Edexcel A level Geography

Topic Guide for Topic 6: The Carbon Cycle and Energy Security

Practical support to help you deliver this Edexcel specification

Our specifications offer an issues-based approach to studying geography, enabling students to explore and evaluate contemporary geographical questions and issues such as the consequences of globalisation, responses to hazards, water insecurity and climate change. The specification content gives students the opportunity to develop an in-depth understanding of physical and human geography, the complexity of people and environment questions and issues, and to become critical, reflective and independent learners.

The AS and A levels in Geography are linear, and all assessments are at the end of the course. The AS assessment will be at the end of the first year, and the A level assessment will be at the end of the second year.

The specification has been designed so that the content is clear and manageable for centres to deliver within the guided learning hours over a one-year (AS level) or two-year (A level) period.

The guided learning hours are 180 for an AS level and 360, over two years, for an A level. This document provides a guide for teaching the carbon cycle and energy security and can be adapted by centres to fit their own contexts and teaching styles. It has been produced as an example approach and is not intended to be prescriptive. The topic guides indicate resources that you can use to support your teaching. These are only suggestions and you are encouraged to use a wide range of resources to suit the needs of your own students.

The advised teaching time for Topic 6: The Carbon Cycle and Energy Security, is 18 guided learning hours; i.e. roughly 5–6 hours per enquiry question (EQ). This requires some blending together of the detailed content. In the guidance below, suggestions are made about contextualisation or stretch challenges that may be suitable for more able students, as well as expected lesson outcomes for those less able. Please note that these are suggestions only and not specific syllabus requirements.

A balanced carbon cycle is important in maintaining planetary health. The carbon cycle operates at a range of spatial scales and timescales, from seconds to millions of years. Physical processes control the movement of carbon between stores on land, the oceans and the atmosphere. Changes to the most important stores of carbon and carbon fluxes are a result of physical and human processes. Reliance on fossil fuels has caused significant changes to carbon stores and contributed to climate change resulting from anthropogenic carbon emissions.

The water and carbon cycles and the role of feedback in and between the two cycles provide a context for developing an understanding of climate change. Anthropogenic climate change poses a serious threat to the health of the planet. There is a range of adaptation and mitigation strategies that could be used, but for them to be successful they require global agreements as well as national actions.

Each enquiry question is broken down into groups of lessons, each beginning with a quick overview of the breadth of the enquiry question followed by a more detailed explanation of the key concepts and processes, examples of teaching strategies, guidance on integrating geographical skills, and a summary of the key terminology required. The structure is suggestive, not prescriptive. Though we have aimed suggest lots of resources, teachers are not complied to use them and they are merely suggestions to highlight the broad spectrum of resources that are at hand for students to use.

Synoptic linkages and case study nesting

There are many synoptic themes within this unit in terms of linking the impacts of climate change to Topic 3: Globalisation and the Effects of Deindustrialisation has impacted on energy mixes. For Topic 1: Tectonics there is the potential of natural hazards impacting upon supply, whilst climate change and the impacts on glaciation ad glacial hazards is well documented in Topic 2a: Glaciated Landscapes and Change.

More importantly, some might argue that the overriding issue is how our demand for fossil fuel impacts upon the hydrological cycle, not only in terms of climate change but also in terms of pollution from such techniques as fracking, tar sand production and disasters such as the Deepwater Horizon oil spill of 2010. Beyond that in Topic 4a: Regenerating Places there are the potential problems associated with closure of mining towns, impacts of nuclear energy on places and how these places should be regenerated. Finally, in Topic 7: Superpowers there is ample synopticity between the growth of energy rich states such as Russia and the problems associated with countries whose energy security is beginning to fall such as the USA.

All of these should help students see ‘the bigger picture’, by encouraging them to make geographical links between topics and issues.

EQ1: How does the carbon cycle operate to maintain planetary health?

Teaching approach over 5 hours

Lesson 1 (1hr)	The biogeochemical carbon cycle
Lesson 2 (1hr)	Why most of the earth's carbon is geological and how it became that way. The geological processes that release carbon into the atmosphere
Lesson 3 (1hr)	The biological processes that sequester carbon on land and in the oceans on shorter timescales.
Lesson 4 (1hr)	How the concentration of atmospheric carbon strongly influences the natural greenhouse effect, which in turn determines the distribution of temperature and precipitation.
Lesson 5 (1hr)	How ocean and terrestrial photosynthesis play an important role in regulating the composition of the atmosphere. Why the process of fossil fuel combustion has altered the balance of carbon pathways and stores with implications for climate, ecosystems and the hydrological cycle.

Lessons 1 and 2: Most global carbon is locked in terrestrial stores as part of the long-term geological cycle

Overview

These lessons cover Key ideas 6.1a, b and c and can be used as an introduction to the subject. Understanding what students know will help both the teacher and the student in determining at what level to teach this first topic.

For less able students, simplified diagrams of the carbon cycle (https://www.thinglink.com/scene/720767293927194625) can used as a starting point. More able students may be better suited with more complex flux diagrams of the carbon cycle such as: http://www.lenntech.com/carbon-cycle.htm
Many students will already be aware of the carbon stores in such places as coal, natural gas and permafrost and more recently within rock (a good and useful example of geological timescales).

Key concepts and processes

- The biogeochemical carbon cycle consists of carbon stores of different sizes consisting of:
  - terrestrial such as soils, plants and trees
  - oceans
  - Atmosphere.

- Each of these stores is dynamic and fluxes (movement) between the stores vary in size, rates and different timescales

- Timescales can vary between:
  - short term – up to seconds to minutes
  - medium term – up to decades or centuries
  - long term – millions of years.

Guidance on teaching

Many teachers and students may feel intimidated by all the new terminology they are presented with. In its simplest form, the biogeochemical cycles include the carbon, hydrological and nitrogen cycles and these are natural processes that recycle nutrients in various chemical forms from the environment, to organisms, and then back to the environment. The carbon cycle is only one of these biogeochemical cycles and can be defined as the exchange of carbon between its four main reservoirs—the atmosphere, terrestrial biosphere, oceans and sediments. Each of these global reservoirs may be subdivided into smaller pools, ranging in size from individual communities or ecosystems to the total of all living organisms.

For some students the start of this subject may be fraught with unknowns and therefore it is important to make sure that students progress at the right rate to be able to assimilate all the information.

A good way to develop an understanding is to show students a basic carbon cycle diagram (such as https://eo.ucar.edu/kids/green/cycles6.htm), which is useful in helping less able students develop an awareness of how the cycle works and some of the constituent parts. Beyond this and with the use of presentation, it is worth developing the points in terms of the movement of carbon between the constituent parts and the sizes of these stores.

Furthermore, key terms should be defined and students should be able to identify where these are within the cycle.

The timescales fluxes and rates can be best explained using more complex carbon cycle diagrams such as: http://dilu.bol.ucla.edu/home.html.

Further links can be found below. An excellent start for teachers and more able students as well as general reading material can be found on the University of New Hampshire 'An Introduction to the Carbon Cycle' (http://globecarboncycle.unh.edu/CarbonCycleBackground.pdf). This website's homepage (http://globecarboncycle.unh.edu/cmap1.shtml) offers an excellent range of carbon cycle activities, links and other information as well as teaching aids, many of which are free to use.
For a clear understanding of why most of the earth's carbon is geological, there are several good examples and techniques to get this across to students.
For carbonate rocks such as limestone, a great website (http://sciencelearn.org.nz/Contexts/A-Fizzy-Rock/Sci-Media/Animations-and-Interactives/Limestone-secrets-revealed) provides animations and videos.
Coal diagrams (such as the one found here: http://www.pmfias.com/coal-formation-of-coal-types-of-coal-peat-lignite-bituminous-coal-anthracite-coal/) are useful tools for students to visualise the changes and processes involved.

This website also offers various ideas and resources on the types of coal (including peat) and their formations (http://www.pmfias.com/coal-formation-of-coal-types-of-coal-peat-lignite-bituminous-coal-anthracite-coal/).

Furthermore, information on global carbon cycle stores may help students begin to appreciate the different aspects of stores and sequestration. A great diagram can be found here: http://www.nrs.fs.fed.us/pubs/jrnl/2011/nrs_2011_pan_002.pdf

There are a range of global and local maps available, some of which are linked below.

The final part is looking at how geological processes release carbon into the atmosphere through volcanic out-gassing at ocean ridges/subduction zones and chemical weathering of rocks. Consideration by teachers should be given to the fact that carbon is released through gasses from within the earth they release a cocktail of gases, which includes mainly water vapour but also other gases such as sulphur dioxide, carbon dioxide and hydrogen from volcanic zones. These gases can form with water droplets and produce aerosols.

