1. Lesson 1: Climate and the Earth Systems

| **Knowledge Objective** | **Key Questions and Ideas** | **Teaching and Learning Activities** | **Key Facts** | **Key Resources** | **Assessment opportunities** |
| --- | --- | --- | --- | --- | --- |
| Climate is long-term average weather | * Climate has changed significantly over Earth’s history * How does weather relate to climate? | **Starter:**  Climate as long-term weather. Concept that the earth has existed in different climatic regimes, with impacts on temperature, level of ice, sea level and patterns of vegetation.  **Main Activity:**  Students are shown a chart with changes to the earth’s temperature over the history of the earth. Explanation as to how variations in solar energy have driven long term historic climate change.  Establish the general link between energy flows and climate.  Discuss how energy is stored in three core earth systems (land, oceans and atmosphere) and takes multiple forms (kinetic, potential, heat, light, chemical). Fill the gaps between the input and output energy stores.  **Plenary:**  Students are asked to discuss how a change in the capacity of any input, store or output may impact energy and therefore climate. | Sun’s output has varied over the Earth’s history as the sun has evolved. The level of energy received by the earth has therefore changed. | **Slides:**   * What is Climate? * History of earth’s temperature; * Earth systems; * Energy flow diagram; * Energy flows – fill the gaps;   **Links:**  **Case Studies:** | Students describe how each season differs in weather and how this is linked to the energy received from the sun, with a view to extrapolating the concept to the long term. |
| Climate depends on energy flows around the earth. | * How does energy create weather and therefore climate? * Sun as primary driver of energy input | Energy enters the earth’s atmosphere as thermal and light energy from the sun. Thermal energy is the principal driver of wind, rain and temperature (i.e. weather) |
| The earth has atmospheric, oceanic and land systems (the “Earth Systems”) which act as energy stores. | * What is each Earth System? * What are the key interactions between each Earth System? * Changes in energy inputs and stores comes from natural and human activity. Climate is therefore a function of natural | Once energy has entered the atmosphere, it is either captured and transformed in the land, oceans or atmosphere or reflected back into space.  Thermal energy heats the land, atmosphere and oceans. Plant life uses photosynthesis to convert light energy to chemical energy, absorbing CO2 in the process.  Each Earth System has a different sensitivity to changes in incoming energy.  Distribution of energy around the globe drives wind, rain and temperature patterns and therefore climate. |

1. Lesson 2: The Carbon Cycle

| **Knowledge Objective** | **Key Questions and Ideas** | **Teaching and Learning Activities** | **Key Facts** | **Key Resources** | **Assessment opportunities** |
| --- | --- | --- | --- | --- | --- |
| Carbon exists in different forms within the Earth Systems | * What forms does carbon take in each Earth System? * Carbon as a store of chemical energy | **Starter:**  Carbon is an element that can be present within gases, solids and liquids.  **Main Activity:**  Create the ‘carbon cycle map’ by mapping the various carbon stores with the flows between them, including a description of the key processes:   * Photosynthesis as a means to capture carbon from the atmosphere and eventual presence in land system (e.g. coal, peat) – biological pump; * Combustion as a means to release carbon from the earth system to atmosphere - disturbances; * Erosion and weathering as a means to capture carbon in the ocean system – fossilisation and erosion; * Absorption of carbon into the oceans – solubility pump   Creation of a high level ‘carbon budget’ using the various stores and flows.  Complete the carbon budget exercise.  **Plenary:**  Discussion of the impact various forcing factors to the flows and stores (i.e. the carbon budget) with examples;   * Volcanic eruptions releasing CO2; * Land use change; | Carbon is present in the land (e.g. rocks such as coal), sea (carbonic acid) and atmosphere (CO2).  Carbon is stored as chemical energy in the Earth System. | **Slides:**   * Carbon cycle diagram; * Natural and man-made examples of carbon cycle * Carbon cycle example - Limestone; * Carbon cycle example – Coal; * Carbon budget exercise;   **Links:**  **Case Studies:** | Students complete the carbon budget exercise.  Students identify carbon stores and flows in their local area (e.g. forests, the sea, power stations)  Students describe how these stores have changed / how may they change in the future  If they were to change, what would be the result on the carbon budget in the local area, the atmospheric store of carbon and temperature? |
| The Earth Systems are inter-linked and energy in the form of carbon flows between Earth Systems | * Carbon cycles between each Earth System * How does energy flow? | Carbon moves between the atmosphere to the ocean and land Earth Systems through chemical reactions (e.g. photosynthesis), erosion (e.g. limestone), combustion (e.g. forest fires) and is typically in equilibrium between the various Earth System Stores. |
| Natural and man-made changes to an Earth System will impact upon the other Earth Systems, affecting the balance of stores of carbon | * How do changes in one Earth System impact upon the other Earth Systems? * Carbon in the atmosphere as a store of energy and increased atmospheric concentrations lead to warming. | Changes to the level of input of energy into the atmosphere and/or additional processes (e.g. humans, volcanic eruptions) impacts the position of the equilibrium. |

