# Topic 8: Energy production

8 hours

**Essential idea:** The constant need for new energy sources implies decisions that may have a serious effect on the environment. The finite quantity of fossil fuels and their implication in global warming has led to the development of alternative sources of energy. This continues to be an area of rapidly changing technological innovation.

## 8.1 – Energy sources

**Nature of science:**

Risks and problem-solving: Since early times mankind understood the vital role of harnessing energy and large-scale production of electricity has impacted all levels of society. Processes where energy is transformed require holistic approaches that involve many areas of knowledge. Research and development of alternative energy sources has lacked support in some countries for economic and political reasons. Scientists, however, have continued to collaborate and share new technologies that can reduce our dependence on non-renewable energy sources. (4.8)

**Understandings:**

- Specific energy and energy density of fuel sources
- Sankey diagrams
- Primary energy sources
- Electricity as a secondary and versatile form of energy
- Renewable and non-renewable energy sources

**Applications and skills:**

- Solving specific energy and energy density problems
- Sketching and interpreting Sankey diagrams
- Describing the basic features of fossil fuel power stations, nuclear power stations, wind generators, pumped storage hydroelectric systems and solar power cells
- Solving problems relevant to energy transformations in the context of these generating systems

**International-mindedness:**

- The production of energy from fossil fuels has a clear impact on the world we live in and therefore involves global thinking. The geographic concentrations of fossil fuels have led to political conflict and economic inequalities. The production of energy through alternative energy resources demands new levels of international collaboration.

**Theory of knowledge:**

- The use of nuclear energy inspires a range of emotional responses from scientists and society. How can accurate scientific risk assessment be undertaken in emotionally charged areas?

**Utilization:**

- Generators for electrical production and engines for motion have revolutionized the world (see *Physics* sub-topics *5.4* and *11.2*)
- The engineering behind alternative energy sources is influenced by different areas of physics (see *Physics* sub-topics *3.2*, *5.4* and *B.2*)

| 8.1 – Energy sources | |
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| • Discussing safety issues and risks associated with the production of nuclear power<br>• Describing the differences between photovoltaic cells and solar heating panels<br>**Guidance:**<br>• Specific energy has units of J $kg^{-1}$; energy density has units of J $m^{-3}$<br>• The description of the basic features of nuclear power stations must include the use of control rods, moderators and heat exchangers<br>• Derivation of the wind generator equation is not required but an awareness of relevant assumptions and limitations is required<br>• Students are expected to be aware of new and developing technologies which may become important during the life of this guide<br>**Data booklet reference:**<br>• $\text{Power} = \frac{\text{energy}}{\text{time}}$<br>• $\text{Power} = \frac{1}{2} A \rho v^3$ | • Energy density (see *Chemistry* sub-topic *C.1*)<br>• Carbon recycling (see *Biology* sub-topic *4.3*)<br>**Aims:**<br>• **Aim 4:** the production of power involves many different scientific disciplines and requires the evaluation and synthesis of scientific information<br>• **Aim 8:** the production of energy has wide economic, environmental, moral and ethical dimensions |

**Essential idea:** For simplified modelling purposes the Earth can be treated as a black-body radiator and the atmosphere treated as a grey-body.

## 8.2 – Thermal energy transfer

**Nature of science:**

Simple and complex modelling: The kinetic theory of gases is a simple mathematical model that produces a good approximation of the behaviour of real gases. Scientists are also attempting to model the Earth's climate, which is a far more complex system. Advances in data availability and the ability to include more processes in the models together with continued testing and scientific debate on the various models will improve the ability to predict climate change more accurately. (1.12)

**Understandings:**

- Conduction, convection and thermal radiation
- Black-body radiation
- Albedo and emissivity
- The solar constant
- The greenhouse effect
- Energy balance in the Earth surface–atmosphere system

**Applications and skills:**

- Sketching and interpreting graphs showing the variation of intensity with wavelength for bodies emitting thermal radiation at different temperatures
- Solving problems involving the Stefan–Boltzmann law and Wien's displacement law
- Describing the effects of the Earth's atmosphere on the mean surface temperature
- Solving problems involving albedo, emissivity, solar constant and the Earth's average temperature

**International-mindedness:**

- The concern over the possible impact of climate change has resulted in an abundance of international press coverage, many political discussions within and between nations, and the consideration of people, corporations, and the environment when deciding on future plans for our planet. IB graduates should be aware of the science behind many of these scenarios.

**Theory of knowledge:**

- The debate about global warming illustrates the difficulties that arise when scientists cannot always agree on the interpretation of the data, especially as the solution would involve large-scale action through international government cooperation. When scientists disagree, how do we decide between competing theories?

## 8.2 – Thermal energy transfer

**Guidance:**

- Discussion of conduction and convection will be qualitative only
- Discussion of conduction is limited to intermolecular and electron collisions
- Discussion of convection is limited to simple gas or liquid transfer via density differences
- The absorption of infrared radiation by greenhouse gases should be described in terms of the molecular energy levels and the subsequent emission of radiation in all directions
- The greenhouse gases to be considered are $CH_4$, $H_2O$, $CO_2$ and $N_2O$. It is sufficient for students to know that each has both natural and man-made origins.
- Earth's albedo varies daily and is dependent on season (cloud formations) and latitude. The global annual mean albedo will be taken to be 0.3 (30%) for Earth.

**Data booklet reference:**

- $P = e\sigma AT^4$
- $\lambda_{max}(\text{metres}) = \frac{2.90 \times 10^{-3}}{T(\text{kelvin})}$
- $I = \frac{\text{power}}{A}$
- $\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$

**Utilization:**

- Climate models and the variation in detail/processes included
- Environmental chemistry (see *Chemistry* option topic *C*)
- Climate change (see *Biology* sub-topic *4.4* and *Environmental systems and societies* topics *5* and *6*)
- The normal distribution curve is explored in *Mathematical studies SL* sub-topic *4.1*

**Aims:**

- **Aim 4:** this topic gives students the opportunity to understand the wide range of scientific analysis behind climate change issues
- **Aim 6:** simulations of energy exchange in the Earth surface–atmosphere system
- **Aim 8:** while science has the ability to analyse and possibly help solve climate change issues, students should be aware of the impact of science on the initiation of conditions that allowed climate change due to human contributions to occur. Students should also be aware of the way science can be used to promote the interests of one side of the debate on climate change (or, conversely, to hinder debate).