Carbon also plays an important role in terms of weathering of rocks. Carbon dioxide dissolves in surface waters and forms a weak acid called carbonic acid. This acid can react with rocks and many common minerals. Some of this carbon is returned to the atmosphere via metamorphism of limestone at depth in subduction zones or in orogenic belts. More information on this can be found here: http://www.columbia.edu/~vjd1/carbon.htm

Lesson 3: The biological processes that sequester carbon on land and in the oceans on shorter timescales

Overview

This lesson covers Key idea 6.2: biological processes sequester carbon on land and in the oceans on shorter timescales. It looks at the processes that sequester carbon photosynthesis in the oceans and on land, and how biological carbon can be stored as dead organic matter in soils, or returned to the atmosphere via biological decomposition over several years.

Students will need to develop a good appreciation of photosynthesis, respiration and decomposition and their role within the carbon cycle. More able students should be able to develop an awareness of the influence that these factors have and potential issues that could impact on these rates, and also determine their significance in maintaining planetary health.

Key concepts and processes

- How biological processes sequester carbon on land and in oceans:
  - The role of photosynthesis in ocean carbon sequestration at surface levels

- The movement of carbonate shells into the deep ocean water through the carbonate pump and action of the thermohaline circulation

- The role of terrestrial primary producers and how they sequester carbon during photosynthesis, and the impacts of respiration in returning this to the atmosphere

- The role of death and decomposition in the storing of biological carbon

Guidance on teaching

Students need a clear understanding of photosynthesis and some students may have a grounding of this from previous subjects. Each can be reviewed in terms of:

- terrestrial photosynthesis
- ocean photosynthesis
- biological decomposition.

An interesting start is the second video on this webpage called 'Where Do Trees Get Their Mass from?'. This page also has some simple questions and discussion points that could be manipulated to suit the areas you need to cover as well as links oceans and the carbon cycle (http://serc.carleton.edu/eslabs/carbon/1a.html). Diagrams of photosynthesis are widespread such as: http://scienceunraveled.com/Photosynthesis

A simple formula for photosynthesis can be written as:

$CO_2 + H_2O = \text{sugar} + O_2$

(Photosynthesis uses CO_2 from the atmosphere and produces O_2.)

However, for more able students it can also be shown as the more complex formula:

$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$ (carbon dioxide + water = glucose + oxygen)
(For ocean photosynthesis, a good start would be to look at what phytoplankton are – see http://earthobservatory.nasa.gov/Features/Phytoplankton/). A phytoplankton bloom has been defined as a high concentration of phytoplankton in an area, caused by increased reproduction. Phytoplankton population explosion-blooms occur when sunlight and nutrients are readily available to the plants, and they grow and reproduce to a point where they are so dense that their presence changes the colour of the water in which they live. These can be quick events or last several weeks.

Students of more ability may wish to look at specific blooms that occur on a seasonal basis such as those in the Gulf of Maine (http://serc.carleton.edu/eet/phytoplankton/primer.html).

Less able students may be more satisfied with a simpler approach of the reasons for these, most of which are transient in nature:

- Water temperature
- Density, and salinity
- Hydrography of the region (underwater topography)
- Availability of nutrients
- What species and the amount of phytoplankton biomass that is present
- The type of zooplankton that are grazing on the phytoplankton
- Available sunlight levels.

There are very few factors that can be considered permanent in this except for the hydrography and bathymetry (depth and relief of ocean waters).

To understand stratification, weaker students may wish to appreciate the temperature changes within ocean levels. This can be done using simple graphs such as this: http://serc.carleton.edu/details/images/1957.html

In principal, stratification is changes in temperature underwater. Similarly, temperatures change on land. The higher up one climbs a mountain, the lower the temperature is, due to lower air pressure. Underwater, the temperature, salinity, density and pressure changes.

Density is controlled by salinity and temperature warmer water floats on top of cooler water and, as the depth of water increases, the salinity and temperature changes to provide a water column where there are barriers to the water mixing. Just like in terrestrial seasons, oceans have these as well where temperature changes. This is why blooms can become seasonal as water variables change, as noted above. Water columns can be explored further here:
http://earthobservatory.nasa.gov/Features/Phytoplankton/page4.php
http://serc.carleton.edu/eslabs/carbon/6b.html

The role of biological carbon and decomposition can be looked at simply as when something dies, such as a plant or tree, decomposers (detrivores), such as worms and fungi, feed on dead organic matter and break it down into CO_2, nutrients and water. The carbon is reclaimed and put back into cycle so other living organisms can use it through soils.

As the last part of the cycle, this should then allow students of all abilities to help explain why it remains a cycle and why some is dynamic and moves quickly whilst the timescales can be vastly different depending on the factors that influence it rates of exchange.

Lessons 4 and 5: A balanced carbon cycle is important in sustaining other systems but is increasingly altered by human activities

Overview

In these lessons students will be looking at Key idea 6.3: the concentration of atmospheric carbon and how it strongly influences the natural greenhouse effect. Students will need to appreciate that this itself can help determine the distribution of temperature and precipitation.

Whilst students are often aware that carbon dioxide can be detrimental to the atmosphere, these lessons should help to explain why.

Differentiation is achievable throughout, as often all students understand that the greenhouse effect is being altered by human activity. Students could list the reasons why and assess the importance of these reasons by ranking them.

In the second lesson, students need to look at how ocean and terrestrial photosynthesis play an important role in regulating the composition of the atmosphere and how soil health is influenced by stored carbon, which is important for ecosystem productivity.

Finally, students will look at the process of fossil fuel combustion and how it has altered the balance of carbon pathways and stores with implications for climate, ecosystems and the hydrological cycle.

For stronger students there are plenty of areas for development in terms of wider understanding. Websites such as Global Climate Change by NASA is a good starting point (http://climate.nasa.gov/causes/) or https://www.epa.gov/ghgemissions/overview-greenhouse-gases, which has lots of links to further information that can be studied and evaluated in relation to the rest of the specification. Weaker students may be best served by looking at schematic diagrams, which explain the importance of greenhouse gases and the implications of too many: http://www.weather.gov.hk/climate_change/human_activities_e.htm

There should also be plenty of opportunities to use Skill 2: Use of maps showing global temperature and precipitation distribution to help develop students' understanding in lessons 4 and 5.

Key concepts and processes

- The concentrations of carbon are important in maintaining natural greenhouse gases:
  - Before humans, concentrations of CO_2 in the atmosphere rarely peaked above 300ppm. They are expected to reach more than 550ppm by 2050.

- Human activity has led to an increase in the concentrations of greenhouse gases such as:
  - burning of fossil fuels
  - deforestation
  - agriculture
  - industrial processes.

- That enhanced greenhouse gases can impact upon climate and precipitation.

- Ocean and terrestrial photosynthesis play an important role in regulating the composition of the atmosphere:
  - Photosynthesis helps removes CO_2 from the atmosphere and release oxygen.

- Carbon stored in the ground can influence levels of soil health, which can impact upon ecosystems and their productivity:
  - The productivity of soils is influenced by the level of organic carbon within it.
  - Lack of nutrient-rich organic carbon matter can lead to soil erosion.

- Understand that increased carbon emissions through the burning of fossil fuels has altered the balance of the carbon cycle including the pathways and stores, which has implications for:
    - climate
    - ecosystems
    - hydrological cycle.

Guidance on teaching

Maintaining a balanced carbon cycle has been very important in helping keep the earth a productive and habitable place. This can be shown through the use of diagrams associated with global temperature such as: http://www.globalissues.org/article/233/climate-change-and-global-warming-introduction

In fact, this website offers an excellent range of diagrams, graphs interactive maps and lots of information which would be useful for both teachers and students alike. For more able students, there is a wealth of information that covers these areas and many websites are listed below. For less able students, the use of diagrams, SAM and PowerPoints, which cover the information in detail, may often be the best approach.

An excellent range of maps can be accessed via the NOAA website on global temperature. Precipitation maps, many of which date back to pre-1900, could be used for evaluative purposes and to look for anomalies or trends to help students appreciate the importance of data use and how the carbon balance is becoming altered. Much of the old legacy specification covers Key idea 6.3a and old material could be used.

To add some perspective over a longer period of time, students may benefit from seeing what systems were like over a much larger timescale, as shown here: https://scripps.ucsd.edu/programs/keelingcurve/)

Soil health is an important part of ecosystem health and the quantity of carbon stored in soil is also important. Factors such as deforestation and changes to climate can influence the level of stores and therefore reduce fertility levels. Examples here would include deforestation in the Amazon and the impact this has on soil fertility whilst desertification in the Sahel region of Africa and Southern Spain offer examples that are climate based.

This website (http://www.iberianature.com/material/spain_drought.htm) looks at the problems in Spain, which has access to several radio documentaries on the area. Other interesting websites include http://www.nytimes.com/2008/06/03/world/europe/03dry.html?_r=0 and http://www.unesco.org/mab/doc/ekocd/spain.html, all of which look at the issues facing ecosystems and soil fertility and erosion in this area.

Furthermore, there is ample information on the Sahel including: http://www.eden-foundation.org/project/desertif.html and https://confluence.furman.edu:8443/display/Lipscomb/Desertification, which looks at various countries.