1. Lesson 3: Human Production of Greenhouse Gases

| **Knowledge Objective** | **Key Questions and Ideas** | **Teaching and Learning Activities** | **Key Facts** | **Key Resources** | **Assessment opportunities** |
| --- | --- | --- | --- | --- | --- |
| Humans rely on the earth to live | * What are the main interactions between humans and the environment in relation to carbon? | **Starter:**  CO2 is a greenhouse gas. Concentrations of CO2 have been increasing in our atmosphere. This represents a flow of carbon from land and ocean stores to the atmospheric store.  **Main Activity:**  Describe each of the ways in which humans produce carbon dioxide, together with the carbon flows in each case (linking back to the carbon cycle):  Energy – electricity, heat and transport;  Land use change;  Waste management;  Discuss the rate of each flow i.e. the rate at which the carbon is being released is occurring more rapidly than the absorption of carbon by the land and oceans.  Create a greenhouse gas diary for each student.  **Plenary:**  Finish by introducing the man-made greenhouse effect and the evidence pointing to temperature increases (which is expanded on in the final lesson). | Humans rely on the earth for food, water, energy, warmth.  The rate of consumption of some natural resources has exceeded the rate at which natural processes create the resource (e.g. coal) | **Slides:**   * Atmospheric CO2 concentrations; * How do humans produce greenhouse gases? * Man-made greenhouse effect; * Earth surface temperature anomaly chart;   **Links**:  **Case studies:** | Each student identifies at least five activities that have contributed to a release of carbon to the atmosphere. Includes transport, foods, electricity etc.  For each, identify the natural store of carbon |
| Energy production releases carbon to the atmosphere | * How is carbon released into the atmosphere from electricity, heat and transport, land use change and waste management? * Rate of carbon capture by natural processes is significantly slower than the rate of use by humans. | Burning fossil fuels (wood, coal, gas and oil) to produce electricity, heat and in transport releases carbon from the land earth system to the atmospheric system.  Creation of coal over millions of years and the rate at which it is being used is faster than the earth can re-capture the carbon through the natural process.  Population is growing, particularly in the developing world, resulting in large increases in energy demand and increasing use of fossil fuels globally. |
| Link between carbon and temperature | * The man-made greenhouse effect means increases in CO2 lead to increased temperatures. | Increases in CO2 lead to increased temperatures due to increased absorption of heat in the atmosphere.  Global temperatures have been increasing. |

1. Lesson 4: The impact of carbon dioxide increases

| **Knowledge Objective** | **Key Questions and Ideas** | **Teaching and Learning Activities** | **Key Facts** | **Key Resources** | **Assessment opportunities** |
| --- | --- | --- | --- | --- | --- |
| Carbon dioxide in the atmosphere increases the absorption of solar irradiation and global temperatures | * How are carbon dioxide and temperature linked? * How much carbon dioxide has been released? * How much have temperatures risen? | **Starter:**  Recap on the Man-Made Greenhouse Effect and evidence that the earth temperature anomalies point to increases in temperature.  **Main Activity:**  Consider the various primary and secondary impacts of a change in temperature, based on environmental, social and economic impacts.  Identify that feedback loops can have the potential to magnify the initial change.  Students identify the impacts on different people through considering scenarios – how temperature changes would impact them, an inhabitant of a developed world city and a developing world small island state.  A risk based approach to forecasting considers the likelihood of outcomes and the magnitude of outcomes. Whilst we cannot be 100% certain of the likelihood of particular effects, the magnitude of the effects has the potential to be very high.  **Plenary:**  Introduce the potential to mitigate and adapt to the effects of climate change.  Ask students to identify mitigation and adaptation actions and discuss the potential issues with each. | Carbon dioxide in the atmosphere increases the absorption of solar radiation, resulting in temperature increases.  Compared with the average temperatures from 1961-1990, the temperature has risen by c. 1 degree.  It is widely accepted that we need to limit the increase in temperature to less than 2 degrees compared with pre-industrial levels to avoid significant detrimental impacts to the environment, societies and economies. | **Slides:**   * Man-made greenhouse effect; * Earth surface temperature anomaly chart; * Primary and secondary effects; * Feedback loops; * Impacts table; * Dealing with the effects of climate change   **Case studies:** | Each student identifies the effects of a changing climate on different individuals.  Using a risk-based approach, rank a number of different risks.  Identify 3 means of mitigating and 3 means of adapting to climate change, along with the potential challenges (i.e. why aren’t we doing these things anyway?) |
| Increases in temperature impacts upon the environment, societies and economies | * How do temperature increases impact the world? * How will temperature increases impact human activity? | Increase in temperature is a primary effect of increases in carbon dioxide concentrations. Temperature increases have multiple secondary impacts:   * Changes to environments, such as increased extreme weather event, changing vegetation patterns etc. * Social impacts such as migration; * Economic impacts such as changing food production patterns;   Further, a secondary effect can act to re-inforce or reduce the initial temperature increase through feedback loops.  There are multiple secondary effects as part of a complicated system, which makes it hard to predict changes. |
| Mitigation and adaptation are the potential responses to climate change | * How do we limit carbon emissions? | Societies can respond to the risks of climate change through mitigating the causes of climate change (i.e. reducing greenhouse gas emissions) and/or adapting to the effects of climate change. |