Topic 8: Energy, power and climate change

8.1 Energy degradation and power generation

	Assessment statement	Teacher's notes
8.1.1	State that thermal energy may be completely converted to work in a single process, but that continuous conversion of this energy into work requires a cyclical process and the transfer of some energy from the system.	
8.1.2	Explain what is meant by degraded energy.	Students should understand that, in any process that involves energy transformations, the energy that is transferred to the surroundings (thermal energy) is no longer available to perform useful work.
8.1.3	Construct and analyse energy flow diagrams (Sankey diagrams) and identify where the energy is degraded.	It is expected that students will be able to construct flow diagrams for various systems including those described in sub-topics 8.3 and 8.4.
8.1.4	Outline the principal mechanisms involved in the production of electrical power.	Students should know that electrical energy may be produced by rotating coils in a magnetic field. In sub-topics 8.2 and 8.3 students look in more detail at energy sources used to provide the energy to rotate the coils.

8.2 World energy sources

	Assessment statement	Teacher's notes
8.2.1	Identify different world energy sources.	Students should be able to recognize those sources associated with CO2 emission. Students should also appreciate that, in most instances, the Sun is the prime energy source for world energy.
8.2.2	Outline and distinguish between renewable and non-renewable energy sources.	
8.2.3	Define the *energy density* of a fuel.	Energy density is measured in $J\ kg^{-1}$
8.2.4	Discuss how choice of fuel is influenced by its energy density	The values of energy density of different fuels will be provided.
8.2.5	State the relative proportions of world use of the different energy sources that are available.	Only approximate values are needed.
8.2.6	Discuss the relative advantages and disadvantages of various energy sources.	The discussion applies to all the sources identified in sub-topics 8.2, 8.3 and 8.4.

8.3 Fossil fuel power production

	Assessment statement	Teacher's notes
8.3.1	Outline the historical and geographical reasons for the widespread use of fossil fuels.	Students should appreciate that industrialization led to a higher rate of energy usage, leading to industry being developed near to large deposits of fossil fuels.
8.3.2	Discuss the energy density of fossil fuels with respect to the demands of power stations	Students should be able to estimate the rate of fuel consumption by power stations.
8.3.3	Discuss the relative advantages and disadvantages associated with the transportation and storage of fossil fuels.	
8.3.4	State the overall efficiency of power stations fuelled by different fossil fuels.	Only approximate values are required
8.3.5	Describe the environmental problems associated with the recovery of fossil fuels and their use in power stations.	

8.4 Non-fossil fuel power production

	Assessment statement	Teacher's notes
	Nuclear power	
8.4.1	Describe how neutrons produced in a fission reaction may be used to initiate further fission reactions (chain reaction).	Students should know that only low-energy neutrons (≈ 1 eV) favour nuclear fission. They should also know about critical mass.
8.4.2	Distinguish between controlled nuclear fission (power production) and uncontrolled nuclear fission (nuclear weapons).	Students should be aware of the moral and ethical issues associated with nuclear weapons.
8.4.3	Describe what is meant by fuel enrichment.	
8.4.4	Describe the main energy transformations that take place in a nuclear power station.	
8.4.5	Discuss the role of the moderator and the control rods in the production of controlled fission in a thermal fission reactor.	
8.4.6	Discuss the role of the heat exchanger in a fission reactor.	
8.4.7	Describe how neutron capture by a nucleus of uranium-238 (238U) results in the production of a nucleus of plutonium-239 (^{239}Pu).	
8.4.8	Describe the importance of plutonium-239 (^{239}Pu) as a nuclear fuel.	It is sufficient for students to know that plutonium-239 (^{239}Pu) is used as a fuel in other types of reactors.
8.4.9	Discuss safety issues and risks associated with the production of nuclear power.	Such issues involve: • the possibility of thermal meltdown and

		how it might arise • problems associated with nuclear waste • problems associated with the mining of uranium • the possibility that a nuclear power programme may be used as a means to produce nuclear weapons.
8.4.10	Outline the problems associated with producing nuclear power using nuclear fusion.	It is sufficient that students appreciate the problem of maintaining and confining a high-temperature, high-density plasma.
8.4.11	Solve problems on the production of nuclear power.	
	Solar power	
8.4.12	Distinguish between a photovoltaic cell and a solar heating panel.	Students should be able to describe the energy transfers involved and outline appropriate uses of these devices.
8.4.13	Outline reasons for seasonal and regional variations in the solar power incident per unit area of the Earth's surface.	
8.4.14	Solve problems involving specific applications of photovoltaic cells and solar heating panels.	
	Hydroelectric power	
8.4.15	Distinguish between different hydroelectric schemes.	Students should know that the different schemes are based on: • water storage in lakes • tidal water storage • pump storage.
8.4.16	Describe the main energy transformations that take place in hydroelectric schemes.	
8.4.17	Solve problems involving hydroelectric schemes.	
	Wind power	
8.4.18	Outline the basic features of a wind generator.	A conventional horizontal-axis machine is sufficient.
8.4.19	Determine the power that may be delivered by a wind generator, assuming that the wind kinetic energy is completely converted into mechanical kinetic energy, and explain why this is impossible.	
8.4.20	Solve problems involving wind power.	