The burning of fossil fuels is the last section to cover and much of this content may well have already cropped up in earlier lessons. A good starting point, however, could be articles such as http://carboncycle.aos.wisc.edu/fossil-fuels/, which has lots of useful information for less able students to get to grips with.

The impacts on ecosystems can vary but websites such as these will help students develop an awareness of the problems they face: http://theconversation.com/leave-it-in-the-ground-how-fossil-fuel-extraction-affects-biodiversity-19484

For more able students and teachers how fossil fuels impact on water quality can be read about in Chapter 4 of *The World's Water Volume 7:* 'Fossil Fuels and Water Quality' (http://worldwater.org/wp-content/uploads/2013/07/chapter_4_fossil_fuel_and_water_quality.pdf). This gives ample opportunities for students to begin to assess how fossil fuels can impact on water quality. For less able students, websites such as http://www.conserve-energy-future.com/Disadvantages_FossilFuels.php give a great introduction to the problems of fossil fuels.

Key vocabulary for EQ1

Key Term	Definition
Carbon sink	A carbon reservoir that takes in and stores (sequesters) more carbon than it releases. Carbon sinks can serve to partially offset greenhouse gas emissions. Forests and oceans are both large carbon sinks.
Carbon pool	A system that has the capacity to store or release carbon (of which there are five)
Carbon fixation	The incorporation of carbon into organic compounds by living organisms, chiefly by photosynthesis in green plants
Flux	The rate of exchange between reservoirs
Thermohaline circulation	The flow of ocean water caused by changes in density
Shortwave radiation	Solar radiation from the sun in the form of visible light and ultraviolet radiation
Longwave radiation	Radiation returning from the earth in the form of infrared radiation or heat

Further reading

http://dilu.bol.ucla.edu/home.html – University of California Carbon Cycle information and resources
http://www.stroudcenter.org/livablelandscape/climate_change.shtm – Stroud Water Research Centre. The Carbon Cycle and Climate Change are useful for evaluation skills
http://www.pmel.noaa.gov/co2/story/Carbon+Cycle – PMEL Carbon Program (Noaa.gov)
http://www.nrs.fs.fed.us/pubs/jrnl/2011/nrs_2011_pan_002.pdf – contains some potentially useful large datasets for a large and persistent carbon sink in the world's forests
http://www.carbon-biodiversity.net/Issues/CarbonStorage – carbon storage via ecosystems
http://www.nature.com/nclimate/journal/v3/n10/fig_tab/nclimate1951_F2.html – global distribution of soil carbon pools
http://msue.anr.msu.edu/news/the_important_role_of_photosynthesis – the important role of photosynthesis
http://noc.ac.uk/science-technology/climate-sea-level/carbon-ocean/biological-carbon-pump – biological Carbon pump
http://www.fao.org/docrep/009/a0100e/a0100e05.htm – soil organic matter, the soil food web, decomposition process
https://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-7-3.html – good for more able students and teachers for higher order skills
http://www.indiana.edu/~geol105b/1425chap8.htm – excellent article on climate regulation by University of Indiana
http://earthobservatory.nasa.gov/Features/Desertifica tion/ – NASA defining Desertification; good for all levels
http://www.geocurrents.info/geopolitics/insurgencies/boko-haram-insurgency-stem-environmental-degradation-climate-change Excellent discussion/ – evaluation point for more able students who might wish to take the ideas of desertification further

EQ2: What are the consequences for people and the environment of our increasing demand for energy?

Teaching approach over 5–6 hours

Lesson 6 (1hr)	Consumption of energy and the energy mix, and the factors that can impact upon the levels of consumption
Lesson 7 (1hr)	Energy players have different roles in securing pathways and energy supplies
Lesson 8 & 9 (2hr)	How reliance on fossil fuels to drive economic development is still the global norm
Lesson 10 & 11 (2hr)	The costs and benefits of alternatives to fossil fuels

Lessons 6 and 7: Energy security is a key goal for countries, most relying on fossil fuels

Overview

These lessons cover Key idea 6.4a, b, c as well as covering Skill 3: Graphical analysis of the energy mix of different countries, including change over time. The main thrust is the idea that energy security is important to countries and there is still a high reliance on fossil fuels. For teachers there is much crossover with the legacy specification *Unit 3 Contested Planet: Energy Security*.

The first lesson looks at consumption of energy and its relation to GDP and the mix of energy types a country uses to help maintain security. It explores how access to and physical availability of resources depends on several important factors such as cost, technology, public perception and level of development as well as the environmental priorities of a country.

For less able students, the development of Key ideas is really important in helping to understand the need for energy mixes. Whilst this could be case study driven (e.g. USA v France) in terms of energy mix, it will also be important to compare those countries who have different priorities such as less developed countries or those who are resource rich.

More able students can look at and assess the variety of mixes from various countries and try to explain why this would be the case, especially those that might be harder to explain from energy mix graphs such as Norway.

Whilst it is also important for less able students to remember that numbers are often in percentage form, this is often overlooked. For instance, the amount of energy gained from renewables is very low as a percentage in China but in fact is far higher in terms of actual MTOE than the UK whose percentage is higher.

The second lesson looks at Key idea 6.4c: energy players and their role in securing energy supplies. There is much scope here for both less-able and more-able students to role play and develop evaluative ideas. You can also use exam material from the previous legacy specification including GEO3 paper January 2010 1b or the synoptic paper within GEO3 paper January 2011 Section B Energy Security.

Key concepts and processes

- That consumption of energy per capita is often related to level of development:
  - Higher levels of development are linked to high use of energy due to increased wealth and demand for consumer goods such as TVs, fridges or cars

- That there are many different sources of energy:
  - Conventional and non-conventional fossil fuels as well as renewable energies, such as wind, solar, biomass, nuclear, geothermal and HEP

- That many countries rely on a mix of energy to help maintain energy security:

- By relying on a range of energy sources countries are able to control issues such as cost, lack of supply of one type of energy

- That there are different types of energy including, primary, secondary, domestic and foreign as well as renewables and non-renewables

- Understand the factors that are affecting energy security:
  - Physical factors such as exhaustion of supply or disruption to supply due to natural hazards
  - Environmental – protests about environmental damage
  - Economic – rises in costs due to supply problems or price hikes
  - Geopolitical – conflict or political instability within producer countries

- That there are major energy players who are involved within the movement of energy including:
  - TNCs – such as Shell, Texaco, Exxon
  - governments – who are decision makers, choice of energy mix and investment in renewables, policies on fossil fuel use (e.g. the UK and nuclear power)
  - OPEC – global intergovernmental organisation that govern the supply of oil from major producing states. There are 14 of these including, Saudi Arabia, Kuwait, Qatar and Venezuela
  - Consumers and environmentalists – the people who use energy and those that campaign against environmental issues created by energy

Guidance on teaching

There is some excellent material on energy use already available on the legacy specification, which is worth reviewing. Energy use per capita is a good starting point and you might be to get students to view the large map found at BURN an Energy Journal website: http://burnanenergyjournal.com/how-much-energy-are-we-using/ This is a world map with energy use per country shaded and would be a good discussion point. More able students might benefit from trying to find anomalies within the map while less able students will appreciate that poorer nations use less energy that wealthier ones.

The NASA-NOAA satellite view of the night sky image is also an excellent resource to look how 'switched on' in terms of energy consumption they are. On this page (http://www.nasa.gov/mission_pages/NPP/news/earth-at-night.html) there are many images that represent our use of energy which may benefit less able students who can see a visualisation of the countries usage or not. The Nile River image is ideal to illustrate to students how the river breeds economic life into the country. Sources of energy use are best attempted through cost benefit analysis to allow all students an understanding of the positives and negatives of each energy such as the one below, which lists all the energies but leaves out some of the positives and negatives.

The website CarbonBrief.org offer an insight into the way the UK's energy mix has changed (https://www.carbonbrief.org/five-charts-show-the-historic-shifts-in-uk-energy-last-year), which has some excellent information and diagrams that might be useful.

Similarly a useful chart that might help more able students details the energy changes over time in the USA and dates back to 1950: https://financere.nrel.gov/finance/content/us-power-sector-undergoes-dramatic-shift-generation-mix

Using this chart, students may wish to design pie charts for 1950, 1975 and 2012 to show the change and explain reasons why this might be the case, such as price, resource availability, technology and environmental priorities. Further information on this and other resources are found below.

Interestingly, when looking at MEDCs, this table has many talking points for more able students: http://thebreakthrough.org/archive/which_nations_have_reduced_car)

This site also offers a lot of information relating to decarbonisation, not only on which nations have reduced carbon intensity fastest but also small studies on Sweden and France and their state-led shift to zero-carbon energy supplies.

The final area are players within energy security. Those players include:

- OPEC
- TNCs
- governments
- consumers and environmentalists.

Much of the legacy specification covers these in helpful detail. Good case studies to help students could be the UK for governments, Gazprom or BP for TNCs.

