-day lives through burning fossil fuels for electricity, heating, transport, and so on.

The carbon footprint is a measurement of all the greenhouse gases we individually produce. It has units of tonnes (or kg) of carbon dioxide equivalent per year (or other unit of time). It is made up of the sum of two parts, the primary footprint and the secondary footprint.

The primary footprint is a measure of our direct emissions of CO_2 from the burning of fossil fuels including domestic energy consumption and transportation (such as car and plane). We have direct control over these.

The secondary footprint is a measure of the indirect CO_2 emissions from the whole life cycle of products we use – those associated with their manufacture and eventual breakdown. To put it very simply – the more we buy, the more emissions will be caused on our behalf.

Reducing CO_2 in the atmosphere

Five options for dealing with CO_2 emissions from fossil fuels are:

1. trap it and store it

2. turn it into something useful

3. travel in ways that produce less

4. use less electricity at home

5. generate electricity without making CO_2.

For further information, look at the CPD module on closed loop theory.