	Wave power	
8.4.21	Describe the principle of operation of an oscillating water column (OWC) ocean-wave energy converter.	Students should be aware that energy from a water wave can be extracted in a variety of different ways, but only a description of the OWC is required.
8.4.22	Determine the power per unit length of a wavefront, assuming a rectangular profile for the wave.	
8.4.23	Solve problems involving wave power	

8.5 Greenhouse effect

	Assessment statement	Teacher's notes
	Solar radiation	
8.5.1	Calculate the intensity of the Sun's radiation incident on a planet.	
8.5.2	Define *albedo*.	
8.5.3	State factors that determine a planet's albedo.	Students should know that the Earth's albedo varies daily and is dependent on season (cloud formations) and latitude. Oceans have a low value but snow a high value. The global annual mean albedo is 0.3 (30%) on Earth.
	The greenhouse effect	
8.5.4	Describe the greenhouse effect.	
8.5.5	Identify the main greenhouse gases and their sources.	The gases to be considered are CH4, H2O, CO2 and N2O. It is sufficient for students to know that each has natural and man-made origins.
8.5.6	Explain the molecular mechanisms by which greenhouse gases absorb infrared radiation.	Students should be aware of the role played by resonance. The natural frequency of oscillation of the molecules of greenhouse gases is in the infrared region.
8.5.7	Analyse absorption graphs to compare the relative effects of different greenhouse gases.	Students should be familiar with, but will not be expected to remember, specific details of graphs showing infrared transmittance through a gas.
8.5.8	Outline the nature of black-body radiation.	Students should know that black-body radiation is the radiation emitted by a "perfect" emitter.
8.5.9	Draw and annotate a graph of the emission spectra of black bodies at different temperatures.	
8.5.10	State the Stefan–Boltzmann law and apply it to compare emission rates from different	

	surfaces.	
8.5.11	Apply the concept of emissivity to compare the emission rates from the different surfaces.	
8.5.12	Define *surface heat capacity Cs*.	Surface heat capacity is the energy required to raise the temperature of unit area of a planet's surface by one degree, and is measured in J m^{-2} K^{-1}
8.5.13	Solve problems on the greenhouse effect and the heating of planets using a simple energy balance climate model.	Students should appreciate that the change of a planet's temperature over a period of time is given by: (incoming radiation intensity – outgoing radiation intensity) * time / surface heat capacity. Students should be aware of limitations of the model and suggest how it may be improved. **Aim 7:** A spreadsheet should be used to show a simple climate model. Computer simulations could be used to show more complex models (see OCC for details). **TOK:** The use and importance of computer modelling can be explained as a powerful means by which knowledge may be gained.

8.6 Global warming

Global warming

	Assessment statement	Teacher's notes
8.6.1	Describe some possible models of global warming	Students must be aware that a range of models has been suggested to explain global warming, including changes in the composition of greenhouse gases in the atmosphere, increased solar flare activity, cyclical changes in the Earth's orbit and volcanic activity.
8.6.2	State what is meant by the enhanced greenhouse effect.	It is sufficient for students to be aware that enhancement of the greenhouse effect is caused by human activities.
8.6.3	Identify the increased combustion of fossil fuels as the likely major cause of the enhanced greenhouse effect.	Students should be aware that, although debatable, the generally accepted view of most scientists is that human activities, mainly related to burning of fossil fuels, have released extra carbon dioxide into the atmosphere.
8.6.4	Describe the evidence that links global warming to increased levels of greenhouse gases.	For example, international ice core research produces evidence of atmospheric composition and mean global temperatures over thousands of years (ice cores up to 420,000 years have been drilled in the Russian Antarctic base,

		Vostok).
8.6.5	Outline some of the mechanisms that may increase the rate of global warming.	Students should know that: • global warming reduces ice/snow cover, which in turn changes the albedo, to increase rate of heat absorption • temperature increase reduces the solubility of CO_2 in the sea and increases atmospheric concentrations • deforestation reduces carbon fixation.
8.6.6	Define *coefficient of volume expansion*.	Students should know that the coefficient of volume expansion is the fractional change in volume per degree change in temperature.
8.6.7	State that one possible effect of the enhanced greenhouse effect is a rise in mean sea-level.	
8.6.8	Outline possible reasons for a predicted rise in mean sea-level.	Students should be aware that precise predictions are difficult to make due to factors such as: • anomalous expansion of water • different effects of ice melting on sea water compared to ice melting on land.
8.6.9	Identify climate change as an outcome of the enhanced greenhouse effect.	

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$\text{power} = \frac{1}{2} A \rho v^3$

$\text{power per unit length} = \frac{1}{2} A^2 \rho g v$

$$I = \frac{\text{power}}{A}$$

$$\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$$

$$C_s = \frac{Q}{A \Delta T}$$

$\text{power} = \sigma A T^4$

$\text{power} = e \sigma A T^4$

$$\Delta T = \frac{\left(I_{\text{in}} - I_{\text{out}}\right) \Delta t}{C_s}$$