Less well-covered is the growing role of unconventional fossil fuels. Students could investigate these using websites such as: https://www.theguardian.com/sustainable-business/uk-future-energy-mix

This website is an excellent resource for the changing UK energy mix with lots of good charts and interactive graphs: http://www.edie.net/news/10/The-UKs-ever-changing-energy-mix-2015-in-charts/29968/. Websites such as this should generate a great deal of discussion/assessment between students of all abilities.

Consumers are often a neglected player in energy demand and in turn this can impact upon supply needs. Consumers can reduce their use of energy in many ways and, as part of government policy, they can be educated and taxed. This has many positives and negatives in reducing use, which students could look into.

Lessons 8, 9, 10 and 11: There is a reliance on fossil fuels to drive economic development and there are alternatives to fossil fuels but each has its costs and benefits

Overview

This set of lessons aims to cover all aspects of Key idea 6.5 and Key idea 6.6. The first two lessons look into the mismatch between locations of supply and demand, that energy pathways are a key aspect of security but are prone to disruptions from factors such as natural disasters, political disputes and depletion of resources putting

security at risk. Finally, they look at the importance of the growing development in unconventional fossil fuels and the impacts this can have environmentally as well as the social and political aspects associated with this.
Within this there are many areas where weaker students may benefit from the case study approach and though not compulsory may aid students in their appreciation as well as adding perspective to different people's arguments. The Ukraine v Gazprom transit row is well documented in both the legacy specification (GE03 Contested Planet: Energy Security) as well as online and in text.
There is also the opportunity to achieve Skill 4: Analysis of maps showing global energy trade and flows.

Key concepts and processes

- There is a mismatch between locations of conventional fossil fuel supply due to the following:
  - Fossil fuels were formed many millions of years ago from prehistoric plants and animals and coal, gas and oil were formed under specific conditions meaning that geographically some countries have low supply while others have high.
  - Level of development
  - Lack of resources in some countries or resources have peaked (Japan, China, USA, UK)
  - Supply outstrips demand in some countries (e.g. Saudi Arabia, Russia)

- That energy pathways such as are a key aspect of security but can be prone to disruption especially as conventional fossil fuel sources deplete:
  - pipelines
  - transmission lines
  - shipping routes
  - road and rail.

- That there are both costs and benefits to the development of unconventional fossil fuel resources like: tar sands oil shale, shale gas, deep water oil and that these can be classified as social, economic and environmental costs and benefits.

- That the use of unconventional fossil fuels also has implications for the carbon balance and cycle (Increased carbon release reduced carbon sequestration).

- That renewable and recyclable energy could help decouple fossil fuel from economic growth, however, each of these has costs and benefits economically, socially and environmentally as well as in terms of their contribution to a countries energy security (e.g. UK):
  - nuclear power
  - wind power
  - solar power

- Biofuels is growing recyclable energy supply globally. However, these have their own problems such as:
  - implications for food supply

- uncertainty over how 'carbon neutral' they are (e.g. biofuels in Brazil)

- Radical technologies could reduce carbon emissions but uncertainty exists as to how far this is possible. These include:
  - carbon capture and storage
  - hydrogen fuel cells
  - electric vehicles.

Guidance on teaching

The present mismatch between supply and demand can be looked at via the carbon tracker website which, has excellent resources available to use: www.carbontracker.org. (Some articles on here make excellent research and background reading for more able students.) Maps on where fossil fuels can be found as an excellent visualisation for students as well as graphs to show demand versus supply: http://www.energyinsights.net/cgiscript/csarticles/articles/000001/000118.htm

Maps can also be useful including: http://www.bq-magazine.com/economy/2013/09/gulf-explained-40-maps-part-2 and world consumption by region: http://www.eia.gov/todayinenergy/detail.cfm?id=12691

Below are plenty of links to these kind of maps and data.

As this mismatch progresses, less able students can begin to pick out the need for transportation and the potential issues that this might present and that pathways are needed to move resources around the world:

- Pipelines
- Shipping
- Transmission lines
- Road
- Rail

Fossil fuels have set routes already and often they are different. Most gas goes through pipeline unless liquefied while most coal is moved by rail where possible and oil, though transferred by pipeline, is generally exported via ship. There are maps below that show some of these and both less able and more able students should begin to pick out political, economic, environmental and social issues.

Oil supply maps such as http://www.energyresourcefulness.org/Power/world_oil.html offer great links on other forms of energy within North America as well as the rest of the world.

Global gas supply routes are shown here with their equivalent values. These kinds of maps offer a greater degree of complexity and should test students: (http://euanmearns.com/european-and-uk-gas-security/).

Risks can be categorised as shown in Figure 1:

Figure 11: Various factors which can disrupt energy supply (J. Foster)

Good case studies for energy disruption can be drawn from Russia v Ukraine Gas row, for which much information exists on website from newspapers such as http://www.dailymail.co.uk/news/article-1106382/Europe-plunged-energy-crisis-Russia-cuts-gas-supply-Ukraine.html to http://www.economist.com/node/12903050 as well as this useful site: https://www.opendemocracy.net/democracy-ukraine/gas_crisis_3185.jsp. This has been a continual issue beginning in 2006 occurring again in 2009 and has re-awakened in 2016 (http://www.independent.co.uk/news/world/europe/ukraine-crisis-putin-will-cut-gas-to-europe-unless-russia-is-paid-by-the-end-of-the-week-10071475.html).

The development of unconventional sources has grown massively in recent years as the cost of energy rises and the potential for disputes over foreign supplies arise. Unconventionals consist of several types of energy including oil shale/ tar sands and shale gas.

There are excellent resources available for all students with a great starting point being: http://css.snre.umich.edu/css_doc/CSS13-19.pdf, which covers most types and life cycle impacts. An excellent interactive map can be found here: http://www.unconventionalenergyresources.com/viewer/index.html
For Canadian Tar Sands, this site (http://www.capp.ca/canadian-oil-and-natural-gas/oil-sands/what-are-oil-sands) offers a short film about what it is and how it is removed as well as further links to other films and information. For an alternative view, Greenpeace also provides information and a short info-film: http://www.greenpeace.org/canada/en/campaigns/Energy/tarsands/. Further resources are listed below.

Similarly, sites exist for UK fracking which can also be looked into and good research could be undertaken and this would make an idea point for a role play where groups of students have a debate separated into:

- environmentalists
- locals
- government
- TNCs
- scientists.

Each student could give a short presentation and a debate as to whether fracking should go ahead, allowing students to engage at the top end and lower ability students, learning to understand the complexity of the issues surrounding these radical technologies. Websites for this are listed below.

A similar method could be employed on deep water oil drilling in Brazil, or research case study homework using the techniques learnt in the role play, could help all students develop further understanding. Similarly, this could also work with ANWR.

For energy types and how they may help we couple fossil fuel from economic growth, students could draw up a table like that below (which only contains examples and is not extensive). This level of detail may help less able students whilst more able students may benefit from having only the energies filled in:

Energy Type	Positives	Negatives
Coal	• Systems in place for its use • Cheap cost • Abundant	• Releases CO_2 • Considered a dirty fuel • Environmental issues such as acid rain
Natural gas		
Nuclear power	• High energy production • Cheap energy once up and running • 'Green' energy	
Crude oil		
Unconventional fuels	• Large untapped supply • Can increase a countries energy security • As the cost of fuel rises it will become more popular	
Solar energy		
Wind		• Needs large amount of land to generate the necessary energy • NIMBY issues • Only runs when wind is at certain speed
Geothermal		
Biomass	• Recyclable energy • Reduces use of fossil fuels	
HEP		
Other* Can be used for students to develop ideas		

Furthermore, ideas on biofuels and technological fixes such as carbon storage and capture, electric vehicles and hydrogen fuel cells could be developed through research in class in paired work or peer learning groups with differentiated members. Weaker students could draw up a pros and cons list while more able students may wish to develop a clearer understanding of whether these kind of techniques could benefit economic growth or in the long run are they just a method to increase the time we have left with fossil fuels.

Websites for this include:
http://www.ccsassociation.org/what-is-ccs/ – what is carbon capture and storage?
http://www.imperial.ac.uk/carbon-capture-and-storage/ – carbon capture and Storage Research Network
http://www.energysavingtrust.org.uk/travel/electric-vehicles – Energy Saving T and electric vehicles
http://www.afdc.energy.gov/vehicles/electric.html – UK Department of Energy Hybrid and Plug-In Electric Vehicles
http://www.renewableenergyworld.com/hydrogen/tech.html – hydrogen energy
https://www.hydrogen.energy.gov/pdfs/doe_fuelcell_factsheet.pdf – hydrogen energy factsheet

Key vocabulary for EQ2

Key words	Definition
Energy transition	The long-term structural change in energy resources, such as fuelwood to coal
Fracking	Drilling into bedrock, usually sedimentary, which contains methane in small air pockets. Firing a high pressure mixture of water, chemicals and sand to break down the rock and release the gas
LNG	Liquefied natural gas: methane that has been cooled until it becomes a liquid. (This has a higher 'carbon footprint' than normal methane.)
Carbon capture and storage	The process of trapping carbon dioxide produced by burning fossil fuels and storing it so it is unable to affect the atmosphere
Peak production	A date where maximum production has been reached, beyond which production rates will diminish

Further reading

https://financere.nrel.gov/finance/content/us-power-sector-undergoes-dramatic-shift-generation-mix – US. power sector undergoes dramatic shift in generation mix
http://inlinepolicy.com/2016/the-uk-government-energy-in-tray/ – The UK government energy policy in-tray: post-23 June
http://fes.nationalgrid.com/ – National Grid Future energy scenarios
https://www.gov.uk/government/statistics/uks-carbon-footprint – UK government carbon footprint
http://www.greenpeace.org.uk/climate/dirty-energy – Greenpeace on energy policy

https://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG27-TheRussoUkrainianGasDisputeofJanuary2009AComprehensiveAssessment-JonathanSternSimonPiraniKatjaYafimava-2009.pdf – Oxford Institute for Energy Studies, The Russo-Ukrainian gas dispute of January 2009: a comprehensive assessment great for evaluative analysis
http://www.energyresourcefulness.org/Power/world_oil.html – Excellent resource for all levels on all countries for all energy types (Institute for Energy Resourcefulness)
http://www.bq-magazine.com/economy/2013/09/gulf-explained-40-maps-part-2 – great little website looking at the Middle East in graphs
https://www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/4132479/31F06AA1FCF23773E053C92FA8C00010.pdf – useful information on Ukraine v Russia Gas dispute
https://www.ogel.org/article.asp?key=2877 – Russia-Ukraine gas dispute: soft and hard security issues: a view from Russia
http://www.no-tar-sands.org/what-are-the-tar-sands/ – UK says no to Tar Sands (good list of extra resources)
https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking/developing-shale-oil-and-gas-in-the-uk - Government Guidance on Fracking

EQ3: How are the carbon and water cycles linked to the global climate system?

Teaching approach over 7 hours

Lesson 12 (1hr)	How the growing demand for food, fuel and other resources globally has led to contrasting regional trends in land use cover and the impacts on terrestrial carbon stores, the water cycle and soil health. How fossil fuel use has led to ocean acidification and risks crossing the critical threshold for the health of some marine ecosystems
Lesson 13 (1hr)	The impacts that climate change, resulting from the enhanced greenhouse effect, may have on the frequency of drought which could impact on the health of forests as carbon stores
Lesson 14 (1hr)	The extent and pattern of forest loss and how it has implications for human well-being, as well as the growing awareness of the issue in some countries (environmental Kuznets' curve model)
Lesson 15 (1hr)	How increased temperatures affect evaporation rates and the quantity of water vapour in the atmosphere and the impacts this has on global weather systems. How the threats to ocean health impacts on human well-being, especially in developing regions that depend on marine resources as a food source and for tourism and coastal protection
Lesson 16 (1hr)	How future emissions and warming are uncertain owing to natural factors, human factors and feedback mechanisms
Lessons 17 & 18 (2hr)	Strategies for dealing with climate change involve both adaptation and mitigation

Lessons 12 and 13: Biological carbon cycles and the water cycle are threatened by human activity

Overview

These two lessons cover Key ideas 6.7 a, b and c. It starts with the problems associated with the growing demand for food, fuel and other resources globally and how this has led to contrasting regional trends in land use cover, with deforestation and afforestation occurring as well as the conversion of grasslands to farming, and how these can affect the carbon stores, which in turn has implications of the water cycle and soil health.

These lessons will also look at how ocean acidification is increasing due to its role as a carbon sink because of fossil fuel combustion, and now risks crossing the critical threshold for the health of coral reefs and other marine ecosystems that provide vital ecosystem services. Finally, it looks at how climate change that is the result of the enhanced greenhouse effect may increase the frequency of drought due to shifting climate belts as well as the impact that this may have on forests as carbon stores.

For more able students, there is plenty of opportunity to develop research and evaluative skills through looking at events such as drought in the Amazonian basin, while for less able students there several ways of getting this information across including:
- SWOT analysis of deforestation/ afforestation and land use change
- annotated diagrams
- completing crosswords or word searches for key terms
- drivers of biodiversity change diagrams, toillustrate issues in certain areas.

Key concepts and processes

- There is a growing demand for food, fuel and other resources globally:
    - due to increased population growth
    - increased economic growth in NICs
    - improved living standards.
- Certain areas of the world are more affected by changes to land use cover:
    - Deforestation and conversion of grasslands to farming is mainly occurring in NICs, LEDCs and MINT countries
    - Afforestation in mainly MEDCs
- That land use change is having an impact on terrestrial carbon stores with wider implications for the water cycle and soil health:
    - Changes in forest cover is leading to fall in rainfall, digging up of grasslands is also releasing stored carbon
- Increasing acidification of oceans as they begin to absorb more CO_2 due to fossil fuel combustion
- Ocean acidification is impacting upon the biodiversity health of coral reefs and other marine ecosystems, which are vital to human well-being and ecosystem services
- Climate change may increase the frequency of drought due to shifting climate belts, which in turn could impact upon forest health and carbon stores due to forest die back caused by lack of rainfall

Guidance on teaching

In the future as population growth increases there will be a greater demand for food this website points out some interesting facts which could be used as a starting point: https://www.one.org/us/2014/11/12/14-surprising-stats-about-global-food-consumption/

It also contains many different graphs and charts, which would be effective in helping to explain the reasons for this growth for students of all abilities.
This site offers a view in terms of population growth and world food demand with links to ideas upon regional variations and the shift in people's diets in certain countries as their levels of wealth changes an excellent and comprehensive review by GRID Arendal (in collaboration with UNEP) http://www.grida.no/publications/rr/food-crisis/page/3558.aspx.

In terms of fuel demand growth, more able students may well benefit from looking at 'Global Consumption of Fossil Fuels Continues to Increase' from the Institute for energy Research (http://instituteforenergyresearch.org/analysis/global-consumption-of-fossil-fuels-continues-to-increase/). The BP website and summary document holds some really useful information for teachers (BP Statistical Review of World Energy 2015).

For lesser able students, comparing diagrams such as these will help in understanding the growth in fuels: https://ourfiniteworld.com/2015/06/23/bp-data-suggests-we-are-reaching-peak-energy-demand/.

While this same site looks into energy consumption by China, Europe, Japan, Former Soviet Union and the USA via energy type, all of which may be helpful in evaluating the reasons and the problems associated with increased demand for fuel.
The causes of many of the issues often lies within NICs, especially China's economic prosperity, and graphs such as this should help less able students appreciate the growth that it is going through, whilst more able students can be questioned on the reasons why this is the case, linking back to Topic 4: Globalisation with a significant amount of information on this can be found within the legacy specification.

Prosperity brings about issues as people now consume more products such as cars, white goods, foreign holidays and food. More able students may wish to research this area through articles such as http://www.sustainable.soltechdesigns.com/prosperous-way-up-and-down.html. This links to some excellent articles and academic papers as well as an excellent graph at the end which more able students could be challenged to explain: http://www.sustainable.soltechdesigns.com/prosperous-way-up-and-down.html.

Other indicators of fuel production that more able students may wish to develop beyond the specification is the Hubbert Curve of resource production which can be easily searched.

Global deforestation can be looked at via global maps. The WWF have a lot of information on this such as: http://www.worldwildlife.org/publications/living-forests-report-chapter-5-saving-forests-at-risk.

The report highlights many factors in deforestation. Teachers could isolate the most important for analysis and, whilst less able students can benefit from looking at the global distribution of deforestation and try to look for trends in wealth, level of development and latitude, these could then be compared with maps of countries afforesting. An excellent interactive map from The World Resource Institute and ESRI can be found here http://www.wri.org/applications/maps/flr-atlas/#. This could be a very useful tool other maps and resources are linked below.

When converting grasslands to agriculture, it's important for students to appreciate that all of the ecosystems mentioned above and grasslands take up atmospheric CO_2 and mineral nutrients and transform them into organic products. In undisturbed grassland ecosystems, the carbon balance tends to be positive as the carbon uptake through photosynthesis exceeds losses from respiration. Deforestation, degradation of native grasslands and conversion to cropland have prompted losses of biomass and soil carbon of 450–800 Gt/CO_2. Conversion from forests to cropland dominates carbon losses from these valuable sinks. However, substantial amounts have been lost from biomass and soils of grassland systems. Students should appreciate that grasslands as opposed to forests are more of a transient carbon pool as they are herbaceous and not woody, so most of the carbon remains in the soil and is subsequently lost when turned to cropland this impacts on soil health as there is a reduced amount of organic material within the soil. More information can be found here.

Ocean acidification is also well documented a good place for all students to start would be:http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F where there are also links on to other resources. While the impacts of acidification on coral reefs can for less able students be found at: http://www.teachoceanscience.net/teaching_resources/education_modules/coral_reefs_and_climate_change/how_does_climate_change_affect_coral_reefs/ and http://climateinterpreter.org/content/effects-ocean-acidification-coral-reefs.

The following link gives a short video that is great as a starting point for this area produced by the Australian Government: http://www.gbrmpa.gov.au/managing-the-reef/threats-to-the-reef/climate-change/how-climate-change-can-affect-the-reef/ocean-acidification

Increased drought and shifting of climate belts is often difficult for some students to fully appreciate. This article on climate zone shifts is a good starting point with some excellent information on the Köppen-Geiger climate zone classification system: http://research.noaa.gov/News/NewsArchive/LatestNews/TabId/684/ArtMID/1768/ArticleID/10046/New-study-Pace-of-climate-zone-shifts-quickens-as-climate-warms.aspx whilst this can be further enhanced by looking at the world of maps of Köppen-Geiger climate classification: http://koeppen-geiger.vu-wien.ac.at/shifts.htm. This site takes a slightly more local look by adding information about how the warming climate is transforming your garden (USA based): http://www.citylab.com/weather/2015/03/how-the-warming-climate-is-transforming-your-garden/388508/

For the influences climate change has on drought, this site is good for less able students and for case study information on Sydney Australia: http://www.climatehotmap.org/global-warming-locations/sydney-australia.html. It also offers an excellent interactive map for students of all levels on the Global

Warming Effects Around the World: http://www.climatehotmap.org/. This site offers a simplistic view for all students of climate change and food security as well as drought history, and has excellent links on to more complex GIS based sites such as: http://webmap.ornl.gov/wcsdown/dataset.jsp?ds_id=10019&startPos=0&maxRecords=10&orderBy=category_name&bAscend=true with data back to 1870.

A great place to start when looking at forest health can be seen here: http://www.pik-potsdam.de/cigrasp-2/ic/hd/increased_forest_fire_frequency.html. This site has a good array of datasets that might be useful and the website is interactive. A good case study area for this might be the Amazonian drought events and the reasons they are increasing, as well as linking this to the hydrological cycle, globalisation and other parts of the specification to access synoptic skills. PowerPoint presentation may be best suited for students of lower ability or, alternatively, guided research through specific handouts.

Lessons 14 and 15: The implications for human well-being from the degradation of the water and carbon cycles

Overview

These lessons look at Key idea 6.8 and the implications for human well-being from the degradation of the water and carbon cycles. The first one primarily concentrating upon the implications of forest loss on human well-being. Some of the issues associated with deforestation and afforestation will have been covered in the previous lessons. However, this is a good point to introduce the Kuznet Curve for those not familiar with it from GCSE, which shows the relationship between development income and changes and environmental quality. This is a great way for less able students to first visualise the issues, which brings in good opportunities for research by more able students and a discussion on the attitudes of different consumers to environmental problems. For less able students, this might be approached via role play or guided research whilst more able students can research it given links or papers some of which will be listed for guidance below.

With the next lesson students will look at how increased temperatures affect evaporation rates and the quantity of water vapour in the atmosphere, and how this might impact upon precipitation patterns, river regimes and water stores in both the cryosphere and drainage basins. For less able students, there are plenty of graphical and diagrammatical evidence of this and clear 'cause–effect' thinking processes should benefit them as well as teaching aids such as SWOT analysis and a potentially interesting case study into the Arctic and changes in the temperature.

While the final part of the lesson considers the threats to ocean health also pose threats to human well-being, especially in developing regions that depend on marine resources as a food source and for tourism and coastal protection. For less able students, this may best be approached via case study application though not compulsory, whilst for more able students, diagrammatical representations of ocean temperature changes could be used as a starting point for them to research/ evaluate and begin to draw conclusions/ judgements of the impacts through research and background reading.

Key concepts and processes

- Students should understand that forest loss has implications for human wellbeing including:
  - impacts on the hydrological cycle impacting upon water availability and increased droughts or floods
  - reduction in ecosystem services due to factors such as soil health and erosion.

- Understand that forest stores are being protected and even expanded, especially in countries at higher levels of development:
  - Both as a reaction to losses elsewhere and because of the importance of forests as a natural resource.

- Appreciate the importance of the environmental Kuznets' curve model:
  - In understanding that it is a hypothetical curve representing the trajectory of environmental degradation in developing nations as a function of per capita income and the three separate parts, which will be highlighted below.

- Students must have an awareness that increased temperature affects evaporation rates and the quantity of water vapour in the atmosphere, which in turn impacts upon:
  - precipitation patterns
  - river regimes
  - water stores both cryosphere and drainage basin stores.

- Understand that threats to ocean health also pose threats to human wellbeing, especially in developing regions that have a dependence upon:
  - marine resources as a food source
  - tourism
  - coastal protection.

Guidance on teaching

A good place to begin here for these lessons is to present students with a Kuznet Curve such as this one shown here: https://environmentaleconomics.wordpress.com.

Ask students why the three types of economies have different impacts on the environment. This should push more able students as well as testing less able students though prompts could be offered in terms of example countries. For more able students, the introduction of Pollution Havens (whereby polluting industries are shifted to poor countries with lax environmental regulations) as a reason for the reduction in environmental degradation is an excellent link and synoptic link back to globalisation in Topic 3. A good starting point for students of all levels is this: https://environmentaleconomics.wordpress.com/ whilst below are some excellent links for more able students on the Kuznets' Curve.

Applying the curve to forest loss could be done by looking at global maps of forest loss. (Some of the links from previous lessons will provide useful documentation here as well as the interactive map: http://www.wri.org/applications/maps/flr-atlas/#&init=y when looking at afforestation.) Another good way to highlight forest loss as well as gains is using the 'Earth Outreach Global Forest Change, 2000–2012' short animation, which can be searched online as well as their time-lapse animation on Amazon Deforestation, which can also be sought online using that search criteria (Amazon Deforestation: Time-lapse). These are great resources for showing less able students the extent of deforestation in developing nations.

Global Forest Watch also has a good interactive map, which can be changed to show either forest gain and loss, or both, with interesting results that may question what some students believe. The more able students may be able to draw conclusions from this whilst lesser able students may need some help in this area: http://www.globalforestwatch.org/map/3/11.58/37.90/ALL/grayscale/forestgain?tab=analysis-tab&threshold=30&dont_analyze=true.

Changes to precipitation, which were mentioned in the previous lesson, are now drawn on again in terms of evaporation rates and increased temperatures. For lesser able students a good start might be to graphics shown on Watch: Water and Global Change: http://www.waterandclimatechange.eu/evaporation, which has good links to freshwater, rainfall and soil moisture. The EPA US government website hase a good students' guide on global climate change (Though mainly referencing the USA): https://www3.epa.gov/climatechange/kids/impacts/signs/precip-patterns.html, which features good links and also graphics. The British Government has a similar factsheet: https://www.gov.uk/guidance/climate-change-explained. For river regimes there is a good site from the National River Flow Archive, which looks at UK river and flow regimes: http://nrfa.ceh.ac.uk/uk-river-flow-regimes. It is also a great site for getting data, the majority of which is free to use. This covers daily river flows, peak river flow data, catchment information, and catchment rainfall data. It also has long records that cover many years where students would be able to graphically analyse the impacts of falling or rising precipitation on UK catchment areas.

For water stores, a good place to start, though US based, is https://www3.epa.gov/climatechange/impacts/water.html, which is good for students who may be looking into California as well as a useful diagram showing the impacts on the US seen below, which might be a good discussion point based on climatic change and the further implications of loss of water stores. A good diagram of projected water changes can be found here. There is an excellent array of data also available from globalchange.gov (http://www.globalchange.gov/). This is suitable for all levels of students and there are some excellent and usable multimedia graphics which will help teachers and students alike. Within this there are links to the reports they came from and the site offers an excellent array of research opportunities.

Increase temperatures on the Arctic are well documented and, though there is cross over with Unit 1 World at Risk: Climate Change from the legacy specification, students can research and draw up a small case study of the impacts or enlarge to cover aspects including ANWR and periglacial environments or high latitude environments, to show how vulnerable these places are. This area is also a good opportunity to bring in Skill 7: Analysis of climate model maps to identify areas at most risk from water shortages or floods in the future. Climate wizard (http://www.climatewizard.org/) allows you to look at past and future potential changes which can be compared and analysed.

Areas in higher latitudes will face more impacts than most as this NASA GISS map illustrates: https://nsidc.org/cryosphere/arctic-meteorology/climate_change.html. The site in general offers a lot of detailed explanations and looks into various factors that all levels of students may find accessible including:

- Arctic people
- climate change
- patterns in Arctic weather and climate
- factors affecting Arctic weather and climate.

All these factors will enable students to benefit from background reading and case study development. For teachers it also contains educational resources including:

- glossary
- repeat glacier photography
- data on Glacial change
- atlas of the Cryosphere
- printable multimedia researches.

Most of these resources are free as well as providing excellent links to academic research and further resources.

The final area here is ocean health and how it effects human well-being. A starting point might be for students to consider the implications of a fall in marine biodiversity to specific areas such as areas where coral reefs exist. The website Coral Reef Systems (http://coralreefsystems.org/) is a good place for all students to begin to assess the importance of these systems for certain ways of life.

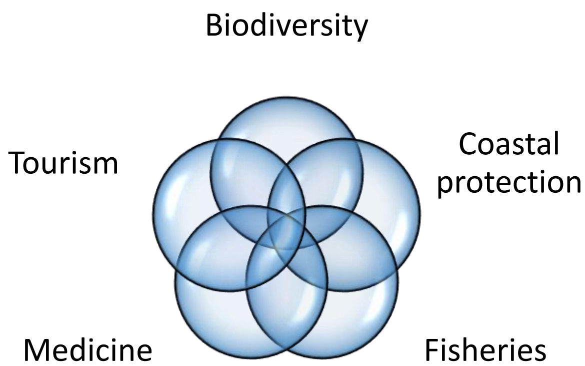

Figure 2: The values of coral reefs (J. Foster)

Students of differing ability could work together to look at the values and why they might be classed as valuable ecosystems.

Value of ecosystems				
Biodiversity	**Coastal protection**	**Fisheries**	**Medicine**	**Tourism**
Essential spawning, nursery, breeding grounds for fish	Reefs can help dissipate much of the force of incoming waves	The fish that grow and live on coral reefs are a significant food source for over a billion people worldwide	Medicines and other useful compounds have led to coral ecosystems being referred to as the medicine cabinets of the 21st century	Resorts thrive due to scuba diving, protected beaches, reef tours, hotels injecting billions into local economies worldwide

Above are just some examples that students could look into and develop a key understanding of these important environments. The map here shows these.

These could be overlain with maps of levels of development which are easily searchable, e.g. http://www.vox.com/2014/8/26/6063749/38-maps-that-explain-the-global-economy. Some of these countries, such as St Lucia and areas around Indonesia, can then be investigated using websites such as CIA factbook (https://www.cia.gov/library/publications/the-world-factbook/) to find out how they make their money. There is plenty of scope for both more able and less able students to develop an awareness of the issues through discussions, questioning and worksheets based on the information given. For the less able students it might be a good idea to develop case studies that run concurrently for benefits, problems and solutions. As well as this, excellent examples exist for mangrove destruction in Thailand with plenty of websites such as http://mangroveactionproject.org/shrimp-farming/. There is then the opportunity to develop these further in terms of protection schemes. Less able students often benefit from case studies that are developed within the topic. Although this is not compulsory, students can often be rewarded with the increase in extended knowledge.

Lessons 16, 17 and 18: Further planetary warming risks large-scale release of stored carbon, requiring responses from different players at different scales

Overview

These final few lessons are based around Key idea 6.9 Further planetary warming risks large-scale release of stored carbon, requiring responses from different players at different scales. The first part centres around the concept of future emissions and atmospheric concentration levels owing to both human and natural factors. There is also the introduction here of feedback mechanisms and a chance to get key skill 8: Plotting graphs of carbon dioxide levels, calculating means and rates of change. For more able students there are plenty of opportunities here to look at some rather in-depth work on the role of carbon sinks and the impacts of economic growth population and different energy sources. Within this they can consider different scenarios and assess why models are so difficult to fully predict the future. For less able students, taking diagrams, graphs and different scenarios and presentations might better help develop an understanding.

The second part is looking at adaptation strategies, which include an array of different ideas and concepts including:
- water conservation and management
- resilient agricultural systems
- land-use planning
- flood-risk management
- solar radiation management.

These ideas can be looked at in groups or teams with each group doing a cost benefit analysis on the different adaptation strategies. For less able students, desks could be arranged where students move around looking at information for each one and they are to come up with the benefits and costs before moving to the next area.

The final area is 6.9c and looks at the re-balancing of the carbon cycle and how it could be achieved through different mitigation strategies but this would require global co-operation and action, which as has been seen in the past can be fraught with issues. More able students may wish to suggest ways here and develop ideas without prompts whilst less able student may need prompts and to then be asked whether or not these are feasible solutions to the problems and, if not, why not. For more able students there is the opportunity for debate between different countries; students could be split into groups of countries and TNCs and try to find common ground in terms of mitigation strategies. Teams could include: USA, Russia, China, Brazil, Ethiopia and TNCs such as Shell, Nestle or alternatives.
Alternatively, less able students could carry out group work into the different types of mitigation techniques and the positives and negatives of each can be reviewed. To improve understanding, they may wish to rank these in order of importance and justify these within a discussion. Mitigation techniques should include:
- carbon taxation
- renewable switching
- energy efficiency
- afforestation
- carbon capture and storage.

Key concepts and processes

- Future emissions, atmospheric concentration levels and climate warming are uncertain owing to:
    - natural factors:
        - the role of carbon sinks
    - human factors:
        - economic growth
        - population and population growth
        - energy sources and use

- Feedback mechanisms can play a part in future uncertainty such as carbon release from:
    - peatlands
    - permafrost
    - tipping points (including forest die back and alterations to the thermohaline circulation).

- Adaptation strategies to deal with the impacts of climate change are varied and are different between countries, each having both costs and benefits, and consist of:
    - water conservation and management
    - resilient agricultural systems
    - land-use planning
    - flood-risk management
    - solar radiation management.
- Re-balancing the carbon cycle could be achieved; however, there are many different problems that would need to be overcome first in terms of attitudes of countries, TNCs as well as individuals.

- Mitigation strategies have costs and benefits associated with them and consist of:
  - carbon taxation
  - renewable switching
  - energy efficiency
  - afforestation
  - carbon capture and storage.

- That global scale agreements are often difficult to achieve due to countries having different priorities.

Guidance on teaching

Plotting graphs of carbon levels (Skill 8) can be done using the data from noaa.gov and the Mauna Loa CO_2 records these exist here: http://www.esrl.noaa.gov/gmd/ccgg/trends/data.html. Although these datasets are very large they can be copied and reduced to suit the best set of data, which may well be 'Mauna Loa CO_2 annual mean data'. This website also offers a great deal of information on other data as well as a short video on the history of atmospheric carbon dioxide from 800,000 years ago until January, 2014. It also features a video which shows the accumulation of CO_2 in the atmosphere from the burning of coal, oil, and natural gas.

The role of carbon sinks can be discussed using information gathered with previous learning as well as excellent resources such as http://www.fern.org/campaign/carbon-trading/what-are-carbon-sink,s which allow all abilities of students to look at the ideas from 'green' groups and the issues they have with carbon sinks. An interesting diagram such as this may be helpful: http://shrinkthatfootprint.com/carbon-emissions-and-sinks.

Using Figure 3, both more able and less able students could be asked to assess how these figures might change in the future and if, as expected fossil fuel use continues to rise, how we can develop more carbon sinks to offset this, especially now the oceans are becoming more acidic.

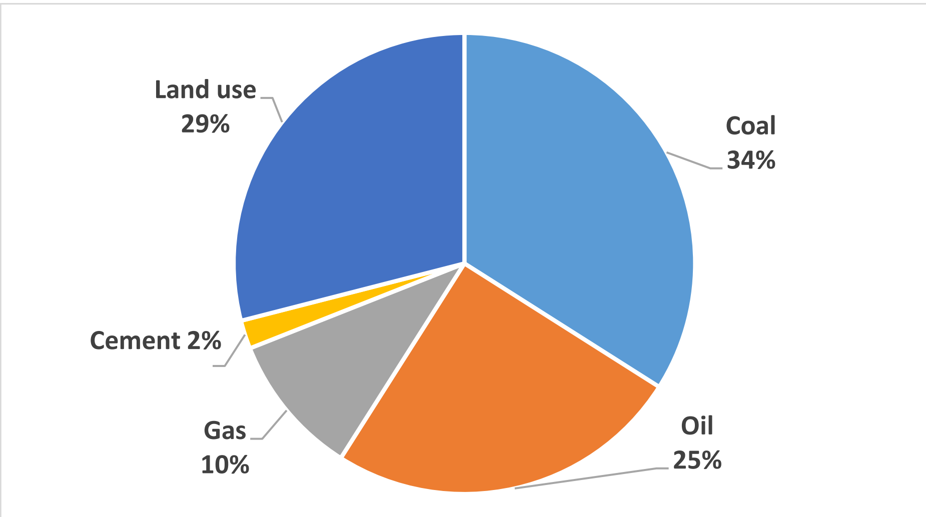

Figure 3: Human induced carbon emissions since the industrial revolution (J. Foster – sourced from IPCC)

Figure 3 could be compared with Figure 4, which shows how our carbon emissions are shared between the various large-scale carbon sinks:

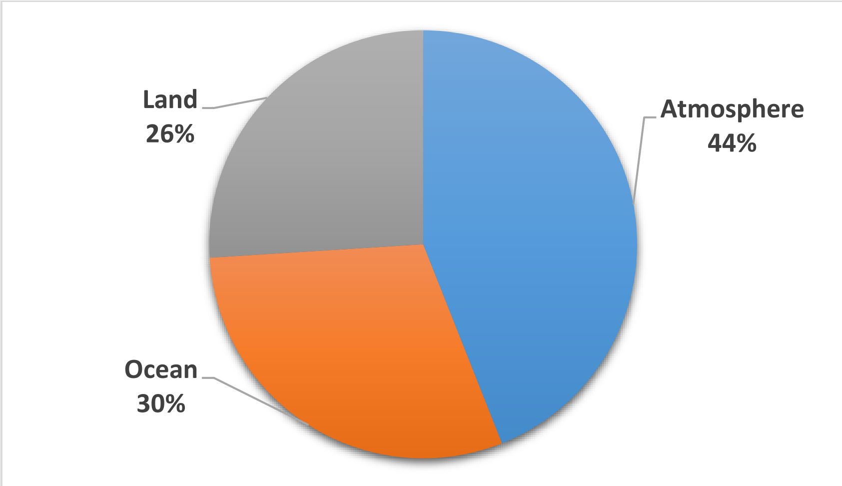

Figure 4: Where our carbon goes (J. Foster – sourced from IPCC)

Given this, more able students should be able to look at the complex layer of human factors surrounding economic growth in NICs. Economic growth rates even since 2010 have shown emerging and developing economies outstripping the advanced economies such as http://www.fin.gov.on.ca/en/budget/fallstatement/2013/chapter2.html.

Students could be given four graphs one of population growth, one of economic growth and one of carbons sinks and one of energy use by source, which can be found here http://www.neweconomics.org/page/-/images/publications/global_energy_use_by_source__NEW_.png. More able students could add a layer of complexity to this graph: https://www.mhi-global.com/discover/earth/issue/history/history.html, which has all areas but also shows how energy consumption from OECD countries is actually reducing overtime.

The impact of feedback mechanisms is important. Peat emits and captures $CO_{2.}$ $_H$owever, when it becomes degraded through reasons such as land use change or removal, drainage becomes a large issue as air can lower the peat's water table allowing air to penetrate and decomposing previously stored CO_2 (http://publications.naturalengland.org.uk/file/78020). This site also offers ideas on peatland restoration. For more able students this academic paper offers some interesting background on the potential for feedback: 'Feedback control of the rate of peat formation' (http://webspace.qmul.ac.uk/clymo/Clymo-article-PDFs/62-Belyea-Clymo-2001-Feedback.pdf).

For permafrost there is also some excellent work carried out by the National Snow and Ice Centre (https://nsidc.org/cryosphere/frozenground/methane.html). Other resources are listed below. An interesting paper written for the FAO called 'Climate Induced Forest Dieback: An Escalating Global Phenomenon?' is good for understanding the concepts and issues faced from this and the implications it has (http://www.fao.org/3/a-i0670e/i0670e10.pdf).

For general information on climate feedback the Met Office has a simple webpage suitable for lower ability students: http://www.metoffice.gov.uk/climate-change/guide/science/explained/feedbacks, whilst for more able students this would be more suitable: http://www.globalchange.umich.edu/globalchange1/current/lectures/Perry_Samson_lectures/feedback_mechanisms/.

Alterations to thermohaline circulation is introduced here for lower level students: http://oceanservice.noaa.gov/education/tutorial_currents/05conveyor3.html while a more in-depth article can be read at http://www.cru.uea.ac.uk/documents/421974/1295957/Info+sheet+%237.pdf/320eba6e-d384-497d-b4fc-2d2c187f805e. This provides scenarios such as 'Will the thermohaline circulation collapse?' And 'What would happen to our climate if the thermohaline circulation collapsed?' with some good diagrams and global maps as well.

Adaptation strategies can be looked at via group research in terms of water conservation. Good ideas can be found in case studies about Singapore (links below) as well as about California and Israel. As students research and develop an awareness of these strategies, they can begin to assess the advantages and disadvantages of them. Simple web searches bring up excellent information on resilient agricultural systems, from this document from ActionAid (http://www.actionaid.org/sites/files/actionaid/exhibition_document_-_final_draft.pdf) to this website http://www.scidev.net/global/biotechnology/opinion/how-to-create-resilient-agriculture-1.html, all of which offer valuable infomration to all students and teachers.

The final area here is the re-balancing of the carbon cycle where students could look into and assess the contrbution mitigation techniques might have for this here is a good place to start: https://www.weforum.org/agenda/2015/04/can-we-rebalance-the-carbon-cycle-while-still-using-fossil-fuels/. Students could be put in groups and asked to research each.

Finally, global agreements could be looked at through the need to address the problems first brought to light for many by the Stern Review in 2006 (Executive Summary linked below) whilst other websites listed give an at a glance view which is good for less able students.

Understanding why global agreements are hard is a question best asked to all students. In groups they could come up with ideas which the teacher could build upon. These could be considered under the economic, social and environmental problems that stand in the way. A timeline of key milestones in the evolution of international climate policy can be found here: http://unfccc.int/timeline/.

This interactive timeline is helpful for students to develop an awareness with videos, newspaper headlines all the way through to Paris in 2015. There is also an array of infographic insights, which can be used as posters or ideas for students to build on.

Another good approach is to do a model debate under the headline of 'Everyone for themselves?' and giving students differentiatied groups to work in as different countries around the table at one of these conferences. For instance, groups could be China, India, USA, Germany and an LEDC such as Ethopia, allowing students to research their countries and then debate how they can hope to change the way the world is to help re-balance the carbon cycle.

Key vocabulary for EQ3

Key Words	Definition
Climate belt	Often called a climate zone, this refers to the climates of specific areas of the world roughly delineated by lines of latitude
Ocean acidification	The reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO_2)
Köppen-Geiger climate zone classification system	A widely used system through which climate in categorised
Pollution havens	A hypothesis based on the reasoning that MEDCs often move there heavy polluting industries to the cheapest locations, generally in LEDCs or NICs due to low costs and low environmental regulations
Adaptation	The way people of animals change as a result of their environment such as building sea walls, or moving away from danger areas
Mitigation	Where people try to stop the root cause of an issue and thereby reduce the changes of the impacts, e.g. switching to renewable energies to reduce climate change
Stern Review	An influential report that set out to examine the economic impacts of climate change
COP Conferences	A conference held by the decision making body of the United Nations Framework Convention on Climate Change (UNFCCC)

Further reading

http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html – BP statistical Review of World Energy 2015
https://ourfiniteworld.com/2015/06/23/bp-data-suggests-we-are-reaching-peak-energy-demand/ – BP data suggests we are reaching peak energy demand
http://planetforlife.com/oilcrisis/oilpeak.html - extrapolating the Hubbert Curve to the Whole Earth
http://www.wri.org/applications/maps/flr-atlas/# – interactive afforestation map
http://www.livescience.com/41215-map-reveals-global-deforestation.html – global deforestation map (Vanishing Forests)

http://www.fao.org/fileadmin/templates/agphome/documents/climate/AGPC_grassland_webversion_19.pdf – challenges and opportunities for carbon sequestration in grassland systems: a technical report on grassland management and climate change mitigation

http://publications.naturalengland.org.uk/publication/1412347 – Carbon Storage by Habitat report by Natural England (good for teachers)

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3545782/ – persistent effects of a severe drought on Amazonian forest canopy

http://www.independent.co.uk/news/science/special-report-catastrophic-drought-in-the-amazon-2203892.html – special report: catastrophic drought in the Amazon

http://www.ox.ac.uk/news/2015-03-04-first-direct-evidence-drought-weakened-amazonian-forests-%E2%80%98inhale-less-carbon%E2%80%99 – first direct evidence that drought-weakened Amazonian forests 'inhale less carbon'

http://nrfa.ceh.ac.uk/long-records – UK river catchment records

http://www.fern.org/ – website by FERN; a non-governmental organisation (NGO) created in 1995 to keep track of the European Union's involvement in forests and coordinate NGO activities at the European level

http://empslocal.ex.ac.uk/people/staff/pmc205/papers/2004/Cox_et_al_04_TAC.pdf – Amazonian forest dieback under climate-carbon cycle projections for the 21st century; early academic paper with some interest for more able students.

https://www.researchgate.net/publication/228357326_Water_Management_in_Singapore – 'Water Management in Singapore'; good for more able students and teachers

http://www.unep.org/GC/GCSS-VIII/Singapore.IWRM.pdf – Singapore's Integrated Water Resource Management (IWRM) Programme: suitable for less able and all students

https://www.cuwcc.org/ – California Urban Water Conservation Council; also has an array of useful videos on water management techniques

http://www.huffingtonpost.com/jennifer-schwab/israel-is-the-unsung-hero_b_9212810.html – 'Israel Is the Unsung Hero in Water Management'; good for all levels

http://www.oecdobserver.org/news/fullstory.php/aid/4819/Israel:_Innovations_overcoming_water_scarcity.html – 'Israel: Innovations overcoming water scarcity'

http://www.water.ca.gov/wateruseefficiency/agricultural/ – agricultural water use in California; suitable for all levels with good resources for teachers